THE ROLE OF TECHNOLOGY IN THE PRODUCTIVITY OF HIGHWAY CONSTRUCTION IN THE UNITED STATES

by

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ABSTRACT

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The construction industry holds a prominent position in the U.S. economy, not only in terms of its direct contributions to the gross national product and to employment, but also through its provision of physical facilities satisfying a wide variety of social, economic, and technical needs. In light of this, the tendency of construction, over the past fifteen years or so, to consistently exhibit higher price escalation than is the case in industry in general, has generated widespread concern among industry and government officials alike. Rising factor prices without commensurate increases in factor productivities is a frequently cited contributory condition. Productivity is a complex issue in construction where even labor productivity, let alone capital, materials, or total factor productivity, is extremely difficult to measure, due to the heterogeneity of the industry's products as well as of its inputs. Although progress is being made, particularly in the development of measures of labor and materials productivity in individual sectors of construction, measures of capital and total factor productivity are still lacking, and the process of determining the factors influencing this productivity still remains a speculative one.

The role of technology in the construction industry and its influence on productivity and efficiency and product quality and cost is the general focus of the current research. For the U.S. and other developed countries, this is of importance in terms of indicating the direction in which technology has advanced in the past and might do so or be encouraged to do so in the future; as for the developing countries, it is of importance in terms of assessing the potential appropriateness of various technologies in light of their local conditions. In this analysis of technology and its progression over time, efforts are concentrated on the identification and quantification of the magnitude and nature of the technology change that has occurred. The issue of particular interest is whether the observed technology change has been characterized by increasing efficiency or by factor substitution (equipment for labor) or, more likely, a little of both, in which case the extent of their contributions is of interest. The highway sector of the construction industry in the U.S. provides a good basis for this study.

A micro-study approach is pursued in this investigation of technology and productivity in highway construction in the U.S. The basic analytic procedure thus entails first observing and recording the inputs required for and influences impacting the various tasks of production, for alternative means of producing a given output, and then using this data to synthesize a production isoquant for the good which is subjected to further economic analysis. Since it is obviously impossible to actually observe the technologies of the past in the field today, historical data used in a simulation framework must suffice, whereby the various stages of highway construction and complete road projects can be hypothetically built and operated, by means of alternative technical packages and project designs. This is accomplished in two levels of analysis: (1) the stage-level, wherein each stage is considered separately in the analysis of technology and its change; and (2) the project-level, wherein the stages are brought together to form various projects such that the interaction of design and technology in highway construction and operation might be taken into account.

The role of technology in the productivity of highway construction over the years in the U.S. appears indeed to have been a significant one. Highways can be constructed today using considerably less labor and even less capital than was possible in the second and third decades of this century. These advances in highway construction technology appear to have played a major part in keeping project costs down over the years.

Efficiency seems to have played a major role in the observed technology change, although the magnitude and rate of the decrease in resource requirements attributable to efficiency has lessened over time. Substitution brought about by factor price changes, on the other hand, seems to have had effectively no part in the technology change, although it seems likely that expectations of labor's cost rising relative to that of capital, among other conditions, may have tended to induce technology change in the direction of saving labor as was observed.

Increased mechanization and the introduction of new types of equipment appear to constitute the primary means of accomplishment of such technology change before the fifties, while since then it has been largely just improving the equipment and the effectiveness with which it is used. As for the future, although the same basic motivations may be expected to continue, perhaps in a somewhat dampened state, gains in productivity and efficiency achieved by a simple continuation of past means of accomplishing change may be expected to be somewhat less than those previously, if past trends can be taken as indicative of those of the future. As for the developing countries, it appears that the development of technical packages since the early part of this century has been focused on the capital-intensive end of the production isoquant; the labor and animal-intensive packages of the past seem to have been essentially forgotten, although they still appear to be efficient and, under some conditions, economic and their use potentially worth considering.

Thesis Supervisor: Fred Moavenzadeh
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Over the course of this research effort, so many people provided moral and intellectual support that it is impossible to cite them all individually. I would like to single out some of them, however, for service above and beyond the call of duty. Susan Burkhardt and Dianne Glennon, two Undergraduate Research Assistants, aided in the collection and compilation of data and in computer programming. My debt to them is considerable. I would also like to express my thanks to the members of Professor Moavenzadeh's various research projects, especially Fred Berger, Brian Brademeyer, Mike Markow, John Potter, Bruce Van Every, and Bob Wyatt. They provided general consultations, critiques, and advice on many aspects of my research.

My final acknowledgement is to my spouse, Peter Rossow. The mere fact that he has survived three theses, several research reports, and my general exams is a tribute to his extraordinary patience and understanding.

TABLE OF CONTENTS

LIST OF TABLES

(List of Tables Continued)

LIST OF FIGURES

(List of Figures continued)

(List of Figures continued)

(List of Figures continued)

LIST OF ABBREVIATIONS

site prep	= site preparation	sf, ft^2	= square foot
exc/haul	= excavation/hauling	sy	= square yard
spr/comp	= spreading/compaction		
grvl	= gravel	CM	= cubic meter
wbm	= waterbound macadam	LCM	= loose cubic meter
dbst	= double bituminous surface treatment	BCM	= bank cubic meter
		CCM	= compacted cubic meter
dbst/g	= double bituminous surface treatment on a gravel base	ft^3	= cubic foot
dbst/w	= double bituminous surface treatment on a waterbound macadam base on a gravel subbase	cy	= cubic yard
		lcy	= loose cubic yard
		bcy	= bank cubic yard
		ccy	= compacted cubic yard
tp	= technical package	fpm	= feet per minute
p	= project	mph	= miles per hour
mm	= millimeter	hp	= horsepower
cm	= centimeter	dbhp	= drawbar horsepower
M	= meter	fwhp	= flywheel horsepower
km	= kilometer		
		ct	= count
in.	= inch	qty	= quantity
ft,'	= foot	sngl	= single
yd	= yard	dbl	= double
mi	= mile	max	= maximum
		int/dep	= interest and depreciation
SM	= square meter	maint/misc	= maintenance and miscellaneous items
ha	= hectare	ADT	= average daily traffic

HCM = Highway Cost Model - citation:
Moavenzadeh, Fred, Fredric Berger, Brian Brademeyer, and Robert Wyatt, The Highway Cost Model - General Framework, Report No. 75-4, Technology Adaptation Program, Massachusetts Institute of Technology, Cambridge, September 1975.

CHAPTER 1

INTRODUCTION

1.1 Productivity in Construction in the United States

The construction industry's role in the overall functioning of the U.S. economy is one of considerable importance. In recent years, the value of new construction put in place has accounted for some 9 to 11 percent of the gross national product, while the industry has provided some 4 to 6 percent of the nation's nonagricultural employment. Highway construction's share is some 7 to 11 percent of the output and 8 to 10 percent of the employment generated by the industry. At the same time, variations in the rate and level of investment in the industry's various activities have served as a stabilizing influence on the overall economy. Finally, through the provision of physical facilities, the construction industry plays a major role in satisfying society's needs for shelter, infrastructural services, and institutional, commercial, and manufacturing services; in fact, the overall ability of other industries to produce and distribute goods and services for consumers is heavily dependent upon the construction industry.

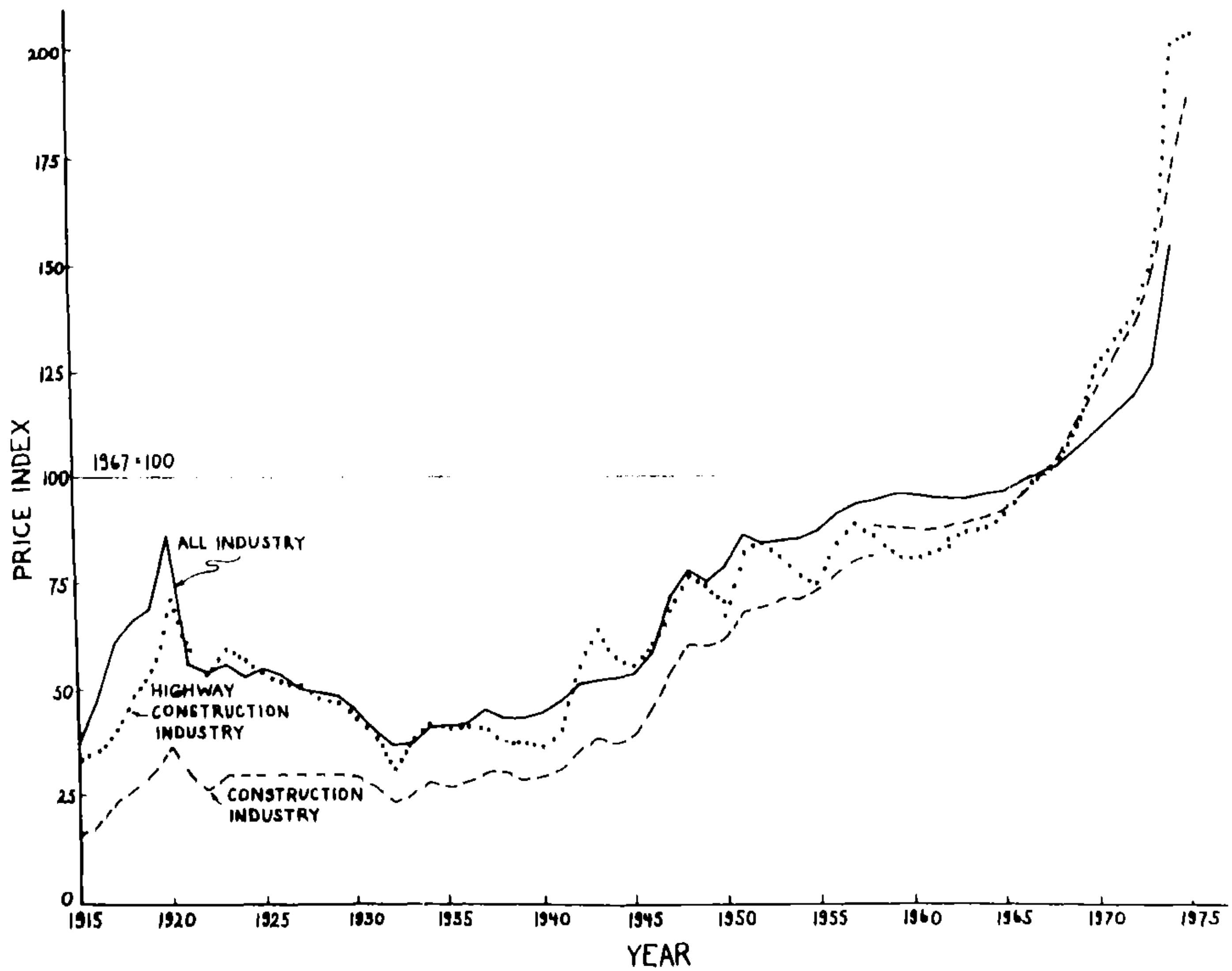
In light of the industry's prominent position, its tendency, over the past fifteen years or so, to consistently exhibit higher price escalation than is the case in industry in general, has generated widespread concern among industry and government officials alike. The price trends* exhibited

* The term price trend is used somewhat loosely here in the case of the construction industry, in that the index is actually based on the costs of the inputs rather than the price of the output and may, therefore, have a certain upward bias (71).

by industry in general and the construction and highway construction sectors over the last sixty years are given in Figure 1.1. As for general trends exhibited by the three categories of industry, up to about World War II the peaks and valleys in the prices essentially balance out, yielding only a slightly upward trend; at that time a distinctly upward trend begins, which continues at a moderate rate to the mid-sixties, when the prices begin a rapid ascent. In the particular case of highway construction's price, it is of interest to note that it generally moves in line with all industry's until the post-war period, at which time it fluctuates around a bit until 1960, when it begins its rapid ascent, similar to that of construction and even exceeding it.

A condition commonly cited as contributing to such price escalation is rising factor prices without commensurate increases in factor productivities. As labor generally constitutes a sizeable share of the costs and is more readily measurable than is capital or materials, output per man-hour is commonly used as a measure of productivity; Figure 1.2 gives the trends in labor productivity exhibited by the three industry categories over the past thirty years or so. For construction in general and highway construction in particular, labor productivity on the average rises steeply until the late fifties or early sixties, at which point it fluctuates for construction, with the peaks and valleys essentially balancing out to no further growth, while it continues a steady upward trend at a somewhat reduced pace for highway construction; it should be noted that this is the same point at which prices began to rapidly escalate in both sectors. As for all industry, its labor productivity exhibits exactly opposite trends; it might be remembered that its recent price escalation has not been quite as rapid as that of the

Figure 1.1: Price trends exhibited by industry in general and the construction and highway construction sectors over the past sixty years (source: ref. 19, 86, 91, 104).



(Figure 1.1 continued)

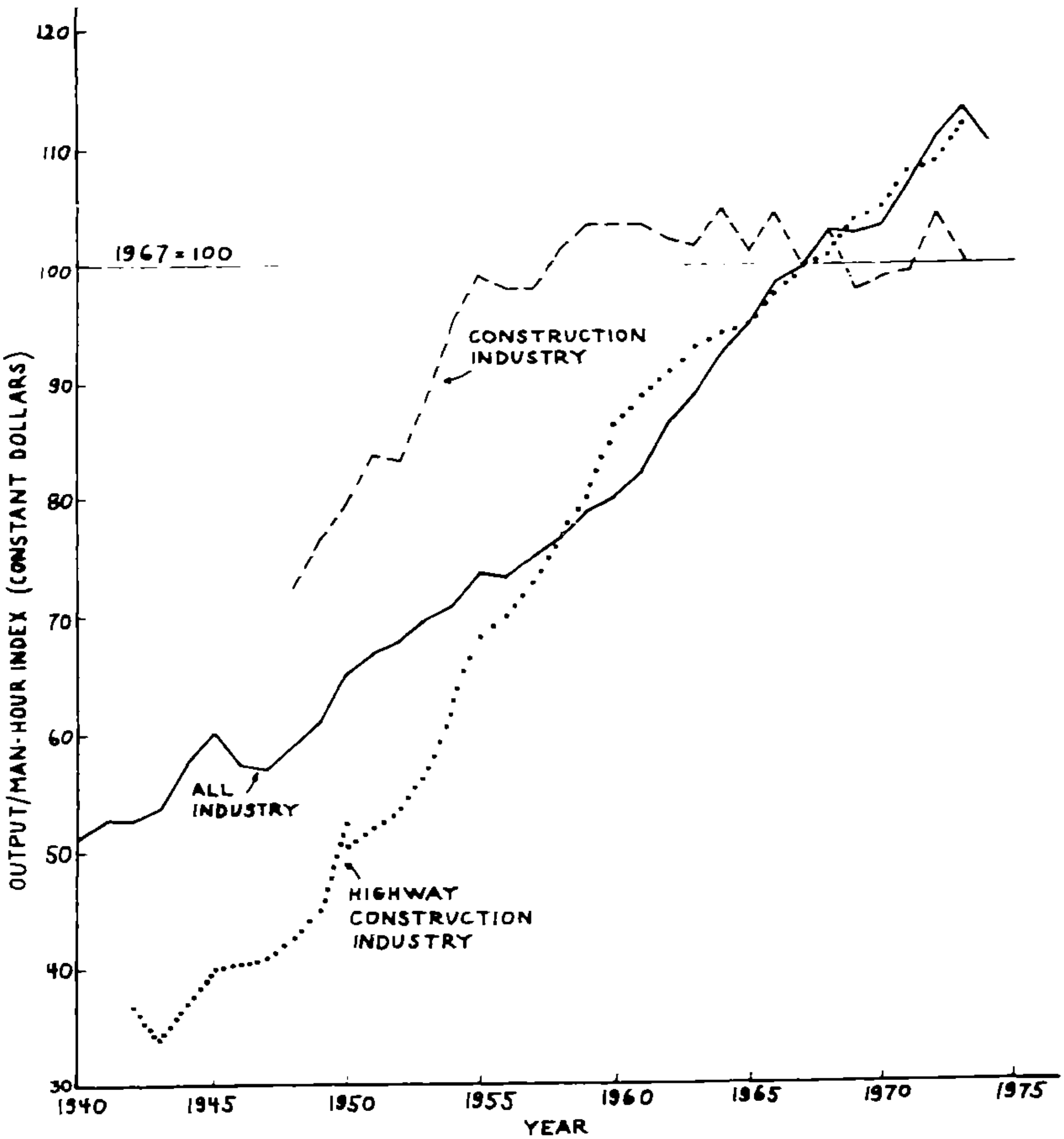
<u>Note</u>:

·····Highway construction industry index is the U.S. Federal Highway Administration's composite contract bid price index for 1922-75, the breaks in the curve representing points in time when the quantities of common excavation, surfacing, and structures used in the derivation of the composite index have been changed; the U.S. Department of Commerce extrapolated the data back to 1915 by means of weighted averaging of various relevant indexes (19, 86, 104).

----Construction industry index is the U.S. Department of Commerce's composite cost index, which is a combination of various indexes weighted by the relative importance of the major classes of construction; as the index is ultimately based on costs of inputs rather than the price of output, it is more properly termed a cost, rather than price, index. The U.S. Department of Commerce revised the index at the time the base was changed to 1967, but did so only back to 1958 (19, 86).

——All industry index is the U.S. Bureau of Labor Statistics wholesale price index for industrial commodities (91).

Figure 1.2: Trends in output per man-hour exhibited by industry in general and the construction and highway construction sectors over the past thirty years or so (source: ref. 86, 87, 89, 91, 101, 103).



(Figure 1.2 continued)

Note:

····· Highway construction industry index is based on the U.S. Federal Highway Administration's figures on man-hours per thousand dollars of construction, adjusted to 1954 constant dollars, for 1950-73; prior to 1950, it is based on their figures for man-hours used per thousand dollars of construction, award or job-started basis, in current dollars, inflated to 1954 constant dollars using their composite bid price index. This output per man-hour index thus covers only on-site employees (86, 101, 103).

- - - - Construction industry index is the U.S. Bureau of Labor Statistics' output per man-hour index for all persons in the construction industry (89).

—— All industry index is the U.S. Bureau of Labor Statistics' output per man-hour index for all persons in the nonfarm sector of the economy, based on establishment data (87, 91).

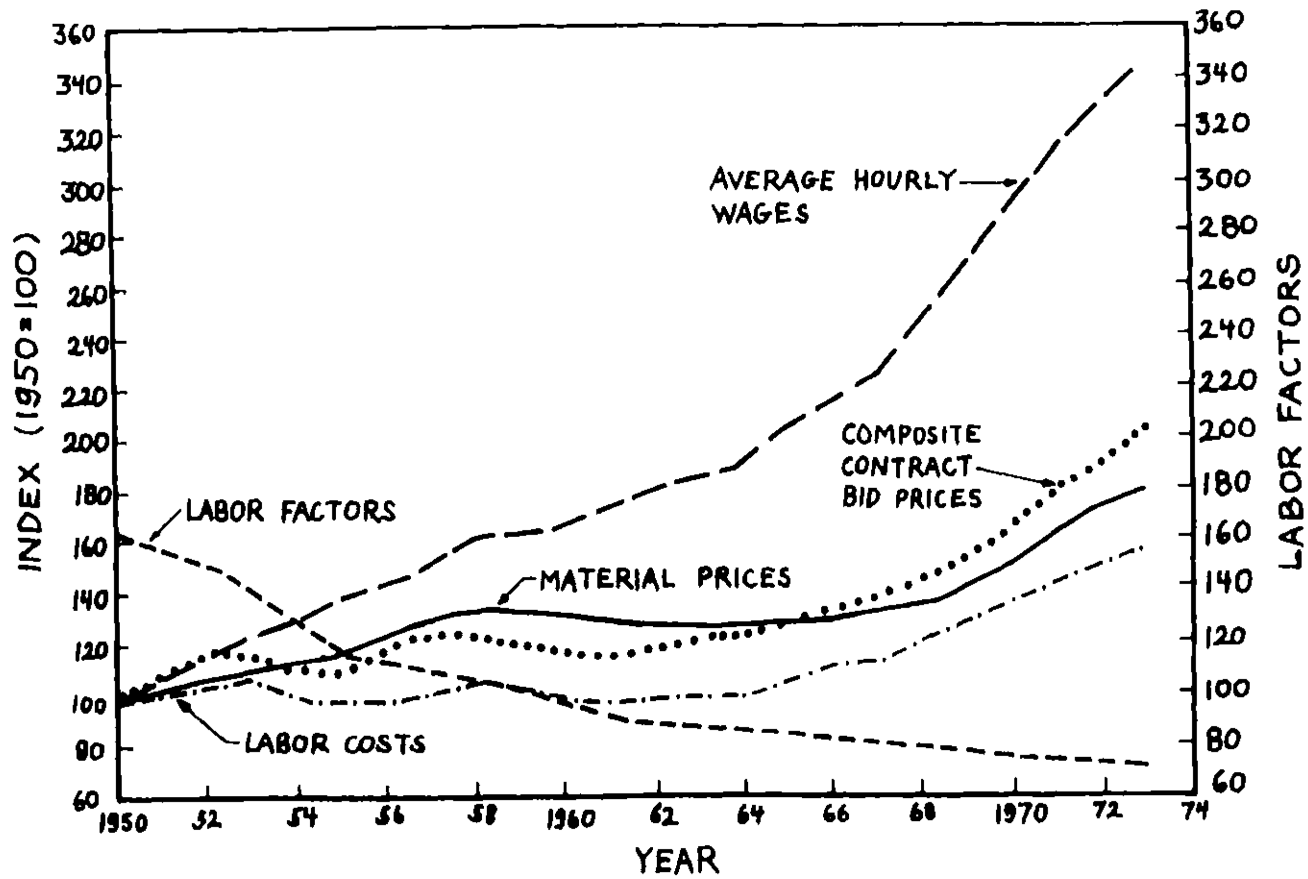
construction sectors. Figure 1.2 also shows that prior to the sixties, highway construction exhibits the highest average rate of productivity growth, with general construction coming in second; after the early sixties turning point, highway construction's rate of growth drops to below that of all industry, while general construction's essentially goes to zero.

The implication of this is that productivity growth prior to the sixties in construction in general and highway construction in particular is reasonably successful at offsetting factor price increases, but since then its reduced rate of growth in conjunction with the increased rate of inflation in factor prices results in productivity's being less successful at offsetting price changes. Figure 1.3 suggests that this is indeed the case for highway construction, showing labor costs (i.e., the product of average hourly wages and manhours required per 1,000 constant dollars of construction) as reasonably constant from 1950 to 1964, at which time they begin to rise.

It might also be noted that although composite contract bid prices follow labor costs reasonably closely in Figure 1.3, it is, not surprisingly, not an exact match, especially in recent years. There are other factors of production, namely materials and capital, the prices and productivities of which have also changed over time, as well as other conditions, such as the magnitude and nature of demand for the product, which influence the final price. Table 1.1 shows the percentage distribution of construction costs among the various factors of production for different types of construction, demonstrating the significance of these other input factors in overall project costs.

Setting aside for the moment concerns over the incompleteness of labor productivity and price as an indicator of productivity and price trends in

Figure 1.3: Cost and labor usage trends for highway construction since 1950 (source: ref.101).



(Figure 1.3 continued)

<u>Note</u>:

•••• Composite contract bid price index, converted from award to expenditure basis.

— — Average hourly wage index.

---- Labor factors, man-hours used per thousand dollars worth of construction, adjusted to 1954 constant dollars.

-·-· Labor cost index, based on product of average hourly wages and labor factors.

—— Material price index, based on weighted average of unit prices for Portland cement, asphalt, aggregates, steel, and lumber.

Table 1.1: Percentage distribution of construction costs, by type of construction, in the U.S. (source: ref. 28, 93, 108).

Type of Construction and Year		On-Site Wages	Materials	Equipment	Overhead and Profit[a]
Federally-aided highways					
	1973	24.6	44.5	-[b]	30.9[b]
	1970	25.6	45.0	-[b]	29.4[b]
	1967	24.8	47.8	-[b]	27.4[b]
	1964	26.0	50.3	11.1	12.6
	1961	24.7	52.6	11.7	11.0
	1958	23.9	50.6	12.0	13.5
Elementary & secondary schools					
	1964-65	25.8	54.2	1.0	19.0
	1959	26.7	54.1	1.4	17.8
Hospitals					
	1965-66	29.6	50.4	1.3	18.7
	1959-60	28.2	53.2	1.2	17.4
Public housing					
	1968	32.4	41.9	1.5	24.2
	1959-60	35.5	45.0	2.5	17.0
Private single-family housing[c]					
	1969	20.4	43.4	0.9	35.3
	1962	22.1	47.2	1.0	29.7
Sewer works					
lines	1962-63	24.3	44.5	11.2	20.0
plants	1962-63	26.6	49.2	8.2	16.0
Civil works (Corps. of Eng.)					
land operations	1959-60	26.0	35.0	19.3	19.7
dredging	1959-60	32.3	17.3	24.9	25.5
Federal office buildings					
	1959	29.0	51.4	1.9	17.7
College housing					
	1960-61	29.3	52.6	1.6	16.5
Multi-family housing					
	1971	27.9	44.2	3.0	24.8

(Table 1.1 continued)

[a]Includes off-site wages, fringes, construction financing costs, inventory, and other overhead and administrative expenses as well as profits.

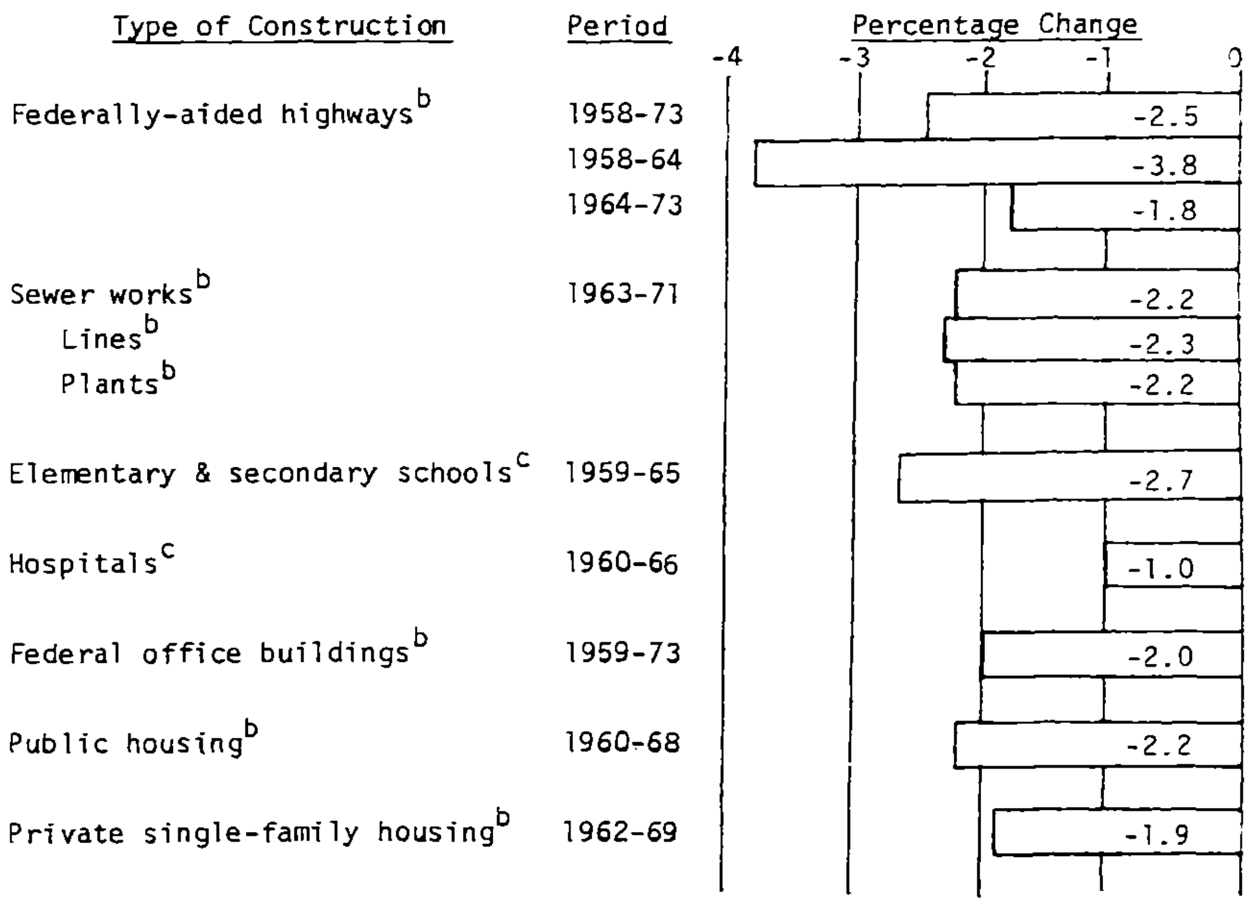
[b]Equipment included in overhead and profit.

[c]Construction costs include selling expenses in addition to construction contract costs (selling expenses were 2.9 percent in 1969).

construction, considerable disagreement still remains as to the appropriate means by which to measure labor productivity in the construction industry. The results of six different methods of estimating output per man-hour indexes for contract construction, for example, are five different figures, ranging from 1.6 to 3.0 percent, for the average annual rate of growth over about a twenty-year period beginning around 1947 (16, 22, 30, 89).
The primary difficulty is the heterogeneous nature of the industry's output, ranging from single-family homes to skyscrapers, industrial plants, and highways, each of which is distinct in its own right in terms of its function, size, quality, performance characteristics, and so forth, while each also has rather different requirements in terms of the type and quantity of labor, let alone the other factors of production; moreover, the nature and mix of products in a single sector of construction is continuously changing, let alone that in the industry as a whole. Such features make the derivation of a reliable output measure, such as the deflated price of a reasonably constant product set, very diffi .c and also make the meaning and usefulness of a measure of the industry's labor productivity somewhat questionable. Another area of difficulty lies in the measurement of the inputs, in that labor is not homogeneous either, although it is generally assumed to be thus.

As a result of these difficulties, certain agencies have begun working with the individual sectors of construction; the U.S. Bureau of the Census, for example, has begun developing price indexes for each sector, while the U.S. Bureau of Labor Statistics since the late fifties has been studying the labor and materials requirements of the various sectors. Figure 1.4 gives some of the results of these efforts, in the form of a chart of average annual percentage changes during the sixties in on-site man-hours

Figure 1.4: Average annual percentage change in on-site labor requirements, by type of construction, for selected periods 1958-1973 (source: ref. 28, 88).



[a]Compound interest method.

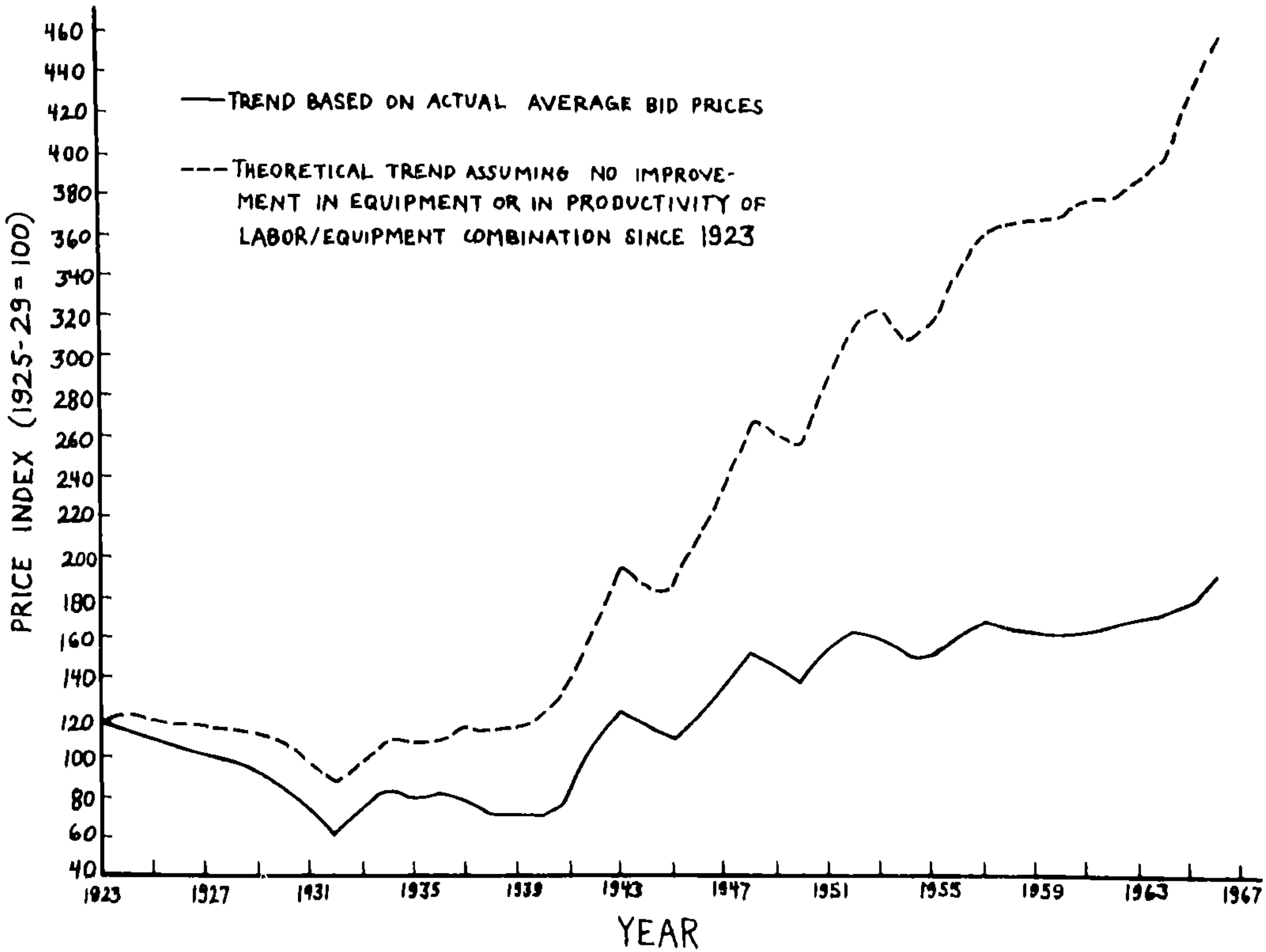
[b]Deflated dollars output measure.

[c]Square feet output measure.

required per unit of output for various types of construction. In line with Figure 1.2, Figure 1.4 suggests that the growth of highway construction's labor productivity has slowed significantly in recent years, although over the full analysis period it still appears to be higher than that of the other sectors of construction, excepting schools. The results for the industry as a whole, however, look much more favorable in terms of the construction industry's exhibiting productivity growth during the sixties, than do those of Figure 1.2. The validity of these new measures will be considerably strengthened by frequent follow-up studies, as have been done for highways at three-year intervals, and by further work in the area of deriving price indexes and other means to achieving reliable measures of output.

Although these new measures of productivity appear promising, measures of capital and total factor productivity are still lacking, and the process of determining the factors influencing this productivity still remains a speculative one. Of primary interest in the current research, for example, is an investigation of the role of technology in the productivity of highway construction in the U.S. Figure 1.5, which shows the trend over time of highway construction bid prices, both as it actually occurred and as it would have occurred had technology not changed as it did, suggests that technology did, indeed, have a significant influence on project costs and presumably factor productivities. Knowing this and knowing that the industry's man-hours requirements dropped over time give little insight into the nature of this technology change however. Labor productivity over time might, for example, have appeared to improve as a result of substituting the cheaper resource, capital, for the more expensive one, labor, as factor

Figure 1.5: Bid price trend for highway construction, both as it actually occurred and as it would have occurred had technology remained constant at that of 1923 (source: ref.100).



prices changed, resulting in a lowering of capital productivity; or labor's productive efficiency might actually have improved, perhaps as a result of implementing technological innovations, such that requirements for both labor and capital were reduced; or both events might have occurred. It is issues of this sort that the current research tries to address. Such knowledge and understanding of the nature of technology change of the past is of utmost importance to industry and government alike if they are to take an active part in guiding technology's course in the future.

1.2 The Situation in Developing Countries

The levels of open unemployment and underemployment and more particularly the growing gap between the rate of new entries to the labor force and the capacity of the economy to absorb them, even in countries where the growth of output is reasonably high, is a problem of increasing concern to many planners in developing countries. Closely akin to this problem is that of inequitable income distribution and poverty in the developing world. At the same time, their supply of capital, by and large, is very limited, forcing them to rely heavily on external loans and grants-in-aid for capital formation. With conditions as they now stand in developing countries, the labor surplus which currently exists, and is expected to grow, cannot be fully utilized without an increase in the supply of capital. A perhaps more feasible solution is to substitute the abundant labor for the scarce capital, thereby generating more employment and output than would be possible otherwise. The developed and developing countries and international agencies in their search for sectors of the economy where substitution might be possible have focused considerable attention on construction, particularly the public works area and even more specifically highways.

Public works facilities play an early and major role in economic development, and represent a large and visible portion of government investment. This makes them a rather natural target for labor-capital substitution. Moreover, being in the public domain, the work can more readily be monitored by the government which can thus enforce the use of labor-intensive techniques and perhaps adjust project timing, for example, to coincide with seasonal surpluses. Finally, the potential for employment in this sector appears promising, especially for the unskilled which is where the surplus lies and the rural underemployed, in that such activities were executed by labor using simple tools and animal power in the past.

Regardless of the labor abundance and capital scarcity in the developing world, the more mechanized techniques developed in the labor-scarce, capital-abundant countries of the developed world have been transferred to and adopted by the developing countries for use in public works and particularly highway construction. Two possible explanations may account for this apparent contradiction: (1) the set of efficient technical alternatives is not, or at least appears not to be, fully defined over the range of possible labor/capital mixes; and (2) inappropriate factor prices (i.e., market prices rather than prices reflecting the relative scarcity and thus the social cost of the various resources) are used in the selection of the labor/capital mix. It is the first alternative which can conveniently be investigated to a limited extent in the course of the current research. If technology change over time in the U.S. is found to be primarily in the direction of increasing efficiency, for example, the more capital-intensive packages of today may comprise the only set of efficient alternatives currently available, although new developments in the direction of utilizing labor may still be possible. Alternatively, it may be that some of the more labor-intensive packages of the past are equally efficient (e.g., technology change may have been largely in the direction of simple substitution of equipment for labor), but that they have been forgotten in the labor-scarce developed countries, or that institutional biases and rigidities in the developing countries themselves prevent their use. Such insights into the progression of technology over time in the U.S. are thus potentially of value to those concerned with the issue of labor-capital substitution, particularly in terms of ascertaining the feasibility of certain developing countries' returning to the use of some of the more labor and animal-intensive techniques of the past.

1.3 Purpose and Scope of Research

The general focus of the research is the role of technology in the construction industry, and its influence on productivity and efficiency and product quality and cost. For the U.S. and other developed countries, this is of importance in terms of indicating the direction in which technology has advanced in the past and might do so or be encouraged to do so in the future; as for the developing countries, it is of importance in terms of assessing the potential appropriateness of various technologies in light of their local technical, economic, and social conditions.

In this analysis of technology and its progression over time, efforts are concentrated on the identification and quantification of the magnitude and nature of the technology change that has occurred. The issue of particular interest is whether the observed technology change has been characterized by increasing efficiency or by factor substitution (equipment for labor) or, more likely, a little of both, in which case the extent of their contributions is of interest. Finding technology change to have been primarily in the direction of substitution, for example, indicates, for the U.S. and other developed countries, the necessity of redirecting efforts in the future toward developing new technical alternatives more able to cope with the upcoming shortages in the materials and energy areas and perhaps also to increase efficiency rather than just substitute. The implication of change characterized by increased efficiency, on the other hand, is that there really has been technological advance, and there is no reason to try to alter its course in the future, as long as the means by which it has been achieved remain viable. For the developing countries, technology change in the direction of increased efficiency suggests that technology may not be too reversible, and that new alternatives in the software and/or hardware areas may need to be developed. The implication of change characterized by substitution, however, is that technology may potentially be reversible, and that it may be worthwhile to begin to more seriously consider and evaluate some of the older, more labor-intensive techniques for use in the developing countries.

The highway sector of the construction industry in the U.S. provides a good basis for this research. Narrowing the scope to a single sector of the construction industry follows directly from the discussion above of the heterogeneity of the industry's products; limiting it to a single country seems only appropriate in view of the wide variation in both inputs and outputs in this single sector from one country to another, making comparisons, for example, of technical alternatives and associated productivities difficult. The highway sector is a particularly interesting sector of the construction industry to study in the U.S., in that its technology has undergone considerable change over the past fifty years or so. Furthermore, it has certain advantages over other sectors of the construction industry in terms of such a study, including: (1) only a few basic steps constitute the construction process, thereby lessening the number of possible interactions and making more possible the study of both the individual steps and the overall project; and (2) its output is more readily measurable in quantity, quality, and use terms. Finally, data also appear to be reasonably available for the highway sector, stemming largely from the U.S. Federal Highway Administration's production studies of alternative highway construction methods carried out in the 1920's, 1950's, and 1970's. In summary then, the focus of the current research is the investigation, in both qualitative and quantitative terms, of the role of technology in the productivity of highway construction over the years in the U.S.

Chapter Two begins with a brief review of the economic concepts and tools pertinent to the analysis of technology and productivity and their change over time; this is followed by a review of related research in the highway field itself, including a series of case studies evaluating alternative technical packages for highway construction and some models for evaluation of alternative designs for highway projects. The literature cited in these reviews, as well as all other references cited in the main body of this study, are given in Appendix A. Drawing upon the literature reviewed in the first two sections, the final section of Chapter Two outlines the method of approach to be followed in the research; a two-step approach is developed: (1) stage-level analysis, wherein each stage is considered separately in the analysis of technology and its change; and (2) project-level analysis, wherein the stages are brought together to form various projects such that the interaction of design and technology in highway construction and operation might be taken into account.

Chapters Three and Four, then, respectively present and discuss the results of the research, each being divided into two parts, the first covering the stage-level and the second the project-level analysis. Before giving the results in each part, Chapter Three covers some largely definitional points pertaining to the level of analysis and briefly describes the actual collection and preliminary work-up of the data. Further details pertaining to the data collection and analysis procedures, as well as presentation of the basic data and some results, can be found in Appendices B and C. Included with the comprehensive discussion of the results given in Chapter Four is the identification of the potential implications of the study's findings for both the U.S. and developing countries. The presentation of the conclusions and recommendations for further research in Chapter Five completes the study.

CHAPTER 2

RESEARCH APPROACH

It is the purpose of this chapter to outline the method of approach employed in this research. It is appropriate to begin with a brief review of some of the literature in the area of technology, productivity, and factor proportions, starting with some of the more general theoretical and macro-study approaches used in a range of industries and ending with some more specific, applied micro-studies in the highway field itself. The final section of the chapter discusses the research approach pursued in the study at hand, in particular the application of some of the methodologies reviewed.

Almost as vast as the array of literature, pertaining to the topics of technique and technology, technical and technological change, and production function and isoquant, is the level of confusion regarding the terminology (27). For the purposes of the research at hand, a certain number of terms and interpretations are necessary. Technical package is used to refer to any factor or resource mix (i.e., labor, equipment, and materials) which can produce a given product (e.g., excavation and hauling of soil twenty feet or gravel surfacing). Technology is defined as the pool of knowledge pertaining to the production of a given product or, alternatively, as the complete set of existing technical packages which can produce this product; often, too, and particularly for the purposes of the research at hand, technology also has a time dimension, such as the

1920's technology of gravel surfacing. Production set is the full set of technical packages representing a particular technology; all existing efficient and inefficient packages are included in this set. Production function is taken as the set of efficient technical packages of a particular production set; that is, those technical packages which produce the most output for the least input. Production isoquant, then, is a part of a production function in that it represents a given amount of a given product. Best-practice technical package is that package which is least-cost when factor prices of a particular period are applied to the resource requirements of the efficient set representing a particular technology.

Finally, technological change relates to the development, due to improved knowledge, of a new set of technical packages which can produce a given product (i.e., a new production function or isoquant) and again to a new time period, such as the technology of the 1950's as opposed to that of the 1920's. Technical change, on the other hand, relates to changes amongst available technical packages or to factor substitution (i.e., a movement along the production isoquant) due to altered factor prices. The term technology change, then, refers to the complete process of changing from a particular technical package, the best-practice one, in one time period to that of a new one, a process which may include both technological and technical change; movements over time of best-practice technical packages thus represent technology change.

2.1 Brief Review of Studies of Productivity and Technology in Other Industries

The identification and more particularly the measurement of technology change in a quantitative sense is an elusive concept which has long plagued economists and engineers alike. Factor productivity, in one form or another, is the oldest and probably still the most commonly used indicator of technology change, and consequently is the first approach generally mentioned by authors reviewing the subject (12, 47, 50, 52, 53, 58). Single factor indexes, defined as average product output per unit of input such as labor or capital, are of limited usefulness in that their dynamic behavior is difficult to interpret. Leaving aside for the moment the problems inherent in measuring inputs and outputs, a change in the index may indicate technological change but it may, alternatively or at the same time, indicate a change in the use of the other factors of production as well as the factor being measured (i.e., technical change).

Multifactor indexes, defined most often as average product output per unit of combined labor and capital input, make up the second and perhaps more useful form of productivity indexes. It was in the late fifties and early sixties that the use of these multifactor productivity indexes in a variety of forms was developed by people like Abramovitz, Solow, Fabricant, and Kendrick. Nadiri (58), as well as others, cites Kendrick's arithmetic measure and Solow's geometric index as the two most often used in empirical research. Kendrick implicitly assumes a homogeneous production function and the Euler condition to obtain the following measure of total productivity change:

$$\frac{dA}{A} = \frac{X_1/X_0}{(wL_1 + rK_1)/(wL_0 + rK_0)} - 1$$

where X = product output

L = labor input

K = capital input

Subscript 1 = current period

Subscript 0 = base period

w = wage rate, changing over time

r = rate of return on capital, changing over time

Solow, in turn, essentially assumes a Cobb-Douglas production function with constant returns to scale and autonomous and neutral technological change and derives the following relation:

$$\frac{dA}{A} = \frac{dX}{X} - [\alpha \frac{dL}{L} + \beta \frac{dK}{K}], \alpha + \beta = 1$$

where dX, dL, dK = time derivatives of X, L, K respectively

α = share of labor in output

β = share of capital in output

It is Brown's (12) observation, however, that the use of moving weights for combining labor and capital as in Kendrick's measure results in an underestimate of the productivity index because change in efficiency, an important aspect of technological change, has no effect on the index. As for Solow's measure, Brown presents an even simpler form:

$$\frac{dA}{A} = \frac{d\chi}{\chi} - \frac{d\kappa}{\kappa}$$

where

$$\chi = X/L$$

$$\kappa = K/L$$

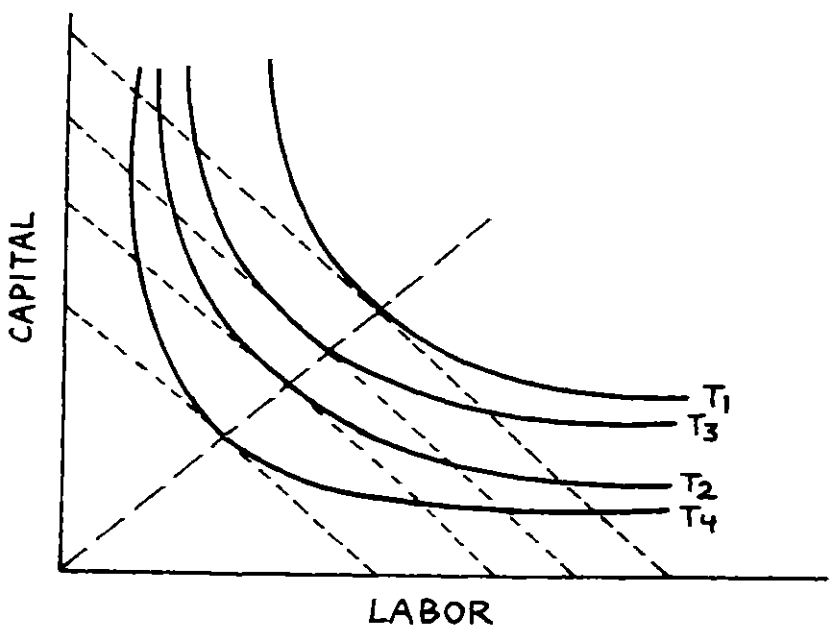
He, among others, still has serious reservations about the measure, however, because of Solow's assuming away all technological change except pure efficiency, although some of it is done with some justification. Nadiri (58), Kennedy and Thirlwall (47), and others cite three possible sources of bias in the use of $\frac{dA}{A}$ as a measure of technological change: (1) the particular form of the production function governing the relation; (2) errors in the measurement of labor and capital and changes in their quality; and (3) relative importance of variables other than labor and capital (e.g., entrepreneurial ability) not included in the measure.

The methodologies discussed thus far have been concerned solely with measuring the change in factor productivity; that is, the change in output not accounted for by changes in inputs, frequently termed the residual and used as a measure of technological change. Salter (73) is probably the first person to make a concerted effort to divide the residual into its component parts. Before proceeding with Salter's analysis, however, it is appropriate to review the general economic characterization of technology and its change as it is discussed by several authors (12, 58, 73). Measures of efficiency, returns to scale, factor bias, and elasticity of factor substitution are the four standardly cited characteristics of a technology and can be conveniently expressed in terms of a production function. The first two are classified as neutral properties in that they affect labor and capital equally, the last two are termed non-neutral properties since they affect the inputs in a biased manner in the sense, for example, of being labor-saving or labor-using.

According to Brown (12), "the efficiency of a technology determines the output that results for given inputs and given the other characteristics of an abstract technology....[The] efficiency characteristic is a scale transformation of inputs into output." Increased efficiency brought about by technological advance, then, results in equal, in a relative sense, across-the-board, factor productivity increases or unit cost decreases. It can be depicted by parallel shifts of the production isoquant toward the origin, such as a shift from T_1 to T_2 in Figure 2.1a, where the T's represent different technologies producing the same amount of output.

Brown (12), in turn, defines technologically-determined returns to scale as "the extent to which a proportionate change in inputs generates a proportionate change in output due to technology and not the scale of operations of the firm." A technology exhibits increasing returns to scale, or economies of scale, for example, if, for a given proportional

Figure 2.1a: Schematic representation of three forms of technological change.



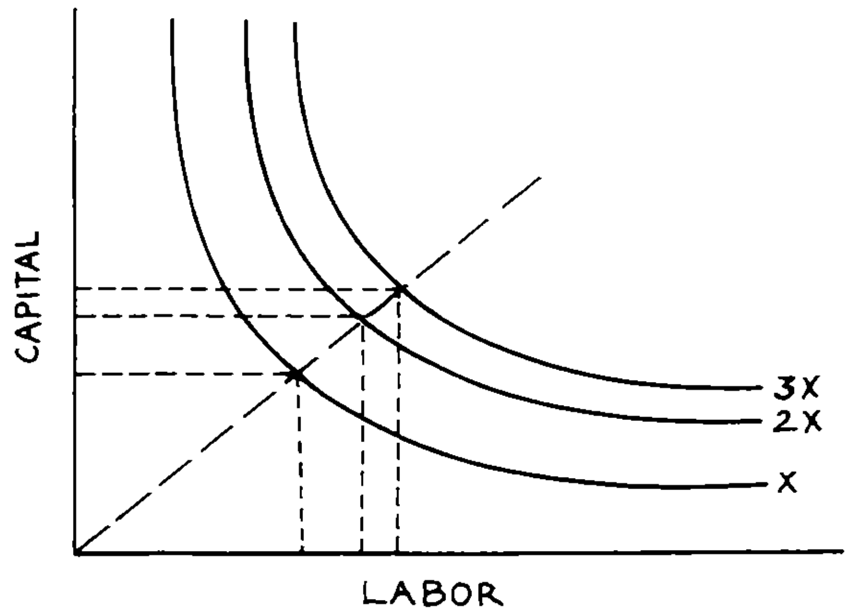
Note: Production isoquants T_1 through T_4 represent different technologies producing the same amount of output.

A shift from: T_1 to T_2 demonstrates increasing efficiency.

T_1 to T_3 demonstrates capital-using bias.

T_1 to T_4 demonstrates decreasing elasticity of factor substitution.

Figure 2.1b: Schematic representation of increasing returns to scale.



Note: The production isoquants represent the same technology but increasing levels of output, beginning with X units near the origin out to 3X units.

increase in all inputs, output is increased by a larger proportion; Figure 2.1b, where the isoquants represent the same technology but increasing levels of output as they move away from the origin, thus demonstrates economies of scale. Technological change, then, may alter the returns to scale characteristic of a set of technical packages, changing it perhaps from decreasing to constant returns to scale.

Factor bias* is most readily defined in a comparative context; that is, given constant elasticity of substitution and relative factor prices, the technology with the higher capital-labor ratio is the more capital-intensive and exhibits a capital-using bias. Bias in technological change denotes greater savings in one input than in the other for all technical packages. A change in the position of the isoquant, more toward one axis than the other, thus represents such bias; that is, a move from T_1 to T_3 in Figure 2.1a results in a proportionately greater increase in the productivity of labor than of capital for all technical packages.

The fourth and final technological characteristic is elasticity of factor substitution; it measures "the ease of exchanging factors of production in the course of the production process" (58) and "thus the extent to which changing factor prices influence techniques" (73). Elasticity of factor substitution is represented by the degree of curvature of the production isoquant; that is, a movement of the isoquant from T_1

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*There is considerable controversy over the definition of factor bias, the two primary schools of thought being Hicks and Harrod, the above definition being basically Hicks; for further discussion see references 47, 58, 72, 73.

to T_4 depicts a decrease in the ease of substitution. Two limiting cases are evident: (1) a right-angle isoquant which has an elasticity of zero and on which factor prices have no influence; and (2) an isoquant approaching a straight line which has an elasticity approaching infinity and on which factor prices have a substantial impact.

There is much discussion throughout the literature (14, 47, 58, 73) of the case of non-neutral change in technology, and the fact that, in most developed countries at least, increases in labor productivity over time have generally been greater than those in capital productivity. Two explanations are commonly presented: (1) technological advance is inherently biased toward labor-saving; and (2) technological advance is largely unbiased but substitution is induced by technological progress in the manufacture of capital goods. Arguments for both views abound, but relatively little progress has been made toward a definitive settlement of the issue.

The nature of the technology itself, as depicted by the technological characteristics discussed above, and relative factor prices are commonly recognized as the primary determinants of factor productivity. In combination, these factors determine the best-practice technique for any particular period. Movements over time of the best-practice technique, then, represent technology change, and it is this which Salter (73) tries to decompose. He begins by assuming constant returns to scale over the range of capacity outputs being considered and then defines quantitative measures for the remaining technological characteristics.

His first parameter is technical advance which measures the rate of movement of the production isoquant toward the origin, basically looking at the effects of efficiency, as defined above, on unit costs. Formally defined, "the extent of the technical advance from one period to another is defined and measured by the relative change in total unit costs when the techniques in each period are those which would minimize unit costs when factor prices are constant" (73); that is:

$$E = \frac{L_{n+1}w_n + K_{n+1}g_n}{L_n w_n + K_n g_n} \qquad \text{for the discrete case, and}$$

$$E_r = \frac{wdL + gdK}{Lw + Kg} \qquad \text{for the continuous case}$$

where

where	Subscript n	=	initial period
	w	=	wage rate
	g	=	price of capital services
	dL, dK	=	time derivatives of L, K
	Subscript r	=	proportionage rate of change, e.g., $T_r = dT/T$

<u>Note</u>: Either period's prices can be used in the discrete case, each giving a slightly different result, due to the inevitable index-number ambiguity problem.

Salter's second parameter is that of factor bias as defined above. Formally, "the labor or capital-saving biases of technical advance are measured by the relative change in capital per labour unit when relative factor prices are constant" (73); that is:

$$D = \frac{K_{n+1}/L_{n+1}}{K_n/L_n}$$ for the discrete case, and

$$D_r = \frac{d(K/L)}{K/L}$$ for the continuous case

Note: $D < 1$, $D_r < 0$, capital-saving bias

$D = 1$, $D_r = 0$, neutral or no bias

$D > 1$, $D_r > 0$, labor-saving bias

His third parameter is elasticity of factor substitution, which is important in determining the effectiveness of changes in relative factor prices in increasing or decreasing the rates of productivity increase established by technological change alone. Elasticity of substitution "measures the proportional change in capital per head in response to a small proportionate change in the relative marginal products (or factor prices) of labour and capital" (73); that is:

$$\sigma = \frac{d(K/L)}{K/L} \cdot \frac{w/g}{d(w/g)},$$ measured at a point on each production isoquant appropriate to the measures of E and D.

Salter finally combines these three parameters to yield a quantitative description of the growth of best-practice productivity in terms of the nature of technological change and changing factor prices. The rate of change of unit labor and capital requirements are thus:

		technical advance effect		bias effect		substitution effect
L_r	=	E_r	-	πD_r	+	$\sigma\pi(g/w)_r$
K_r	=	E_r	+	$(1-\pi)D_r$	+	$\sigma(1-\pi)(w/g)_r$

where π = share of capital costs in total costs

Salter criticizes his own work from the standpoint that the measures represent a drastic and only approximate summary, resulting in such difficulties as the index-number problem inherent in such work and the failure to consider returns to scale, although he does propose a means to alleviate this latter simplification. Brown (12) sees Salter's work as producing well thought out measures, but questions their applicability due to the difficulty of holding each constant while measuring the others. Little empirical testing of these measures has been done, although in the second part of his book Salter does perform an analysis of a range of British and American industries; in this he concludes that neutral technological advances and potential and realized economies of scale are primarily, and factor substitution less so, responsible for the differing rates of labor productivity increase in the industries studied.

The production function, a tool repeatedly mentioned above particularly in conjunction with factor productivity indexes, constitutes yet another approach to the analysis of technology and its change, as reviewed by various authors (12, 47, 50, 58). Dating back nearly fifty years, the Cobb-Douglas production function is probably the most famous, noted for its simplicity in terms of both understanding and applying it and for its possession of certain desirable neoclassical properties (e.g., it does not specify a priori the returns to scale). It was not until about twenty years ago, however, that the Cobb-Douglas function was used in the measurement of technological change. The two-factor Cobb-Douglas production function in its unrestricted form is:

$$X = AL^{\alpha}K^{\beta}$$

where A, α, β = constants to be determined empirically

The technological characteristics, as defined above, can be expressed by various combinations of the empirically determined parameters of the function. A change in the parameter, A, thus indicates a change in efficiency. The sum of the partial elasticities of production, α and β, is an indicator of the returns to scale characteristic (i.e., $\alpha + \beta < 1$ indicates decreasing returns to scale; =1, constant; and > 1, increasing).

The ratio of these same two parameters indicates the factor bias of the technology represented by the Cobb-Douglas function; an increase in β relative to α, for example, demonstrates a capital-using technological change. The fourth and final characteristic, elasticity of factor substitution is fixed at unity in any Cobb-Douglas relation, a feature which severely restricts the applicability of this production function.

Some fifteen years ago a more general form of a production function was developed, the Constant Elasticity of Substitution (CES) function, in which the elasticity of substitution is held constant for any particular technology but can change as technology changes. The CES relation has the basic properties of a neoclassical production function and includes the Cobb-Douglas function as a special case. The two-factor CES production function is:

$$X = \gamma \left[\delta K^{-\rho} + (1-\delta) L^{-\rho}\right]^{-\mu/\rho}$$

where $\gamma, \mu, \delta, \rho$ = constants to be determined empirically

As in the case of the Cobb-Douglas relation, the characteristics of any technology can be expressed in terms of these empirically determined parameters. An increase in γ represents an upward shift in efficiency; the value of μ indicates the degree of returns to scale, and a change in μ may be attributable to some change in technology. As for the non-neutral technological characteristics, the factor bias parameter is δ, which is defined over the interval 0 to 1 and measures the extent to which the technology is capital-using; the elasticity of factor substitution, σ, is represented by $1/(1+\rho)$ in the CES relation, a change in σ indicating a change in technology.

Attempts to use aggregate production function theory in the estimation of total factor productivity or the parameters representing the characteristics of technology and its change have encountered various difficulties and criticisms, which have often been countered with potential solutions. The data base for such studies is generally an industry as a whole or even the entire economy of a country, which leads to many problems in the measurement of factor inputs and product outputs. The factors of production and the products themselves are heterogeneous elements with divergent characteristics, and yet they are standardly aggregated into labor and capital inputs and a single output. In an effort to avoid measuring capital, which has to be done in value terms, Johansen and others, cited by various writers (1, 47, 50, 63), have derived indirect production relations requiring at most a measure of the elasticity of output with respect to capital. An aspect of labor and capital conventionally ignored is that of quality, resulting in changes in factor quality potentially being responsible for a large share of the change in total factor productivity. Attempts to deal with this issue have gone in three directions: (1) models of capital-embodied technological change have been developed (12, 47, 52, 58); (2) the idea of quality adjustment of labor has been pursued by Denison, Griliches, and Kendrick, among others

(47, 58, 107); and (3) the growth accountancy approach has received attention from Denison, Jorgenson, and Griliches, among others (12, 47, 50, 58, 107). One final area of controversy pertaining to the data base is the type of data series used, time-series or cross-sectional, each having its own particular problems (9, 12, 47, 58, 63).

The other major area of difficulties and criticisms, encountered in efforts to use aggregate production function theory in the study of technology and its change, has centered around the limited flexibility of the functional form and difficulties in fitting it to available data. The use of simplifying, often unrealistic assumptions, such as perfect competition in factors and goods markets, constant returns to scale, and entrepreneurs' instantaneous adjustment to exogenous price changes, are a major point of contention (9, 47, 58, 63, 114). Moreover, the form of some of the more common production functions is such that the sources of factor productivity cannot be adequately separated and identified (8, 12, 58, 63). The outcome of this has been the development of more generalized production functions, such as the Variable Elasticity of Substitution (VES) relation, to handle cases where the elasticity of substitution is sensitive to changes in factor proportions, and the Constant Difference Elasticities of Substitution (CDS) relation, to handle cases with more than two factors of production (8, 58, 63). Simultaneity and nonlinearities between the production function and marginal productivity conditions have led to problems in estimation, resulting in the development of new, often less restrictive, estimating techniques (9, 58).

It thus seems that considerable progress has been made in the theory and estimation of aggregate production functions, but empirical evidence on the performance of these new functions and estimating techniques is scanty. Little can be said except that production function based estimates of total factor productivity and parameters of technological change are very sensitive to slight changes in the data, the specification of the production function, and the method of estimation (9, 47, 52, 58, 63). Feelings about the usefulness of the aggregate production function in the analysis of technology and its change range from Brown (12) who strongly supports it, to Nadiri (58) who feels little further progress can be made until the available data is improved, to Acharya et al (1), Baer (6), Bhalla (9), and O'Herlihy (63) who believe a micro-study approach is the route to follow rather than the macro-study approach of the aggregate production function.

As is evident from the above discussion, the economic literature tends to be largely theoretical in nature, and even when the theory is put to a test, it is generally at the aggregate level of an industry or country. In recent years, however, micro-studies at the firm or even process level have begun to come into their own as a means of studying technology. Chenery (17, 18), as long ago as the late forties, introduced the idea of the engineering production function. This is a mathematical statement connecting the physical variables and the output of a process; it can be translated into an economic production function, which relates inputs and outputs in economic rather than physical terms, potentially yielding the isoquants, expansion paths, and cost curves generated by more conventional economic analysis. Its advantages include its being a more explicit representation and analysis of technology and its change, and its not being restricted to observable input combinations. Its disadvantages are that it requires a thorough understanding of the physical technology and is restricted to relatively simple processes, and the range of alternatives is somewhat limited (e.g., fluid transport through pipelines rather than via any mode of transport) (17, 18, 20, 48, 50, 65).

The difficulties inherent in the macro-studies discussed above have thus resulted in a rekindling of interest in this more micro-study or case study approach. It is Sen's observation, in the Foreword to Bhalla's book (9), that this has particularly been the case in the study of choice of technology in developing countries, where the informational dichotomy between the planning and operations level has necessitated it. This is, the planners tend to stress the macro-economic effects of alternative technical packages, greatly simplifying the technology itself, whereas the operations personnel do the opposite; for many years, the emphasis has been on the planning side, but it now seems appropriate to switch the emphasis to operations. Such micro-studies basically entail observing and recording the inputs required for and influences impacting the various stages of production, for alternative means of producing a given output; this data may then be used to synthesize a production isoquant for the good. The advantages include close interaction with engineering data and freedom from the confines of mathematically tractable production functions; the disadvantages include its being expensive and its yielding results which cannot readily be generalized and with no convenient summary measures (1, 6, 9). This shifting in emphasis on the nature of research in the analysis of technology has led to works like Cowing's (20) and Pearl's and Enos' (65) recent applications of the engineering production function, the case studies presented in Bhalla (9) and reviewed in Baer (6) and the array of literature pertaining to highways presented in Section 2.2.

2.2 Brief Review of Related Research in the Highway Field

There are two classes of studies pertaining to highways and their analysis that are directly relevent to the research at hand. Those of the first group, which are reviewed in some detail in Section 2.21, investigate the technical and economic feasibility of alternative technical packages for construction, primarily in conjunction with one design and looking only at construction costs, but being very concerned with deriving accurate and detailed resource productivity and cost data. Those of the second class, which are reviewed only briefly in Section 2.22, investigate the trade-offs among construction, maintenance, and user costs of alternative designs, with the construction technology generally being implicit in the rather aggregate cost and/or productivity data used in the analysis. In the analysis of technology and its change in highway construction, what is ultimately needed, and is used in the study at hand, is a combination of the two efforts, due to the complex interaction of design and technology in highway construction and use.

2.21 Some Case Studies Evaluating Alternative Technical Packages for Highway Construction

With the importance of analytic work based on economic and engineering analyses of individual industries, projects, and processes recognized and research of this type becoming increasingly common, as noted toward the end of Section 2.1, it is this micro-study or case study approach that is reviewed here, as it has been used by numerous authors to study the issue of choice of technology in highway construction, primarily in the context of developing countries. The area of labor-capital substitution in public works construction was a relatively dormant one from the early 1960's to the early 1970's, when interest was again aroused due to its potential for the creation of employment in the developing countries. The studies reviewed here represent the major efforts in the highway field in the seventies, as well as a couple dealing with earthmoving activities from the early sixties that provide some of the groundwork for the more recent studies (see Table 2.1).

The overall objective of this group of studies is to establish the technical feasibility of alternative technical packages for road construction, and, in turn, to relate these technically feasible alternatives to relative factor scarcities such that their economic feasibility can be determined under various institutional and environmental conditions. The majority of the studies, in pursuit of this objective, apply the factor productivity and price data they have collected to one or more real or hypothetical road (dam and canal in the case of Dreiblatt [24]) construction projects and parts thereof in order to determine the economic

Table 2.1: A list of the case studies which are reviewed.

Code Name (Reference Number)	Title of Study	Countries	Year Published
UN (83)	Capital Intensity in Heavy Engineering Construction	United States	1958
(84)	Capital Intensity and Costs in Earth-Moving Operations	United States, Europe, Asia and the Far East	1960
(85)	Eartnmoving by Manual Labour and Machines	Asia and the Far East	1961
Dreiblatt (24)	The Economics of Heavy Earthmoving	India, West Pakistan[a]	1972
Müller (57)	Labour-Intensive Methods in Low-Cost Road Construction: A Case Study	A country in Subtropical Africa	1970
IBRD-I (42)	Study of the Substitution of Labor for Equipment in Road Construction, Phase 1: Final Report	Various countries	1971
IBRD-II (41)	Study of the Substitution of Labor and Equipment in Civil Construction, Phase II: Final Report	India, Indonesia	1974
IBRD-III (38)	Scope for the Substitution of Labor and Equipment in Civil Construction: A Progress Report	India, Indonesia, Kenya, Honduras	1976
(39)	Study of the Substitution of Labor and Equipment in Civil Construction, Phase III: Technical Report No. 1	India, Indonesia	1974
(40)	World Bank Study of the Substitution of Labor and Equipment in Civil Construction - Technical Memorandum No.1-25	India, Indonesia[a]	1975-76
IBRD-Indonesia (37)	Iron Deficiency Anemia and the Productivity of Adult Males in Indonesia	Indonesia	1974
ILO-Thailand (45)	Thai Workers in Heavy Road Construction Activities - An Ergonomic Pilot Study	Thailand	1974

(Table 2.1 continued)

Code Name (Reference Number)	Title of Study	Countries	Year Published
ILO-Iran (44)	Roads and Redistribution, A Social Cost-Benefit Study of Labor-Intensive Road Construction Methods in Iran	Iran[a]	1973
ILO-Philippines (43)	Men or Machines, A Philippines Case Study of Labour-Capital Substitution in Road Construction	Philippines	1974
ILO-Nepal (69)	Comparative Evaluation of Road Construction Techniques in Nepal	Nepal	1973
Vaidya (111)	The Choice of Technology in Highway Construction Industry - A Case Study of Nepal	Nepal	1974

[a]Data used in at least some of the analysis came from various countries.

feasibility of the various technically feasible alternatives observed. IBRD-I (42) and IBRD-II (41) represent a major portion of the work in the productivities area, although several other studies including Dreiblatt (24), Müller (57), and Vaidya (111) also focus more on resource productivities than prices. ILO-Iran (44), ILO-Philippines (43), and ILO-Nepal (69), on the other hand, are largely concerned with deriving various sets of factor prices, which may more truly reflect relative factor scarcities in a developing country than do the prevailing market prices; these studies are thus able to additionally investigate how the economic competitiveness of alternative technical packages varies with factor price.

IBRD-III (38, 39, 40), one of the exceptions to the basic procedure, is largely concerned with devising means to improve labor productivity; it thus tends to focus on factor productivities and prices at the disaggregate activity/task level, although it does consider some project-level implementation in its demonstration projects and studies of broader issues like management and organization. The UN studies (83, 84, 85) can also be singled out due to their concentration on resource productivity and unit cost at the task-level without ever aggregating it to the project level. The last two studies, IBRD-Indonesia (37) and ILO-Thailand (45); concentrate exclusively on factor productivities, in that they are studies of the relationship between health, nutrition, and general physical condition of the workers and their productivity.

The case study approach to the analysis of labor-capital substitution in highway construction may entail three basic activities: (1) collecting the data; (2) applying it to one or more real or hypothetical road construction projects or parts thereof; and (3) analyzing the results. The data required for these studies consists of alternative technical packages for road construction activities, tasks, or stages, and the resource productivities and costs of these packages under various institutional and environmental conditions. The general paucity, lack of detail, and questionable reliability of the data in the engineering and economic literature and the important impact of institutional and environmental conditions on productivity and cost, as revealed by IBRD-I (42) and UN (83, 84, 85) among others, led to the use of field studies and project records in one or two countries in most cases. This is particularly true for the more labor-intensive packages, and efforts were thus largely concentrated on these. As for the equipment-intensive packages, it is felt that better records are generally kept, and thus more reliance is placed on the data already available, in some published form or in the form of contractor's and project records. Both the IBRD (IBRD-I [42], IBRD-II [41], and IBRD-III [38, 39, 40]) and UN (83, 84, 85) studies consider a large number of alternative technical packages for various construction activities or tasks, while the other cases are somewhat more limited in scope.

The case studies exhibit a broad range in emphasis on collecting and analyzing productivity data. Dreiblatt (24), for example, after mentioning the importance of institutional and environmental considerations, ignores them completely in this comparative analyses; ILO-Nepal (69) and Vaidya (111) consider them in a rather qualitative, descriptive manner, although ILO-Nepal does at least use a frequency distribution, rather than a single value, to express the quantity of each factor required for a given output in the hilly regions. Some of the other studies, such as ILO-Iran (44), ILO-Philippines (43), and, to a lesser extent, IBRD-I (42) and UN (83, 84, 85), specify at least some of the institutional and environmental parameters in association with productivity figures for various activities and tasks and consider them in the analysis of alternative technical packages. ILO-Iran (44), for example, develops a production model for each task and technical package, in which a normal productivity is specified with percentage adjustments for changes in work and team factors such as earth type and labor quality.

Finally, the most sophisticated, and only statistically-based, approach is that of IBRD-II (41) which is extended somewhat in IBRD-III (38, 39, 40). A large share of the IBRD's efforts are concentrated on quantifying the relationships among resource inputs, product outputs, and various institutional and environmental parameters for various construction activities and tasks. A generalized Cobb-Douglas type specification fit by regression is used to model these relations, the data base being field observations of on-going civil construction activities and tasks. The data requirements for this are substantial, however, and so far it has been done for only a few parameters, some of the more important activities and tasks, and the more labor-intensive technical packages;

moreover, the particular functional form is being investigated in IBRD-III (38, 39, 40). In the specific area of quantifying the relationships between the general physical well-being of the workers or animals and their productivity, IBRD-Indonesia (37), ILO-Thailand (43), and a few of the technical memorandums in IBRD-III (40 - Numbers 4, 11, 21) make certain contributions.

In addition to factor productivities, factor prices are necessary in order to convert the physical productivities to unit costs to be used in an evaluation of the economic feasibility of alternative technical packages. In all of the cases dealing with one or two countries, and even in the case of IBRD-I (42) which gathers productivity data from a variety of countries, a prevailing, or market, hourly cost is determined for each of the various resources. In the case of labor, this is quite straightforward, the local wage rates for different types of labor, although there is some discussion concerning such costs as provision of amenities and transport for labor and mobilization of labor and whether they should be incorporated here or in the project overhead, with the frequent result that they are ignored. Hourly equipment costs are more complicated to derive, being made up of ownership costs such as interest, depreciation, and maintenance and repair labor and materials and operating costs such as equipment consumables, tires, and operating labor. Assumptions as to equipment life and utilization and maintenance and repair facilities, which are often very different in developing countries than in the developed ones, have an important influence on the hourly cost;

there is even some disagreement over what should be included in the capital cost of a piece of equipment, let alone its hourly cost.

A perhaps more interesting area of difference of opinion pertaining to factor prices is the use of alternative pricing schemes.* The UN studies (83, 84, 85) just gloss over the factor prices issue, looking at productivities and unit costs for the alternative technical packages, while Dreiblatt (24) and Müller (57) apply a single set of factor prices, those estimated to be prevailing, to their productivity data; all three, however, recognize the possibility of using shadow prices. The IBRD studies (IBRD-I [42], IBRD-II [41], and IBRD-III [38, 39, 40]) and Vaidya (111) also use a single set of prevailing labor and equipment prices, but they then perform a sensitivity analysis on the price of one or both resources. Sensitivity analysis in conjunction with a cost minimizing production routine, like that used in IBRD-II (41) or proposed in Vaidya (111), can be used to derive the production isoquant for a particular output. In IBRD-I (42), a breakeven wage rate,** defined for a given set of

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*Prevailing or market costs of resources are those costs actually incurred in any business transaction. In many developing, and even developed, countries, however, these costs may diverge from their true social costs, in which case such resources may be shadow priced to more truly reflect their relative scarcity as well as perhaps certain developmental objectives.

**Breakeven wage rate: $W = (E_1 - E_2)/(L_2 - L_1)$, where E = equipment cost, L = unskilled labor hours, and subscript 1 denotes equipment-intensive technical package and 2 labor-intensive; W also represents the marginal rate of substitution of equipment for labor under these assum-- tions.

equipment prices as that unskilled wage rate at which the cost of executing an activity by labor is identical to that by equipment, is often used to look at the trade-off between equipment and labor in various construction activities, tasks, and stages.

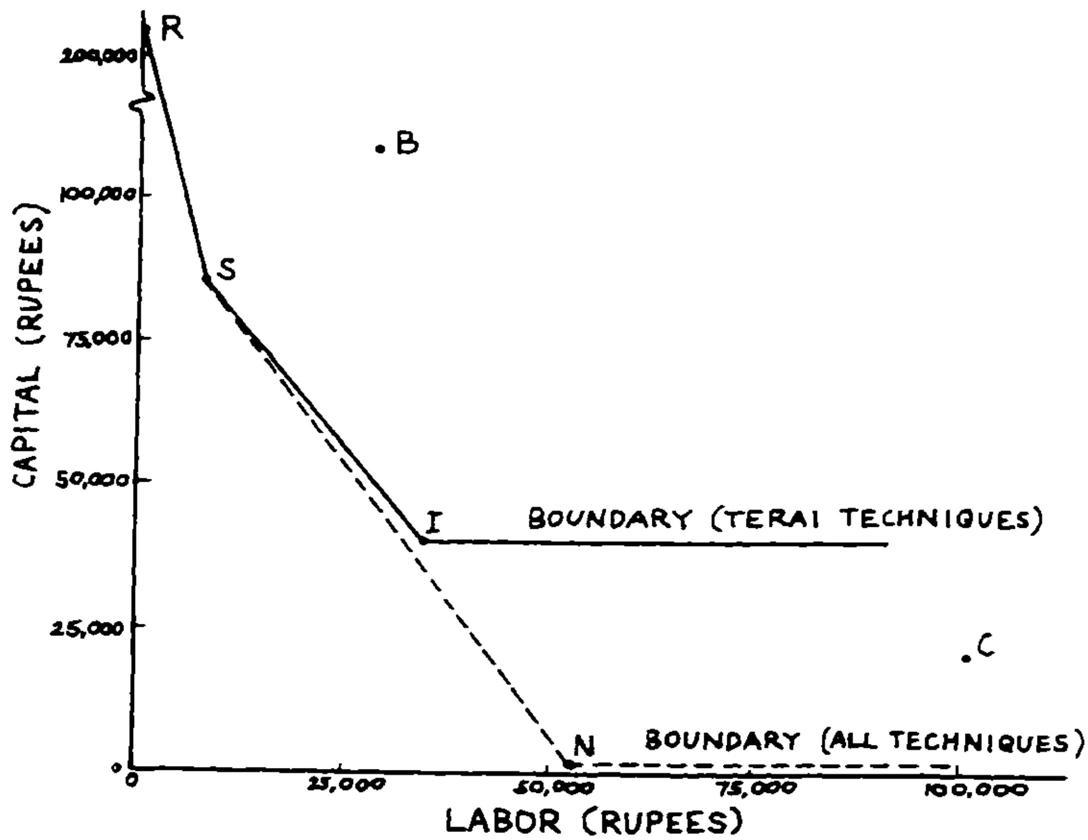
It is the three ILO studies (ILO-Iran [44], ILO-Philippines [43], and ILO-Nepal [69]) that really focus on the relative factor prices issue, much as the IBRD's work focuses largely on factor productivities. Because market prices prevailing in developing countries do not always properly reflect relative factor scarcities, various sets of input prices, which reflect different approaches to the question of optimal allocation of resources available to an economy, might be feasible and should be investigated. Using established methods for deriving shadow prices (basically those of UNIDO [23], OECD [51], and a mix of Sen [74] and UNIDO [23]) and varying certain assumptions which ultimately influence the relative input prices, the ILO studies (43, 44, 69) try various sets of labor and equipment prices in conjunction with their productivity data in order to investigate variations in the economic competitiveness of alternative technical packages with factor prices.

Given that the data has been collected, the final two steps to any case study entail applying the data to one or more real or hypothetical road projects or parts thereof and analyzing the results, and are best discussed concurrently. The UN studies (83, 84, 85) are rather limited in this regard in that only a couple of earthmoving tasks are considered, and the economic analysis is simply a tabular/graphical comparison of their unit costs when various technical packages are used under a few varying environmental conditions. The primary difficulty with these studies is that the data is from a wide range of countries and projects, resulting in a wide variety of unmeasured institutional and environmental factors. Some of the other studies, such as ILO-Philippines (43), IBRD-II (43), and IBRD-III (38, 39, 40), do a similar type of analysis at the activity/task level, but their data is limited to one country, and thus the variability of unmeasured influences should be less.

In the cases of Dreiblatt (24), Müller (57), and ILO-Philippines (43), a wider range of activities/tasks is studied as well as the product, road, dam, or canal, they produce. The basic steps involved are as follows: (1) activities/tasks in the project are identified, and their quantities estimated; (2) for each, a capital and labor-intensive, and in ILO-Philippines (43) sometimes a modified labor-intensive, technical package is defined, and its resource requirements determined; (3) each package is then priced (with market and shadow prices in ILO-Philippines [43]), and comparisons can be made at the activity/task level; and (4) the activity/task costs are then summed for each category of technical packages, except in the case of Müller (57) who also sums over a combination of the capital and labor-intensive packages, and comparisons can be made at the project level. Although this method gives the costs of the various technical packages alone and in combination, it says nothing about their relative efficiencies. Still, it is straightforward to use and reasonably useful as long as the number of activities/tasks and categories of technical packages is limited, or there is limited interest in mixing the packages of the various technical categories.

ILO-Nepal (69) and Vaidya (111) pursue the same basic approach, with some exceptions and extensions. These two studies are somewhat different from the other cases reviewed here, in that they are based on five different projects in Nepal, each constructed by a different country with its own particular set of technical packages, ranging from the highly labor-intensive practices of the Chinese to the highly capital-intensive ones of the Russians. Resource inputs for a given unit of output have been gathered at the stage level for each project, and a single set of quantities is used to aggregate the stages, representing one set of technical packages or a mix, to a standard kilometer of road. The validity of such comparisons is necessarily constrained by differences among the projects, some of which could be alleviated, but others of which could only be qualitatively described; for example, road design and quality which will later affect maintenance and user costs differ among projects, the environmental and institutional conditions differ, the actual activities/tasks and materials used in the different stages differ, and so forth. As an extension to the above discussed methodology, ILO-Nepal (69) plotted production isoquants in order to determine the relative efficiencies of the alternative sets of technical packages at each stage and in the aggregate (see Figure 2.2 for a sample graph); it also employed a number of matrices (e.g., a technical package, resource price [containing project, standard, and shadow prices], and total cost matrix)

Figure 2.2: Capital and labor inputs of the various technical packages for the earthwork stage of the Nepal projects, valued at standard prices for Nepal (source: ref. 69).



Note:

Project	Total Cost (Rs/10,000CM)
R - Russian	219,352
B - British	137,748
S - Standard[a]	94,421
I - Indian	75,159
N - Nepali	55,457
C - Chinese	121,144

[a]This represents the standard technical package for embankment formation from the UN-HMG Nepal Road Feasibility Study Report (referenced throughout ILO-Nepal [69]) and is included for the sake of comparison.

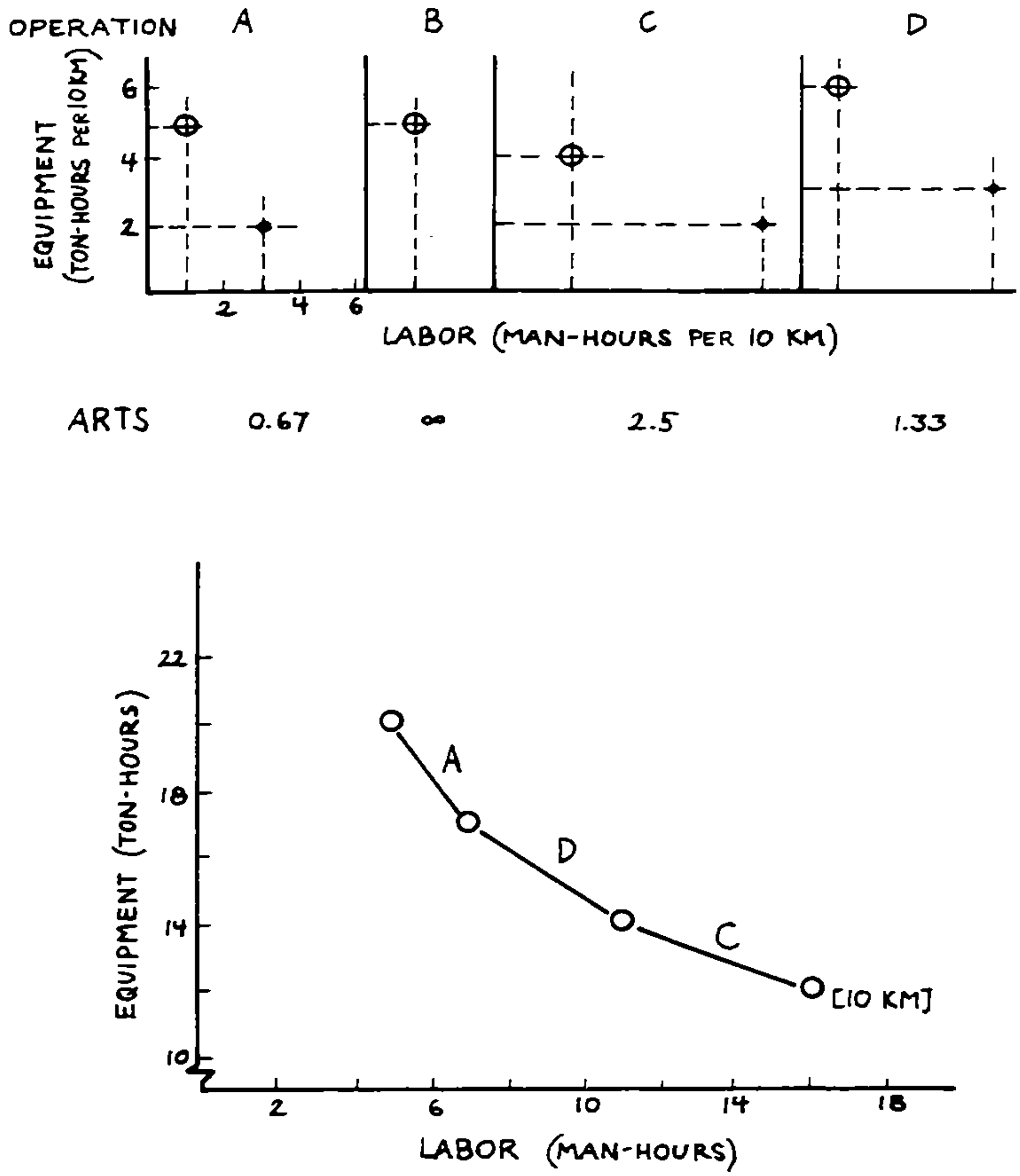
A distinction can be made between the techniques used in terai road construction and those employed in the hills (i.e., Chinese and Nepali projects); in terai road construction, earthwork entails lifting of the embankment material, while in side hill cutting the earth merely has to be pushed over the side of the formation, resulting in earthwork per cubic meter generally being cheaper in the latter case. Two separate boundaries have thus been inserted linking the efficient technical packages (at least efficient relative to those observed); it should be noted that the British technical package is inefficient relative to the other terai techniques, while the Chinese is inefficient relative to the Nepali project.

as an effective means of organizing the data.

Productivities and technical packages are best observed at the disaggregate level of activities or perhaps tasks, while the object of interest is the road itself and the mix of packages to be used in its construction. This aggregation from the activity to task to stage to project level can be accomplished in the additive manner described above; if, however, it is desirable to consider mixing the technical packages at the disaggregate level and to consider only the relatively efficient combinations as is usually the situation, then a production function approach, as employed in IBRD-I (42), and ILO-Iran (44), is more appropriate. The derivation of an aggregate production isoquant is illustrated in notional form in Figure 2.3. ILO-Iran (44) and IBRD-I (42) both use this approach quite successfully for a limited number of technical packages and conditions. ILO-Iran (44), for example, uses it to aggregate eight activities/tasks (those where substitution is possible) to the project level, considering two packages for each activity/task, for five different projects representing various road classes and terrains; it then calculates the average rate of technical substitution for each project as a whole, and finding them all to be about the same, it proceeds to look at the direct employment generated in each case as the labor-intensive activities are substituted for the capital-intensive ones.

There are several difficulties inherent in such aggregation of construction activities. First, it assumes the activities are independent, requiring that activities which are not for certain technical packages

Figure 2.3: Notional representation of the derivation of an aggregate production isoquant (source: ref.44)



(Figure 2.3 continued)

Note: The basic procedure for deriving the aggregate production isoquant is as follows: (1) suppose the construction consists of four operations, A through D, and for all except B there are two technical packages; (2) calculate the average rate of technical substitution of labor for equipment

$$ARTS = \frac{L_2-L_1}{E_1-E_2}$$

for the pairs of technical packages using it to rank the packages; (3) beginning with the most capital-intensive package for each operation, sum the resources across the operations and plot this on the production isoquant graph; (4) next, for the pair of packages with the lowest ARTS (A in this case) use the resources of the more labor-intensive package, combining these with the resources of the capital-intensive packages for the other operations (B through D), and plot the sum; and (5) so forth, until all of the labor-intensive technical packages have been substituted for the capital-intensive ones. The result is a production isoquant representing the efficient mixes of packages (efficient relative to those available). In the interests of minimizing cost, it is economically feasible to substitute labor for equipment up to the point where the average rate of technical substitution equals the ratio of the average price of equipment to that of labor; for example, if

$$\frac{P_E}{P_L} = 1.5,$$

then one can economically use the labor-intensive packages for operations A and D and capital-intensive ones for B and C. Alternatively, one might price the points on the isoquant to determine the least cost solution.

In IBRD-I (42), the breakeven wage rate is used instead of ARTS; this is the inverse of ARTS with equipment measured in dollars rather than ton-hours. The major disadvantage of this approach is that the price of equipment cannot be varied as readily, although it eliminates the problem of finding an average price for equipment (a nonhomogeneous set) and the question of what to do with equipment that cannot be measured in ton-hours.

(e.g., labor's productivity in loading depends on the haul vehicle due to the impact of load height) be treated as a single item. Perhaps more importantly, there are certain interdependencies among activities and impacts of substitution that are more subtle and harder to handle (e.g., the effect on equipment's utilization rate of substituting it by labor for a particular activity), and thus it is not clear that optimization on an activity basis is compatible with that on a project basis. Further, each aggregation is restricted to a particular set of institutional, environmental, and design conditions, and the number of possible alternatives is tremendous. Moreover, rather than looking at alternative mixes of technical packages for building one specific road, it is desirable to consider building various roads of equal quality and service, in that a particular technique might be more suited to one design than to another. If one begins to try to incorporate project scale, time, and other constraints such as minimizing foreign exchange cost or taking account of the availability and mobilization costs of labor and equipment, the problem becomes very complex indeed. Even ignoring this, this approach gets rather tedious and difficult to do if there are more than two technical packages for each activity or if the aggregation is done in a stepwise manner.

These types of difficulties and complexities encountered in the aggregation process led to the development of a computerized linear programming model in IBRD-II (41). The objective of this model is to select a set of methods to be used in constructing a given civil works project (or set of projects) to minimize total cost, subject to the country's available resources and technology. Using the same type of activity/task level data required above, this approach can quickly select the optimum mix of technical packages for a project from a large set of alternatives. Through successive applications of the model, alternative institutional and environmental conditions, project designs, pricing schemes, and so forth can be investigated, all rather quickly; testing the sensitivity of the results to alternative values of various parameters is a prime feature of linear programming models. An aggregate production isoquant can readily be derived by using a continuum of labor prices and solving for the minimum cost solution.

Furthermore, a number of features already incorporated or that could be incorporated in the model help to alleviate some of the difficulties in aggregation discussed above. Resources, for example, may be subject to minimum or maximum constraints (e.g., a minimum might be set on the amount of labor to be employed); new resources incur a set-up cost, while resources already on the site are available for only a limited number of hours during any period; and certain resources can be used only in integer or discrete quantities, an option which might be used to incorporate some features of economies of scale. Time has been introduced into the model through the use of time periods and a discount rate, and a certain limited amount of scheduling of tasks and resources is possible through constraints. The model is, however, still restricted to comparing alternative mixes of technical packages for building a specific road (i.e., a given set of design standards), rather than building different roads of equal quality and service; the suggestion has been made, however, to use it in conjunction with models, such as those discussed in Section 2.22, which can analyze design standards. This model thus seems a potentially useful tool in the study of alternative technical packages, alone and in various combinations, for civil works construction and warrants further consideration and application, particularly in the field; in IBRD-II (41), for example, it is used only in a single road project and in a set of projects entailing four categories of roads.

In completing the review of this set of a dozen case studies, it seems only appropriate to briefly state their general findings, conclusions, and directions for further research. It is generally agreed that there exists a broad range of possible technical packages for use in highway construction, and that it is technically feasible to substitute labor for equipment in a wide variety of activities. The issue of economic efficiency of alternative technical packages, however, is much less clear-cut: (1) several of the studies, including Dreiblatt (24), Müller (57), IBRD-II (41), and ILO-Iran (44), find that although certain labor-intensive techniques may be efficient relative to the others observed, they are generally not economically competitive at the market prices judged to be prevailing in the study country; and (2) certain other studies, including IBRD-III (38, 39, 40), ILO-Philippines (43), ILO-Nepal (69), and Vaidya (111), on the other hand, find certain of the relatively labor-intensive packages to be economically feasible at market prices. Finally, it is generally agreed that the application of shadow prices, as demonstrated by the three ILO studies (43, 44, 69), makes the labor-intensive techniques more competitive, often to the point of being socially profitable. Recognizing the necessarily restricted nature of these studies and questions remaining as to appropriateness of market versus shadow prices, the general consensus, with but one exception (Dreiblatt [24]), seems to be that efforts should be expended in the direction of increasing labor's role in highway construction in labor-abundant, capital-scarce countries. It is thus proposed that future efforts be directed toward devising means to improve labor productivity and to effectively implement more labor-intensive practices.

2.22 Some Models Evaluating Alternative Designs for Highway Projects

A shortcoming of the case studies reviewed above is their focusing on alternative means of construction of a single project design, rather than extending the project beyond the construction phase to that of operation, such that various project designs might be investigated in conjunction with alternative technical packages. Considerable progress has been made toward developing a model to evaluate alternative design, construction, and maintenance strategies for low volume roads, in terms of construction, maintenance, and user costs since the mid-sixties, when Soberman (76) made his preliminary, largely theoretical contributions to the field. Lago (49) followed shortly with the development of a model for estimating total road transport costs. Building upon this earlier work, Vance (112) in the late sixties, using the concept of production function based cost functions, produced a new version of a road transport cost estimating model, one that was suitable for hand calculation and could handle, for example, staging of construction and alternative labor/capital mixes for use in road construction and maintenance. Concurrently, personnel at M.I.T. were developing the first version (36) of the Highway Cost Model (HCM), a computer-based, cost-estimating, simulation model which met the objectives outlined above and brought together in a decision-making framework the work to date in the field. Since then, the model has been subject to extensive revisions and expansion of its capabilities, particularly in the areas of estimation of road surface deterioration and the impact of design standards and surface conditions on road user costs, as new information has become available (e.g., 80, 81), culminating in the most recent version (56) of the model which is now being tested and used in Ethiopia. Somewhat parallel and complementary to M.I.T.'s efforts have been those of the Transport and Road Research Laboratory (TRRL) which, largely on the basis of field work carried out in Kenya in the seventies, produced their own road transport investment model for developing countries (82).

It is the HCM which is used in the study at hand because it integrates many of the existing methodologies of evaluating alternative designs in terms of the three costs; it is also operational, computerized, and readily available with personnel at M.I.T. knowledgable about and willing to assist in its use. As the HCM is representative of this class of models, it seems appropriate to make a few comments about its basic framework and more pertinent features.

Project-level engineering decisions, such as choice of alignment, geometric standards, surface type, maintenance policy, and construction and maintenance methods, and their implications for total transport costs are the focus of the model. The basic function of the HCM, estimating construction, maintenance, and user costs for a road, is done by simulating the life of the road, beginning with its initial construction and proceeding through periodic upgrading as well as the yearly cycle of use, deterioration, and maintenance. On a year-by-year basis throughout the analysis period then, construction and maintenance activities to be performed are determined, and road conditions, traffic volumes, and all associated costs are estimated; Figure 2.4 gives the basic structure of the model. The output of the simulation includes a yearly accounting of construction, maintenance, and user costs as well as a detailed history of the status and deterioration of the road. Construction and maintenance costs can be broken down into their components of labor, equipment, materials, and overhead and profit, while user costs can be disaggregated to the vehicle operating costs for each type of vehicle using the road. It might additionally be noted that all estimates in the course of the simulation are made in terms of physical quantities, from which total costs are obtained by applying the appropriate unit rates, allowing the use of any monetary system. Moreover, construction and maintenance technology are inherently expressed in the unit costs input to the model, while transport technology is inherent in the vehicle characteristics

Figure 2.4: Basic structure of the HCM (source: ref. 56).

DATA REQUIREMENTS

National or Regional Parameters

- Design Standards
  - Geometric standards
  - Pavement sections
  - Material characteristics
- Maintenance Standards
  - Routine maintenance criteria for earth, gravel, and paved roads
  - Resurfacing criteria

Highway Program Parameters

- Construction Unit Costs
- Maintenance Unit Costs
- Basic Vehicle Characteristics and Ownership and Operating Costs

Project Parameters

- Traffic
- Physical Characteristics of the Alignment
- Specific Design and Maintenance Standards to Be Studied
- Schedule for Implementation

SIMULATION OF ROAD LIFE CYCLE

For each year in analysis period

↓

Estimate costs for road construction or upgrading based on physical characteristics of the alignment, design standards, and construction unit costs

↓

Update the status of the road based on project completions

↓

Preliminarily estimate this year's traffic based on that of past year and expected growth

↓

Estimate road deterioration as a function of design standards, past year's surface conditions, traffic, and environment; effects of maintenance and their costs; and average surface conditions

↓

Estimate user costs based on geometric standards and surface type and condition

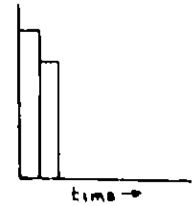
↓

Update traffic projections based on actual user costs

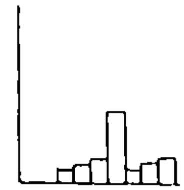
(loop back to "For each year in analysis period")

RESULTS

Construction Costs

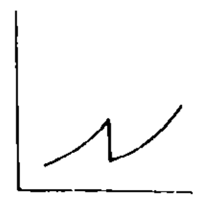


Maintenance Costs



Surface Conditions (present serviceability index)

User Costs ($/vehicle/kilometer)



and costs input, and thus all can be varied.

2.3 Method of Approach Used in Research

The analysis of technology and its change in highway construction in the U.S. in the research at hand follows a micro-study approach patterned after the case studies reviewed in Section 2.21. In an effort to also consider the interaction of design and technology in highway construction and use, the current study goes somewhat beyond these earlier ones in implementing one of the models of Section 2.22 for evaluating total project costs. Moreover, certain of the economic concepts and tools discussed in Section 2.1 are used in the analysis of the results.

The basic analytic procedure thus entails first observing and recording the inputs required for and influences impacting the various tasks of production, for alternative means of producing a given output; this data is then used to synthesize a production isoquant for the good which is subjected to further economic analysis. Since it is obviously impossible to actually observe the technologies of the past in the field today, historical data used in a simulation framework must suffice; thus, the various stages of highway construction and complete road projects can be hypothetically built and operated, by means of alternative technical packages and project designs. This is accomplished in two levels of analysis: (1) the stage-level, where each of the various stages of construction constitutes an output, with the labor, capital, and materials of the various technical packages for each stage being the inputs; and (2) the project-level, where a road project capable of handling a particular volume of traffic constitutes the output, with the construction, maintenance, and user costs of the alternative projects designed for the particular traffic being the inputs, although these are also considered in a more disaggregate sense as, for example, the labor, capital, and materials requirements of the construction phase. Each level of analysis is discussed in turn below.

2.31 Stage-Level Analysis

The basic data required for the stage-level analysis consists of the alternative technical packages, available at various points in time in the U.S., for the various stages of road construction, and the resource productivities and costs of these packages under typical environmental and institutional conditions. The productivities of the various resources included in each technical package are generally available at the activity or task level and are thus aggregated to the stage level. At this point, the unit prices of the resources can be applied, for example, to arrive at the unit costs of the various technical packages of each stage of construction. For each technical package for each stage of construction, where output is measured in physical units of a given rate of production (e.g., 100 bank cubic meters per hour) or units produced (e.g., 100 bank cubic meters), the following set of results is generated for further analysis: (1) skilled and unskilled labor input, separately or in combination, expressed in physical units of men or man-hours or in cost terms; (2) equipment input measured in value terms of investment, straight-line depreciation (thus introducing life), or total ownership and operating cost (or its various components of capital recovery, maintenance and miscellaneous, and fuel and lubrication costs); (3) animal (horse) input expressed in value terms along the lines of those of equipment; (4) materials input measured in cost terms; and (5) total unit cost, including all resources involved. This is done for each of three technology periods under various pricing conditions. Section 3.1 and Appendix B provide further details on the collection and preliminary analysis of data for the stage-level analysis.

Given these results then, the analysis of technology change in highway construction over time in the U.S. is basically a three step process: (1) a qualitative investigation of how the technical packages, in terms of the resources constituting them, have changed; (2) an efficiency analysis, whereby graphical and numerical techniques are used in narrowing the production set to those technical packages, which are efficient, for each stage of construction, for each technology period and over all periods; and (3) an analysis narrowing the efficient set of technical packages for each technology period and over all periods to those which are best-practice at prices representative of each of the three technology periods, such that technology change and its characteristics can be identified and quantified.

The qualitative analysis concerning changes in the nature of the technical packages requires, for each stage of construction for each technology period, a listing of the technical packages and the resources constituting them, as well as a graphical representation of the resource requirements of each package. The graphs used in the graphical efficiency analysis, discussed next, can fulfill any need for analytic tools at this step.

Narrowing the full set of technical packages to those which produce the most output for the least input can be accomplished by means of graphical or numerical analytic techniques; both are used in the case at hand. The graphical approach basically entails plotting the labor and capital requirements of the various technical packages for each period for a given rate or level of production, potentially yielding production isoquants. Certain difficulties are encountered in this approach, including the omission of other resources required for production, such as materials, although they could be included as additional dimensions, and selection of the units of measurement of the resources, some possible measures of capital, for example, being investment, hourly depreciation, or hourly ownership and operating costs at various possible base periods. Discussion and testing of alternative solutions to these difficulties for the case at hand is covered in Section 4.11. The outcome is that omission of resources other than labor and capital is justified; labor is reasonably measured in terms of unskilled men, where the skilled input is weighted by the skilled/unskilled wage ratio at the time of the technology, before being added to the unskilled input, while capital is most suitably measured in 1974 (i.e., current) investment dollars.

A numerical efficiency analysis is used as a back-up to the graphical approach, whereby the engineering variables are held constant while the economic ones are allowed to vary over a wide range; efficient technical packages are defined as those which are least-cost under at least one set of reasonable economic conditions. The following equation is used throughout the study to estimate the total unit costs of the technical packages:

$$\text{UNITCOST} = \overbrace{(\text{skcost} \cdot \text{SKREQ} + \text{unskcost} \cdot \text{UNSKREQ})}^{\text{labor costs}} +$$

$$\overbrace{\sum_k \left\{ \left\{ P_{kt} \left[\frac{\text{index}}{\text{INDEX}_t} \right] \left[\frac{\dfrac{(1+i)^{N_k}\, i}{(1+i)^{N_k} - 1}}{H_k} + \frac{\text{MAINT}_k}{N_k H_k} + .055\, \frac{(N_k + 1)}{2N_k H_k} \right] + 1.35\,(\text{ccost} \cdot \text{CREQ}_k + \text{gcost} \cdot \text{GREQ}_k + \text{dcost} \cdot \text{DREQ}_k) \right\} \cdot \text{EQREQ}_k \right\}}^{\text{equipment costs}} +$$

$$\underbrace{(\text{hcost} \cdot \text{HREQ})}_{\text{horse costs}} + \underbrace{\sum_j (\text{mcost}_j \cdot \text{MREQ}_j)}_{\text{material costs}}$$

where small letters indicate economic variables

capital letters indicate engineering variables

subscript k = item or equipment

subscript t = year of equipment investment cost

subscript j = material

___cost = hourly or per unit quantity cost of the resource, with sk = skilled labor, unsk = unskilled labor, c - coal, g = gasoline, d = diesel fuel, h = horse, m = material*

___REQ = hours or quantity of the resource required per unit of output (exceptions: $CREQ_k$, $GREQ_k$, $DREQ_k$ = quantity of fuel consumed per hour by equipment k), with prefixes as for ___cost adding EQ = equipment

P_{kt} = investment cost of equipment k in year to

index = index used to inflate or deflate equipment investment cost in line with particular economic conditions being considered

$INDEX_t$ = equipment investment cost index in year t

i = interest rate

N_k = life in years of equipment k

H_k = annual hours of utilization of equipment k

$MAINT_k$ = maintenance over life as a percentage of investment cost of equipment k

*Generally only site preparation materials are included, as those for surfacing are the same across all technical packages for one surface type.

The economic variables are divided into four groups, labor (skilled and unskilled), interest rate, equipment (index, equipment consumables, and materials assisting in construction), and horse, and various sets of economic conditions (e.g., the U.S. in 1974) are defined. The economic conditions of the four resource groups are allowed to vary independently of one another, and the unit costs of the full set of technical packages are calculated for each combination of economic conditions; thus the technical packages which arise as least-cost under at least one reasonable combination of economic conditions can be identified. The result, for each stage, for each technology period and over all periods, is the set of efficient technical packages, which can be compared to the respective result of the graphical analysis. The primary shortcoming of this analytic technique is that the range of combinations of economic conditions encountered in the analysis may not be fully representative of those in existence, and the results may, therefore, not be all-inclusive. Given the two analytic techniques, however, it seems a reasonably reliable picture of the set of efficient technical packages should be obtainable.

In beginning to address the issue of efficiency and substitution and their role in technology change, it was decided to pursue an approach either (1) along the lines of Salter (73), who tries to divide the change in factor productivity into its component parts; or (2) along the lines of the theoretical production functions, such as the Cobb-Douglas and CES, whereby the characteristics of a technology can be expressed by various combinations of the empirically determined parameters of the function.

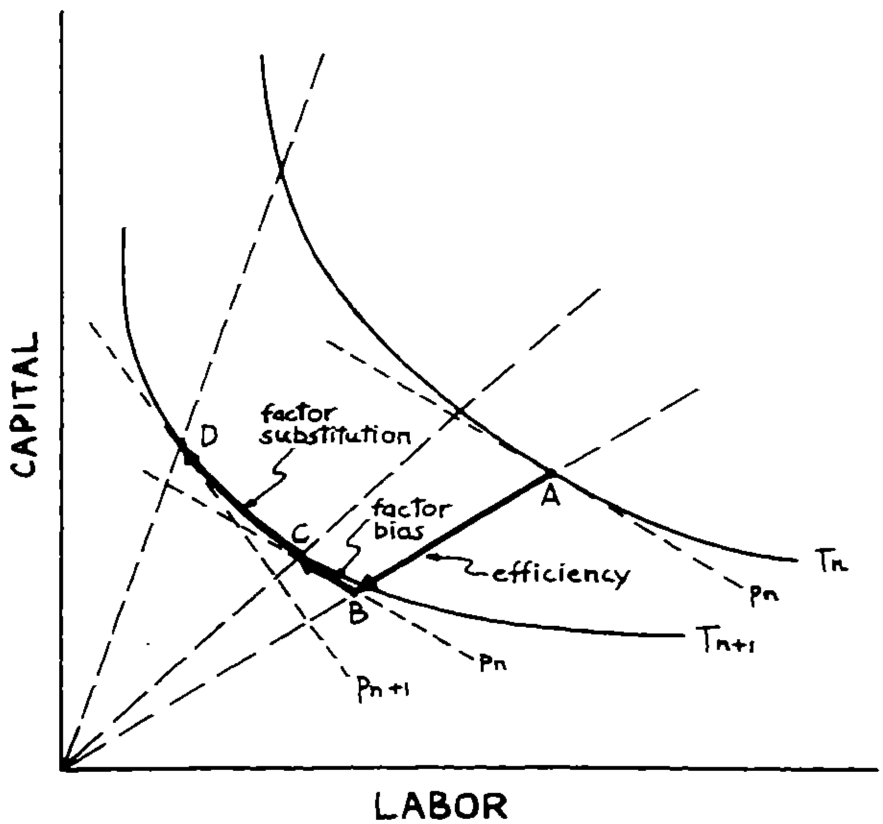
Both approaches are discussed in Section 2.1 along with their various shortcomings. The results of the efficiency analysis, however, pretty much preclude the use of theoretical production functions. Production functions were found to exist for the various stages of construction for only the first of three technology periods identified in the course of the analysis and for the overall case. Furthermore, in the two cases where production functions do exist, the measurement of capital is a problem; investment cost is the standardly accepted measure in the economic literature, but it does not seem so appropriate here due to the wide variation in the lifetime, maintenance as a percentage of investment, and fuel consumption exhibited by the items of equipment included in the efficient set. An approach along the lines of Salter's seems somewhat more viable and is thus the one pursued in the study at hand.

Salter views technology change as represented by movements over time of the best-practice techniques. The first step, therefore, consists of narrowing the set of technical packages for each technology period to those which are least-cost, and thus best-practice, at prices representative of each of the three technology periods. The full set of technical packages for each stage of construction is costed by means of the unit cost equation given above, and the least-cost packages are identified as well as any others that are within 10 percent in cost; these, then, make up the least-cost set.

Having thus reduced the set of technical packages to the best-practice ones, it is useful to return to a graphical approach to observe the magnitude of the technology change that has occurred over the years in terms of overall costs and factor inputs. For example, it is of interest to see the progression of the unit costs of each stage of construction over time, both as they actually occurred and as they would have occurred had technology not changed as it did. Coincidently, as suggested by Carter (15), and in line with Salter's analysis, it is useful to observe the change over time in the quantities of various resources required to produce a certain rate or level of outdut. After testing alternative measures in Section 4.12, it is decided to use unskilled men and 1974 investment costs, as in the graphical efficiency analysis; this is perhaps more appropriate here, as the equipment of the earlier best-practice packages is somewhat more in line with that of later packages than is generally the case. For each stage of construction, then, the labor and capital requirements of the best-practice packages of each technology period are looked at as a percentage of those of previous technology periods.

Given this quantitative measure of technology change then, by means of Salter's approach, it is possible to begin to divide it into its component parts. Figure 2.5 is useful as a first step in that it depicts the disaggregation of the movement of best-practice packages over time into its component parts. It should be noted that in this study, as in Salter's analysis, returns to scale are assumed constant, leaving efficiency, factor bias, and factor substitution as the characteristics of technology change. As indicated by Figure 2.5, factor substitution occurs with changes in relative factor prices. In the course of deriving

Figure 2.5: Schematic representation of dividing technology change, represented by movements over time of best-practice techniques, into its component parts.



Note: Constant returns to scale are assumed.

A = best-practice technical package at the prices of period n, given T_n as the production isoquant.

B = theoretical technical package defined to separate the effects of efficiency and bias; its capital/labor ratio is the same as that of A, while its cost is the same as that of C.

C = best-practice technical package at the prices of period n, given T_{n+1} as the production isoquant, or both T_n and T_{n+1}.

D = best-practice technical package at the prices of period n + 1, given T_{n+1} as the production isoquant, or both T_n and T_{n+1}.

the set of best-practice packages for each technology period and over all periods at prices representative of each of the three technology periods, however, it was discovered that, with but a few minor exceptions, the best-practice packages for each stage of construction in each technology period are the same for all three price periods (i.e., points C and D are the same in Figure 2.5); moreover, the best-practice packages of each technology period exhibit lower costs than those of previous periods for all three price periods (i.e., point C is lower in cost than is point A in Figure 2.5). The first finding suggests that substitution, brought about by changes in factor prices over the period covered by the technologies being studied, has not played a significant role in the technology change observed over that period; the second suggests that efficiency has had some part. This approach is similar to one used by Buechner (14) in determining whether observed occupational changes were the result of technological or technical change.

What remains in the study at hand, then, is the separation of the roles of efficiency and factor bias; such is depicted in Figure 2.5. Based on Salter's work and after some testing of alternative pricing schemes as discussed in Section 4.12, the following generic form of the equation for estimating the fractional change in unit resource requirements accounted for by efficiency was selected:

$$\frac{L_B - L_A}{L_A}, \quad \frac{K_B - K_A}{K_A} = \frac{w_n L_C + g_n K_C}{w_n L_A + g_n K_A} - 1$$

where subscripts A, B, C refer to points on Figure 2.5

subscript n = initial period

L = labor in men required for a given rate of production

K = capital in investment dollars required for a given rate of production; any price period may be used on the left side of the equation, but period n must be used on the right side

w_n = hourly wage rate in period n

g_n = hourly capital recovery factor in period n

This measure of efficiency can readily be derived by simultaneously solving two equations defining point B in Figure 2.5, one stating the equality of the capital/labor ratios at points A and B and the other stating the cost equality of points B and C. In the case at hand, a uniform wage rate and capital recovery factor do not exist, and thus each item of labor (i.e., skilled and unskilled) and equipment (i.e., varying in terms of lifetime) is priced at its own wage rate or capital recovery factor before summing on the right-hand side of the above equation; L and K on the left-hand side are respectively measured in unskilled men and 1974 investment costs.

Salter also develops an equation for estimating the fractional change in unit resource requirements accounted for by bias as follows:

$$\frac{L_C - L_B}{L_A} = -\pi_n \left(\frac{K_C/L_C}{K_A/L_A} - 1 \right)$$

$$\frac{K_C - K_B}{K_A} = (1 - \pi_n) \left(\frac{K_C/L_C}{K_A/L_A} - 1 \right)$$

where π_n = share of capital costs in total costs in period n; in the case at hand, it is interpreted as the average for the packages (i.e., points A and C) being compared

Salter's measure of bias, however, is but an indication of the direction and potential magnitude of bias' influence on resource quantities and not really a true measure. In this study, the specific resource requirements of points A and C are known, and thus bias' part in the fractional change in unit resource requirements is simply as follows:

		total fractional change		efficiency's share
$\frac{L_C - L_B}{L_A}$	=	$\frac{L_C - L_A}{L_A}$	-	$\frac{L_B - L_A}{L_A}$
$\frac{K_C - K_B}{K_A}$	=	$\frac{K_C - K_A}{K_A}$	-	$\frac{K_B - K_A}{K_A}$

With these analytic tools, then, the relative roles of efficiency, bias, and substitution in technology change over time, as well as the magnitude of technology change itself, can be identified and quantified for the various stages of road construction in the U.S.

2.32 Project-Level Analysis

Variations in project designs and/or construction procedures can potentially lead to trade-offs among the various stages of construction and/or between the construction and operation phases of a highway project, and can thus be investigated only at the level of the complete project. Such interaction of design and technology in highway construction and use makes it important to extend the stage-level analysis to the project-level. In an effort to begin to investigate some of these issues, this research looks at alternative surfacing materials, various subgrade strength/surface design combinations, and alternative scenarios for obtaining fill materials, for a couple of design standards and traffic volumes.

The data required for the project-level analysis consists of the construction quantities and the efficient technical packages (and thus resource requirements and unit costs from the stage-level analysis) for each technology period and over all periods, for the various stages of construction of a representative set of alternative projects; also needed are the maintenance and user costs associated with these projects at various price periods. Although it seemed desirable at the outset to use designs commensurate with each technology period, this proved to be somewhat infeasible due to a paucity of early design information; it was decided instead to design projects at the low and high end of the spectrum for today's two-lane, low volume, rural roads for two different traffic volumes. The production function based aggregation procedure, as performed in the IBRD-I (42) and ILO-Iran (44) studies discussed in Section 2.21, seemed to present a suitable means by which to aggregate the various stages of construction, with their respective quantities and sets of efficient technical packages, for each technology period and over all periods, to the alternative projects. The findings of the stage-level analysis given above, however, indicate that, over the range of prices representative of the three technology periods, there is effectively no choice of technology, and thus no need for such an aggregation procedure. It was therefore decided to do the project-level analysis at prices representative of the U.S. over this period, simply using the best-practice technical packages identified in the stage-level analysis. Since production functions do exist in two cases, however, it was decided to also use a more extreme set of pricing conditions (e.g., those of a developing country), such that some of the alternative technical packages in these cases might appear in the least-cost set and be used in the project-level analysis as well.

For each project, under various technology and price conditions, where output is measured in terms of the volume of traffic the project is designed to carry over its life, the following results are generated for further analysis: (1) total, and per unit traffic, construction costs and its various components of labor, capital, materials, and overhead and profit, among other subtotals; (2) total, and per unit traffic, maintenance costs over the life of the project, both expressed in net present value terms and the former in equivalent annual cost terms as well; (3) total, and per unit traffic, user costs over the life of the project, similarly expressed; and (4) total and per unit traffic, project costs over the life of the project, expressed in net present value terms. Section 3.2 and Appendix C provide further details on the collection and preliminary analysis of data for the project-level analysis.

The first step in the project-level analysis is a graphical efficiency analysis, patterned after one proposed by Soberman (76) investigating the trade-offs between current and future expenditures in highway construction and use resulting from the design and technology mix. For each project and each technology period and over all periods, the maintenance and user costs incurred over the life of the project, expressed in terms of equivalent annual costs, are plotted against the construction costs. As these are value rather than quantity-based measures, it is appropriate to do this for a couple of price conditions representative of the U.S. over the period of the technologies observed. In order to broaden the analysis and test the sensitivity of the results to economic conditions, and as there is some choice of technology in the case of one technology period and the overall case, a more extreme set of prices, like those of a developing country today, are also used.

Given the various sets of efficient projects for each project group, under various price and technology conditions, it is next useful to narrow these to those projects which are least-cost in terms of total project costs, expressed as equivalent annual or net present values. Little distinction is found, however, among project alternatives and even among alternative technologies in the various project groups at the level of total project costs. A similar analysis with these costs disaggregated into partial construction (predominantly labor and capital), total construction, maintenance, and user cost components is thus necessary, in order to see the dominance of various cost factors and to see where differences among the projects and technologies lie. A graphical presentation of these cost components (and, in turn, their components) for a couple of projects, for each technology period, at prices representative of the U.S. over this period, serves as a useful tool. It provides some insight into the relative magnitudes of these various cost components as well as their change over time in the U.S., and, most importantly, it indicates the magnitude of the cost-reducing influence of technology change in highway construction at the project level. At the same time, it should be noted that materials usage, maintenance policies and procedures, and transport technology are assumed constant at about the level of today.

CHAPTER 3

DATA COLLECTION AND ANALYSIS

The primary aim of this chapter is the presentation of the results of the two-level analysis of data, one section being devoted to the stage and one to the project-level analysis. Each of the sections begins with some largely definitional comments pertaining to the level of analysis, followed by a brief description of the actual collection and analysis of the basic data such as the nature and scope of the data base and some of the problems encountered and solutions arrived at in its use. The presentation of the results, the detailed discussion of which is left to Chapter 4, finally completes each section. More detailed discussion of the data collection and preliminary analysis procedures, as well as presentation of the basic data and its sources and of some of the results, can be found in Appendices B and C.

3.1 Construction Technologies and Costs

The construction procedure for highways may be divided into various stages: site preparation, earthwork, subbase, base, and surfacing, minor structures, and major structures. Each stage, in turn, is made up of several activities; earthwork, for example, consists of excavate, load, haul, unload, return, spread, and compact and finish. Similarly, tasks can be defined as groups of possibly interdependent activities such as the earthwork activities, excavate through return. The resources used include various types of labor, equipment, and materials.

Some of the environmental conditions which might be of importance on a project are climate, vegetation, terrain, soil/rock type, lift height, and haul distance and condition; similarly, some of the institutional conditions are management and organization, physical condition and skill of the workers, method of payment, social welfare of the workers, and availability and quality of the maintenance and repair facilities. The data required for the study at hand thus consists of the alternative technical packages, available at various points in time in the U.S., for the various stages of road construction, and the resource productivities and costs of these packages under typical environmental and institutional conditions.

3.11 Identification of Technical Packages

For the purposes of this study, the stages of construction are somewhat rearranged, on the basis of their activities, into site preparation, excavation/hauling (with subgroups for haul distance), spreading/compaction (with subgroups for degree of compaction), and surfacing (with subgroups for the material, assuming a constant degree of compaction). It was decided at the outset to eliminate major structures from the analysis, as they are rather distinct and separate from the other stages of construction, and merit a study of their own. Minor structures are also not included, due to the scarcity of data in this area and to their relatively small contribution to highway construction costs. It should be noted, however, that these two stages are often relatively labor-intensive, have considerable potential for labor-capital substitution, and might even be used in place of certain parts of other stages (e.g., using a bridge instead of a large fill, or a retaining wall to lessen the amount of cut necessary).

In identifying the technical packages for the various stages of road construction, three time periods evolve quite naturally: (1) the 1920's, primarily representing those methods in use around 1915 to 1937; (2) the 1950's, representing those around 1945 to 1962; and (3) the 1970's, representing those around 1965 to 1975. These time periods coincide, by and large, with those during which the U.S. Federal Highway Administration (FHWA) carried out their production studies of alternative highway construction methods, these being about 1920-37, 1945-66, and 1971-present; the results of these studies are compiled in various unpublished forms (e.g., 97, 98), as summary articles in Public Roads (e.g., 2, 32, 33), and, for the current studies, as reports available through the National Technical Information Service (e.g., 105). The sources used in identifying alternative technical packages are the same as those used in estimating resource productivities for these packages, including the FHWA studies mentioned above as well as various methods and costs, cost estimating, and engineering books and handbooks (e.g., 29, 46, 67, 77) among other publications of the period.

The set of technical packages identified for each period for each stage of construction is given in Table 3.1, where the various resources constituting each package are specified, the equipment being organized by the major activities or tasks the stage involves. As a convenient means of referring to the various packages, a numbering scheme has been devised. The digits represent the major activities or tasks of the

Table 3.1a: Technical packages for site preparation in the 1920's, 1950's, and 1970's.

Period and No. of Technical Package	Labor	Equipment: Brush and Tree Removal	Equipment: Burning Debris	Materials
1920: 11	Skilled Unskilled	Handtools (201) Horse	Handtools (201)	Dynamite (820) Fuse (821) Caps (822)
21	Skilled Unskilled	80 hp tractor (630) Bulldozer blade (602)	Handtools (201)	
1950: 11	Skilled Unskilled	Chain saw (235) Handtools (207,208)	Handtools (206)	Dynamite (820) Fuse (821) Caps (822)
21	Skilled Unskilled	90 dbhp tractor (642) Bulldozer blade (608)	Handtools (206)	
31	Skilled Unskilled	90 dbhp tractor (642) Bulldozer blade (608) Cable (610)	Handtools (206)	
1970: 11	Skilled Unskilled	Chain saw (236) Brush saw (241) Backhoe (237) Handtools (209)	Handtools (209)	Kerosene (823)
21	Skilled Unskilled	70 dbhp tractor (644) Bulldozer blade (614) Chain saw (236) Pickup truck (336) Handtools (209)	Handtools (209)	Kerosene (823)
31	Skilled Unskilled	180 fwhp tractor (645) Bulldozer blade (615)	Handtools (209)	Kerosene (823)

Table 3.1b: Technical packages for excavation/hauling in the 1920's, 1950's, and 1970's.

Period and No. of Technical Package	Labor	Equipment: Excavation	Equipment: Hauling
1920: 1-1	Skilled Unskilled	Handtools (202)	Wheelbarrow (301)
1-2	Skilled Unskilled	Handtools (202)	Handcart (302)
2-1	Skilled Unskilled	Plow (203) Horse Handtools (202)	Wheelbarrow (301)
2-2	Skilled Unskilled	Plow (203) Horse Handtools (202)	Handcart (302)
3-1	Skilled Unskilled	Plow (203) 20 hp tractor (631) Handtools (202)	Wheelbarrow (301)
3-2	Skilled Unskilled	Plow (203) 20 hp tractor (631) Handtools (202)	Handcart (302)
4-3	Skilled Unskilled	Dragscraper (604) Plow (203) Horse	Dragscraper (604) Horse
5-4	Skilled Unskilled	Fresno (603) Plow (203) Horse	Fresno (603) Horse

Table 3.1b: Technical packages for excavation/hauling in the 1920's, 1950's, and 1970's (continued).

Period and No. of Technical Package		Labor	Equipment	
			Excavation	Hauling
1920:	6-5	Skilled Unskilled	Wheelscraper (605) Plow (203) Horse	Wheelscraper (605) Horse
	7-6	Skilled	60 hp tractor (633) Bulldozer blade (606)	60 hp tractor (633) Bulldozer blade (606)
	8-7	Skilled Unskilled	Elevating grader (205) Horse Handtools (202)	1.5 cy wagon (303) Horse
	9-7	Skilled Unskilled	Elevating grader (205) 30 hp tractor (634) Handtools (202)	1.5 cy wagon (303) Horse
	10-7	Skilled Unskilled	Power shovel (230) 3/4 cy shovel dipper (204) Handtools (202)	1.5 cy wagon (303) Horse
	10-8	Skilled Unskilled	Power shovel (230) 3/4 cy shovel dipper (204) Handtools (202)	5 cy wagon (304) 20 hp tractor (631)
	10-9	Skilled Unskilled	Power shovel (230) 3/4 cy shovel dipper (204) Handtools (202)	3.5 ton truck (330)
1950:	1-1	Skilled	1.5 cy power shovel (231)	10 ton truck (332)
	1-2	Skilled	1.5 cy power shovel (231)	20 ton truck (333)

Table 3.1b: Technical packages for excavation/hauling in the 1920's, 1950's, and 1970's (continued).

Period and No. of Technical Package		Labor	Equipment	
			Excavation	Hauling
1950:	1-3	Skilled	1.5 cy power shovel (231)	8.5 cy wagon (305) 125 fwhp tractor (638)
	1-4	Skilled	1.5 cy power shovel (231)	15 cy wagon (306) 185 fwhp tractor (639)
	2-1	Skilled	2.0 cy power shovel (232)	10 ton truck (332)
	2-2	Skilled	2.0 cy power shovel (232)	20 ton truck (333)
	2-3	Skilled	2.0 cy power shovel (232)	8.5 cy wagon (305) 125 fwhp tractor (638)
	2-4	Skilled	2.0 cy power shovel (232)	15 cy wagon (306) 185 fwhp tractor (639)
	3-1	Skilled	2.5 cy power shovel (233)	10 ton truck (332)
	3-2	Skilled	2.5 cy power shovel (233)	20 ton truck (333)
	3-3	Skilled	2.5 cy power shovel (233)	8.5 cy wagon (305) 125 fwhp tractor (638)
	3-4	Skilled	2.5 cy power shovel (233)	15 cy wagon (306) 185 fwhp tractor (639)
	4-2	Skilled	Elevating grader (234) 90 dbhp tractor (642)	20 ton truck (333)
	4-4	Skilled	Elevating grader (234) 90 dbhp tractor (642)	15 cy wagon (306) 185 fwhp tractor (639)

Table 3.1b: Technical packages for excavation/hauling in the 1920's, 1950's, and 1970's (continued).

Period and No. of Technical Package	Labor	Equipment	
		Excavation	Hauling
1950: 5-5	Skilled	6 cy scraper (611) 125 fwhp wheel tractor (638) 70 hp crawler tractor (641) 8 ft bulldozer blade (607)	6 cy scraper (611) 125 fwhp wheel tractor (638)
6-6	Skilled	9 cy scraper (612) 185 fwhp wheel tractor (639) 90 hp crawler tractor (642) 10 ft bulldozer blade (608)	9 cy scraper (612) 185 fwhp wheel tractor (639)
7-7	Skilled	15 cy scraper (613) 250 fwhp wheel tractor (640) 130 hp crawler tractor (643) 11.5 ft bulldozer blade (609)	15 cy scraper (613) 250 fwhp wheel tractor (640)
8-8	Skilled	70 hp crawler tractor (641) 8 ft bulldozer blade (607)	70 hp crawler tractor (641) 8 ft bulldozer blade (607)
9-9	Skilled	90 hp crawler tractor (642) 10 ft bulldozer blade (608)	90 hp crawler tractor (642) 10 ft bulldozer blade (608)
10-10	Skilled	130 hp crawler tractor (643) 11.5 ft bulldozer blade (609)	130 hp crawler tractor (643) 11.5 ft bulldozer blade (609)
11-0	Skilled	Blade grader (423)	
1970: 1-1	Skilled	1.5 cy power shovel (238)	10 ton truck (337)
1-2	Skilled	1.5 cy power shovel (238)	15 ton truck (338)
2-3	Skilled	2.5 cy power shovel (239)	20 ton truck (339)

Table 3.1b: Technical packages for excavation/hauling in the 1920's, 1950's, and 1970's (continued).

Period and No. of Technical Package		Labor	Equipment	
			Excavation	Hauling
1970:	2-5	Skilled	2.5 cy power shovel (239)	15 cy wagon and tractor (341)
	3-4	Skilled	3.5 cy power shovel (240)	35 ton truck (340)
	3-6	Skilled	3.5 cy power shovel (240)	27 cy wagon and tractor (342)
	4-1	Skilled	1.75 cy front end loader (646)	10 ton truck (337)
	4-2	Skilled	1.75 cy front end loader (646)	15 ton truck (338)
	4-7	Skilled	1.75 cy front end loader (646)	1.75 cy front end loader (646)
	5-3	Skilled	3.0 cy front end loader (647)	20 ton truck (339)
	5-5	Skilled	3.0 cy front end loader (647)	15 cy wagon and tractor (341)
	5-8	Skilled	3.0 cy front end loader (647)	3.0 cy front end loader (647)
	6-4	Skilled	5.0 cy front end loader (648)	35 ton truck (340)
	6-6	Skilled	5.0 cy front end loader (648)	27 cy wagon and tractor (342)
	6-9	Skilled	5.0 cy front end loader (648)	5.0 cy front end loader (648)
	7-10	Skilled	11.5 cy elevating scraper (649)	11.5 cy elevating scraper (649)
	8-11	Skilled	21.5 cy elevating scraper (650)	21.5 cy elevating scraper (650)
	9-12	Skilled	20 cy scraper (651) 270 hp crawler tractor (653) 12 ft bulldozer blade (616)	20 cy scraper (651)

Table 3.1b: Technical packages for excavation/hauling in the 1920's, 1950's, and 1970's (continued).

Period and No. of Technical Package		Labor	Equipment	
			Excavation	Hauling
1970:	10-13	Skilled	30 cy scraper (652) 385 hp crawler tractor (654) 14 ft bulldozer blade (617)	30 cy scraper (652)
	11-14	Skilled	70 hp crawler tractor (644) 8 ft bulldozer blade (614)	70 hp crawler tractor (644) 8 ft bulldozer blade (614)
	12-15	Skilled	180 hp crawler tractor (645) 12 ft bulldozer blade (616)	180 hp crawler tractor (645) 12 ft bulldozer blade (616)
	13-16	Skilled	385 hp crawler tractor (654) 14 ft bulldozer blade (617)	385 hp crawler tractor (654) 14 ft bulldozer blade (617)
	14-0	Skilled	Motor grader (424)	

Note: Technical package 11-0 in 1950 and 14-0 in 1970 are for simply excavating a small ditch alongside a road; in the 1920's this would be done with any package up to and including 6-5.

Table 3.1c: Technical packages for spreading/compaction in the 1920's, 1950's, and 1970's.

Period and No. of Technical Package	Labor	Equipment: Spreading	Equipment: Compaction
1920: 11	Skilled Unskilled	Handtools (401)	2.5 ton roller (501) Horse
21	Skilled Unskilled	7 ft blade grader (402) Horse	2.5 ton roller (501) Horse
12	Skilled Unskilled	Handtools (401)	6 ton roller (530)
22	Skilled Unskilled	7 ft blade grader (402) Horse	6 ton roller (530)
32	Skilled	12 ft blade grader (403) 76 hp tractor (632)	6 ton roller (530)
1950: 11	Skilled	70 hp crawler tractor (641) 8 ft bulldozer blade (607)	Sheepsfoot roller (502) 70 hp crawler tractor (641)
12	Skilled	70 hp crawler tractor (641) 8 ft bulldozer blade (607)	Sheepsfoot roller (502) 90 hp crawler tractor (642)
13	Skilled	70 hp crawler tractor (641) 8 ft bulldozer blade (607)	3 wheel roller (532)
14	Skilled	70 hp crawler tractor (641) 8 ft bulldozer blade (607)	Pneumatic roller (533)

Table 3.1c: Technical packages for spreading/compaction in the 1920's, 1950's, and 1970's (continued).

Period and No. of Technical Package	Labor	Equipment: Spreading	Equipment: Compaction
1950: 21	Skilled	130 hp crawler tractor (643) 11.5 ft bulldozer blade (609)	Sheepsfoot roller (502) 70 hp crawler tractor (641)
22	Skilled	130 hp crawler tractor (643) 11.5 ft bulldozer blade (609)	Sheepsfoot roller (502) 90 hp crawler tractor (642)
23	Skilled	130 hp crawler tractor (643) 11.5 ft bulldozer blade (609)	3 wheel roller (532)
24	Skilled	130 hp crawler tractor (643) 11.5 ft bulldozer blade (609)	Pneumatic roller '533)
31	Skilled	10 ft blade grader (420)	Sheepsfoot roller (502) 70 hp crawler tractor (641)
32	Skilled	10 ft blade grader (420)	Sheepsfoot roller (502) 90 hp crawler tractor (642)
33	Skilled	10 ft blade grader (420)	3 wheel roller (532)
34	Skilled	10 ft blade grader (420)	Pneumatic roller (533)
41	Skilled	13 ft blade grader (421)	Sheepsfoot roller (502) 70 hp crawler tractor (641)
42	Skilled	13 ft blade grader (421)	Sheepsfoot roller (502) 90 hp crawler tractor (642)
43	Skilled	13 ft blade grader (421)	3 wheel roller (532)
44	Skilled	13 ft blade grader (421)	Pneumatic roller (533)

Table 3.1c: Technical packages for spreading/compaction in the 1920's, 1950's, and 1970's (continued).

Period and No. of Technical Package	Labor	Equipment	
		Spreading	Compaction
1970: 11	Skilled	180 hp crawler tractor (645) 12 ft bulldozer blade (616)	Sheepsfoot roller (536)
12	Skilled	180 hp crawler tractor (645) 12 ft bulldozer blade (616)	Sheepsfoot roller (503) 270 hp crawler tractor (653)
13	Skilled	180 hp crawler tractor (645) 12 ft bulldozer blade (616)	Pneumatic roller (537)
14	Skilled	180 hp crawler tractor (645) 12 ft bulldozer blade (616)	Vibratory roller (538)
21	Skilled	385 hp crawler tractor (654) 14 ft bulldozer blade (617)	Sheepsfoot roller (536)
22	Skilled	385 hp crawler tractor (654) 14 ft bulldozer blade (617)	Sheepsfoot roller (503) 270 hp crawler tractor (653)
23	Skilled	385 hp crawler tractor (654) 14 ft bulldozer blade (617)	Pneumatic roller (537)
24	Skilled	385 hp crawler tractor (654) 14 ft bulldozer blade (617)	Vibratory roller (538)
31	Skilled	12 ft motor grader (425)	Sheepsfoot roller (536)
32	Skilled	12 ft motor grader (425)	Sheepsfoot roller (503) 270 hp crawler tractor (653)
33	Skilled	12 ft motor grader (425)	Pneumatic roller (537)
34	Skilled	12 ft motor grader (425)	Vibratory roller (538)

Table 3.1c: Technical packages for spreading/compaction in the 1920's, 1950's, and 1970's (continued).

Period and No. of Technical Package	Labor	Equipment	
		Spreading	Compaction
1970: 41	Skilled	14 ft motor grader (426)	Sheepsfoot roller (536)
42	Skilled	14 ft motor grader (426)	Sheepsfoot roller (503) 270 hp crawler tractor (653)
43	Skilled	14 ft motor grader (426)	Pneumatic roller (537)
44	Skilled	14 ft motor grader (426)	Vibratory roller (538)

Note: Technical packages 11, 21, 31 and 41 in 1950 use two 4 ft wide rollers pulled by a tractor, while technical packages 12, 22, 32, and 42 in 1950 use four such rollers and a larger tractor.

Table 3.1d: Technical packages for gravel surfacing in the 1920's, 1950's, and 1970's.

Period and No. of Technical Package	Labor	Equipment	
		Spreading Gravel	Compacting Gravel
1920: 11	Skilled Unskilled	Handtools (401)	2.5 ton roller (501) Horse
21	Skilled Unskilled	5 ft blade grader (404) Horse Handtools (401)	2.5 ton roller (501) Horse
12	Skilled Unskilled	Handtools (401)	6 ton roller (530)
22	Skilled Unskilled	5 ft blade grader (404) Horse Handtools (401)	6 ton roller (530)
1950: 11	Skilled	70 hp crawler tractor (641) 8 ft bulldozer blade (607)	3 wheel roller (534)
12	Skilled	70 hp crawler tractor (641) 8 ft bulldozer blade (607)	Pneumatic roller (533)
21	Skilled	130 hp crawler tractor (643) 11.5 ft bulldozer blade (609)	3 wheel roller (534)
22	Skilled	130 hp crawler tractor (643) 11.5 ft bulldozer blade (609)	Pneumatic roller (533)
31	Skilled	10 ft blade grader (420)	3 wheel roller (534)
32	Skilled	10 ft blade grader (420)	Pneumatic roller (533)
41	Skilled	13 ft blade grader (421)	3 wheel roller (534)

Table 3.1d: Technical packages for gravel surfacing in the 1920's, 1950's and 1970's (continued).

Period and No. of Technical Package	Labor	Equipment: Spreading Gravel	Equipment: Compacting Gravel
1950: 42	Skilled	13 ft blade grader (421)	Pneumatic roller (533)
51	Skilled Unskilled	Gas spreader (422) 20 ton truck (333) Handtools (408)	3 wheel roller (534)
52	Skilled Unskilled	Gas spreader (422) 20 ton truck (333) Handtools (408)	Pneumatic roller (533)
1970: 11	Skilled	180 hp crawler tractor (645) 12 ft bulldozer blade (616)	3 wheel roller (539)
12	Skilled	180 hp crawler tractor (645) 12 ft bulldozer blade (616)	Pneumatic roller (537)
13	Skilled	180 hp crawler tractor (645) 12 ft bulldozer blade (616)	Vibratory roller (538)
21	Skilled	385 hp crawler tractor (654) 14 ft bulldozer blade (617)	3 wheel roller (539)
22	Skilled	385 hp crawler tractor (654) 14 ft bulldozer blade (617)	Pneumatic roller (537)
23	Skilled	385 hp crawler tractor (654) 14 ft bulldozer blade (617)	Vibratory roller (538)
31	Skilled	12 ft motor grader (425)	3 wheel roller (539)

Table 3.1d: Technical packages for gravel surfacing in the 1920's, 1950's and 1970's (continued).

Period and No. of Technical Package	Labor	Equipment: Spreading Gravel	Equipment: Compacting Gravel
1970: 32	Skilled	12 ft motor grader (425)	Pneumatic roller (537)
33	Skilled	12 ft motor grader (425)	Vibratory roller (538)
41	Skilled	14 ft motor grader (426)	3 wheel roller (539)
42	Skilled	14 ft motor grader (426)	Pneumatic roller (537)
43	Skilled	14 ft motor grader (426)	Vibratory roller (538)
51	Skilled Unskilled	Gas spreader (427) 20 ton truck (339) Handtools (410)	3 wheel roller (539)
52	Skilled Unskilled	Gas spreader (427) 20 ton truck (339) Handtools (410)	Pneumatic roller (537)
53	Skilled Unskilled	Gas spreader (427) 20 ton truck (339) Handtools (410)	Vibratory roller (538)

Note: All technical packages also include gravel (830).

Table 3.1e: Technical packages for waterbound macadam surfacing in the 1920's, 1950's, and 1970's.

Period and No. of Technical Package	Labor	Equipment: Spreading Crushed Stone	Equipment: Spreading Screenings	Equipment: Sprinkling and Compacting
1920: 111	Skilled Unskilled	Handtools (401)	Handtools (401)	3 wheel roller (531) Sprinkler wagon (405) Horse
211	Skilled Unskilled	5 ft blade grader (404) Horse Handtools (401)	Handtools (401)	3 wheel roller (531) Sprinkler wagon (405) Horse
1950: 111	Skilled Unskilled	70 hp crawler tractor (641) 8 ft bulldozer blade (607)	Spreader box (409) 10 ton truck (332) Handtools (408)	3 wheel roller (534) Water tank (407) 3.5 ton truck (334)
112	Skilled Unskilled	70 hp crawler tractor (641) 8 ft bulldozer blade (607)	Spreader box (409) 10 ton truck (332) Handtools (408)	Pneumatic roller (533) Water tank (407) 3.5 ton truck (334)
211	Skilled Unskilled	130 hp crawler tractor (643) 11.5 ft bulldozer blade (609)	Spreader box (409) 10 ton truck (332) Handtools (408)	3 wheel roller (534) Water tank (407) 3.5 ton truck (334)
212	Skilled Unskilled	130 hp crawler tractor (643) 11.5 ft bulldozer blade (609)	Spreader box (409) 10 ton truck (332) Handtools (408)	Pneumatic roller (533) Water tank (407) 3.5 ton truck (334)
311	Skilled Unskilled	10 ft blade grader (420)	Spreader box (409) 10 ton truck (332) Handtools (408)	3 wheel roller (534) Water tank (407) 3.5 ton truck (334)

Table 3.1e: Technical packages for waterbound macadam surfacing in the 1920's, 1950's, and 1970's (continued).

Period and No. of Technical Package	Labor	Equipment: Spreading Crushed Stone	Equipment: Spreading Screenings	Equipment: Sprinkling and Compacting
1950: 312	Skilled Unskilled	10 ft blade grader (420)	Spreader box (409) 10 ton truck (332) Handtools (408)	Pneumatic roller (533) Water tank (407) 3.5 ton truck (334)
411	Skilled Unskilled	13 ft blade grader (421)	Spreader box (409) 10 ton truck (332) Handtools (408)	3 wheel roller (534) Water tank (407) 3.5 ton truck (334)
412	Skilled Unskilled	13 ft blade grader (421)	Spreader box (409) 10 ton truck (332) Handtools (408)	Pneumatic roller (533) Water tank (407) 3.5 ton truck (334)
511	Skilled Unskilled	Gas spreader (422) 20 ton truck (333) Handtools (408)	Spreader box (409) 10 ton truck (332) Handtools (408)	3 wheel roller (534) Water tank (407) 3.5 ton truck (334)
512	Skilled Unskilled	Gas spreader (422) 20 ton truck (333) Handtools (408)	Spreader box (409) 10 ton truck (332) Handtools (408)	Pneumatic roller (533) Water tank (407) 3.5 ton truck (334)
1970: 111	Skilled Unskilled	180 hp crawler tractor (645) 12 ft bulldozer blade (616)	Gas spreader (427) 20 ton truck (339) Handtools (410)	3 wheel roller (539) Water tank (412) 4 ton truck (343)
112	Skilled Unskilled	180 hp crawler tractor (645) 12 ft bulldozer blade (616)	Gas spreader (427) 20 ton truck (339) Handtools (410)	Pneumatic roller (537) Water tank (412) 4 ton truck (343)

Table 3.1e: Technical packages for waterbound macadam surfacing in the 1920's, 1950's, and 1970's (continued).

Period and No. of Technical Package	Labor	Equipment		
		Spreading Crushed Stone	Spreading Screenings	Sprinkling and Compacting
1970: 113	Skilled Unskilled	180 hp crawler tractor (645) 12 ft bulldozer blade (616)	Gas spreader (427) 20 ton truck (339) Handtools (410)	Vibratory roller (538) Water tank (412) 4 ton truck (343)
121	Skilled Unskilled	180 hp crawler tractor (645) 12 ft bulldozer blade (616)	Spreader box (411) 10 ton truck (337) Handtools (410)	3 wheel roller (539) Water tank (412) 4 ton truck (343)
122	Skilled Unskilled	180 hp crawler tractor (645) 12 ft bulldozer blade (616)	Spreader box (411) 10 ton truck (337) Handtools (410)	Pneumatic roller (537) Water tank (412) 4 ton truck (343)
123	Skilled Unskilled	180 hp crawler tractor (645) 12 ft bulldozer blade (616)	Spreader box (411) 10 ton truck (337) Handtools (410)	Vibratory roller (538) Water tank (412) 4 ton truck (343)
211	Skilled Unskilled	385 hp crawler tractor (654) 14 ft bulldozer blade (617)	Gas spreader (427) 20 ton truck (339) Handtools (410)	3 wheel roller (539) Water tank (412) 4 ton truck (343)
212	Skilled Unskilled	385 hp crawler tractor (654) 14 ft bulldozer blade (617)	Gas spreader (427) 20 ton truck (339) Handtools (410)	Pneumatic roller (537) Water tank (412) 4 ton truck (343)

Table 3.1e: Technical packages for waterbound macadam surfacing in the 1920's, 1950's, and 1970's (continued).

Period and No. of Technical Package	Labor	Equipment		
		Spreading Crushed Stone	Spreading Screenings	Sprinkling and Compacting
1970: 213	Skilled Unskilled	385 hp crawler tractor (654) 14 ft bulldozer blade (617)	Gas spreader (427) 20 ton truck (339) Handtools (410)	Vibratory roller (538) Water tank (412) 4 ton truck (343)
221	Skilled Unskilled	385 hp crawler tractor (654) 14 ft bulldozer blade (617)	Spreader box (411) 10 ton truck (337) Handtools (410)	3 wheel roller (539) Water tank (412) 4 ton truck (343)
222	Skilled Unskilled	385 hp crawler tractor (654) 14 ft bulldozer blade (617)	Spreader box (411) 10 ton truck (337) Handtools (410)	Pneumatic roller (537) Water tank (412) 4 ton truck (343)
223	Skilled Unskilled	385 hp crawler tractor (654) 14 ft bulldozer blade (617)	Spreader box (411) 10 ton truck (337) Handtools (410)	Vibratory roller (538) Water tank (412) 4 ton truck (343)
311	Skilled Unskilled	12 ft motor grader (425)	Gas spreader (427) 20 ton truck (339) Handtools (410)	3 wheel roller (539) Water tank (412) 4 ton truck (343)
312	Skilled Unskilled	12 ft motor grader (425)	Gas spreader (427) 20 ton truck (339) Handtools (410)	Pneumatic roller (537) Water tank (412) 4 ton truck (343)
313	Skilled Unskilled	12 ft motor grader (425)	Gas spreader (427) 20 ton truck (339) Handtools (410)	Vibratory roller (538) Water tank (412) 4 ton truck (343)

Table 3.1e: Technical packages for waterbound macadam surfacing in the 1920's, 1950's, and 1970's (continued).

Period and No. of Technical Package	Labor	Equipment: Spreading Crushed Stone	Equipment: Spreading Screenings	Equipment: Sprinkling and Compacting
1970: 321	Skilled Unskilled	12 ft motor grader (425)	Spreader box (411) 10 ton truck (337) Handtools (410)	3 wheel roller (539) Water tank (412) 4 ton truck (343)
322	Skilled Unskilled	12 ft motor grader (425)	Spreader box (411) 10 ton truck (337) Handtools (410)	Pneumatic roller (537) Water tank (412) 4 ton truck (343)
323	Skilled Unskilled	12 ft motor grader (425)	Spreader box (411) 10 ton truck (337) Handtools (410)	Vibratory roller (538) Water tank (412) 4 ton truck (343)
411	Skilled Unskilled	14 ft motor grader (426)	Gas spreader (427) 20 ton truck (339) Handtools (410)	3 wheel roller (539) Water tank (412) 4 ton truck (343)
412	Skilled Unskilled	14 ft motor grader (426)	Gas spreader (427) 20 ton truck (339) Handtools (410)	Pneumatic roller (537) Water tank (412) 4 ton truck (343)
413	Skilled Unskilled	14 ft motor grader (426)	Gas spreader (427) 20 ton truck (339) Handtools (410)	Vibratory roller (538) Water tank (412) 4 ton truck (343)
421	Skilled Unskilled	14 ft motor grader (426)	Spreader box (411) 10 ton truck (337) Handtools (410)	3 wheel roller (539) Water tank (412) 4 ton truck (343)
422	Skilled Unskilled	14 ft motor grader (426)	Spreader box (411) 10 ton truck (337) Handtools (410)	Pneumatic roller (537) Water tank (412) 4 ton truck (343)

Table 3.1e: Technical packages for waterbound macadam surfacing in the 1920's, 1950's, and 1970's (continued).

Period and No. of Technical Package	Labor	Equipment: Spreading Crushed Stone	Equipment: Spreading Screenings	Equipment: Sprinkling and Compacting
1970: 423	Skilled Unskilled	14 ft motor grader (426)	Spreader box (411) 10 ton truck (337) Handtools (410)	Vibratory roller (538) Water tank (412) 4 ton truck (343)
511	Skilled Unskilled	Gas spreader (427) 20 ton truck (339) Handtools (410)	Gas spreader (427) 20 ton truck (339) Handtools (410)	3 wheel roller (539) Water tank (412) 4 ton truck (343)
512	Skilled Unskilled	Gas spreader (427) 20 ton truck (339) Handtools (410)	Gas spreader (427) 20 ton truck (339) Handtools (410)	Pneumatic roller (537) Water tank (412) 4 ton truck (343)
513	Skilled Unskilled	Gas spreader (427) 20 ton truck (339) Handtools (410)	Gas spreader (427) 20 ton truck (339) Handtools (410)	Vibratory roller (538) Water tank (412) 4 ton truck (343)
521	Skilled Unskilled	Gas spreader (427) 20 ton truck (339) Handtools (410)	Spreader box (411) 10 ton truck (337) Handtools (410)	3 wheel roller (539) Water tank (412) 4 ton truck (343)
522	Skilled Unskilled	Gas spreader (427) 20 ton truck (339) Handtools (410)	Spreader box (411) 10 ton truck (337) Handtools (410)	Pneumatic roller (537) Water tank (412) 4 ton truck (343
523	Skilled Unskilled	Gas spreader (427) 20 ton truck (339) Handtools (410)	Spreader box (411) 10 ton truck (337) Handtools (410)	Vibratory roller (538) Water tank (412) 4 ton truck (343)

Note: All technical packages also include crushed stone (831), screenings (832), and water (833).

Table 3.1f: Technical packages for double bituminous surface treatment in the 1920's, 1950's, and 1970's.

Period and No. of Technical Package	Labor	Equipment			
		Sweeping the Base	Distributing Bitumen	Spreading Crushed Stone	Compacting
1920: 1111	Skilled Unskilled	Handtools (401)	600 gal pressure distributor (450)	Handtools (401)	6 ton roller (530)
1121	Skilled Unskilled	Handtools (401)	600 gal pressure distributor (450)	Spreader box (406) 5 ton truck (331) Handtools (401)	6 ton roller (530)
1950: 1111	Skilled Unskilled	Drag broom (440) Pickup truck (335)	1000 gal bitumen distributor (452)	Gas spreader (422) 20 ton truck (333) Handtools (408)	Tandem roller (535)
1112	Skilled	Drag broom (440) Pickup truck (335)	1000 gal bitumen distributor (452)	Gas spreader (422) 20 ton truck (333) Handtools (408)	Pneumatic roller (533)
1121	Skilled Unskilled	Drag broom (440) Pickup truck (335)	1000 gal bitumen distributor (452)	Spreader box (409) 10 ton truck (332) Handtools (408)	Tandem roller (535)
1122	Skilled Unskilled	Drag broom (440) Pickup truck (335)	1000 gal bitumen distributor (452)	Spreader box (409) 10 ton truck (332) Handtools (408)	Pneumatic roller (533)
2111	Skilled Unskilled	Power broom (451)	1000 gal bitumen distributor (452)	Gas spreader (422) 20 ton truck (333) Handtools (408)	Tandem roller (535)
2112	Skilled Unskilled	Power broom (451)	1000 gal bitumen distributor (452)	Gas spreader (422) 20 ton truck (333) Handtools (408)	Pneumatic roller (533)

Table 3.1f: Technical packages for double bituminous surface treatment in the 1920's, 1950's, and 1970's (continued).

Period and No. of Technical Package	Labor	Equipment			
		Sweeping the Base	Distributing Bitumen	Spreading Crushed Stone	Compacting
1950: 2121	Skilled Unskilled	Power broom (451)	1000 gal bitumen distributor (452)	Spreader box (409) 10 ton truck (332) Handtools (408)	Tandem roller (535)
2122	Skilled Unskilled	Power broom (451)	1000 gal bitumen distributor (452)	Spreader box (409) 10 ton truck (332) Handtools (408)	Pneumatic roller (533)
1970: 1111	Skilled Unskilled	Rotary broom (441) 60 fwhp tractor (655)	1000 gal bitumen distributor (454)	Gas spreader (427) 20 ton truck (339) Handtools (410)	Tandem roller (540)
1112	Skilled Unskilled	Rotary broom (441) 60 fwhp tractor (655)	1000 gal bitumen distributor (454)	Gas spreader (427) 20 ton truck (339) Handtools (410)	Pneumatic roller (541)
1121	Skilled Unskilled	Rotary broom (441) 60 fwhp tractor (655)	1000 gal bitumen distributor (454)	Spreader box (411) 10 ton truck (337) Handtools (410)	Tandem roller (540)
1122	Skilled Unskilled	Rotary broom (441) 60 fwhp tractor (655)	1000 gal bitumen distributor (454)	Spreader box (411) 10 ton truck (337) Handtools (410)	Pneumatic roller (541)
1211	Skilled Unskilled	Rotary broom (441) 60 fwhp tractor (655)	1500 gal bitumen distributor (453)	Gas spreader (427) 20 ton truck (339) Handtools (410)	Tandem roller (540)
1212	Skilled Unskilled	Rotary broom (441) 60 fwhp tractor (655)	1500 gal bitumen distributor (453)	Gas spreader (427) 20 ton truck (339) Handtools (410)	Pneumatic roller (541)

Table 3.1f: Technical packages for double bituminous surface treatment in the 1920's, 1950's, and 1970's (continued).

Period and No. of Technical Package	Labor	Equipment			
		Sweeping the Base	Distributing Bitumen	Spreading Crushed Stone	Compacting
1970: 1221	Skilled Unskilled	Rotary broom (441) 60 fwhp tractor (655)	1500 gal bitumen distributor (453)	Spreader box (411) 10 ton truck (337) Handtools (410)	Tandem roller (540)
1222	Skilled Unskilled	Rotary broom (441) 60 fwhp tractor (655)	1500 gal bitumen distributor (453)	Spreader box (411) 10 ton truck (337) Handtools (410)	Pneumatic roller (541)

Note: All technical packages also include crushed stone (834) and bitumen (835).

stage in the order given in Table 3.1, and a change in a digit reflects a change in the resource mix for that particular activity or task; the numbering scheme starts over with each period and with each stage. Site preparation, for example, consists of two major activities, brush and tree removal and burning of the debris; in 1920, there are two technical packages, which differ only in the resource mix for the first of these activities. The numbers in parentheses following each piece of equipment and each material in Table 3.1 are their resource numbers; Section 3.12 and Appendix B give further descriptive and quantitative details on all of the resources. Finally, it should be noted that there is a separate list of technical packages for each surfacing material since each requires somewhat different activities and thus different resources, while there is only one list for excavation/hauling and spreading/compaction since the same resources can often be used for various haul distances and degrees of compaction, resulting only in a change in the productivities of the resources.

3.12 Evaluation of Resource Productivities and Costs

Labor, equipment, and materials constitute the resources used in highway construction; a list of their various categories is included as Table 3.2 which also indicates the organization of their resource numbers. Labor is divided into two categories: (1) skilled which includes all heavy equipment operators, drivers of trucks over five cubic yards in capacity, and personnel acting in a supervisory capacity on operations done predominantly by unskilled labor; and (2) unskilled

Table 3.2: The categories of labor, equipment, and materials used in highway construction.

1 -- Labor

01	skilled
02	unskilled

2 -- Excavate, Load Equipment

01-29	unpowered
30-99	powered

3 -- Transport Equipment

01-29	unpowered
30-99	powered

4 -- Spread, Mix, Heat Equipment

01-19	earthwork and soil/aggregate surface treatments - unpowered
20-39	earthwork and soil/aggregate surface treatments - powered
40-49	bituminous surface treatments - unpowered
50-69	bituminous surface treatments - powered
70-79	concrete surface treatments - unpowered
80-99	concrete surface treatments - powered

5 -- Compact, Finish Equipment

01-29	unpowered
30-99	powered

6 -- Multi-Purpose Equipment

01-29	unpowered
30-99	powered

7 -- Miscellaneous Equipment

8 -- Materials

01-19	equipment consumables
20-29	materials aiding in construction
30-99	construction materials

<u>Note</u>: The horse is included as item 601, although it is handled separately in the analysis.

which also includes semiskilled and thus involves common heavy construction laborers, operators of small power tools, drivers of trucks five cubic yards and under in capacity, and drivers of horses, although there are a few exceptions in the 1920's. Equipment is divided into several categories on the basis of the activities in which it is involved. Materials consist of three categories: (1) equipment consumables such as fuel; (2) materials used as aids in construction such as explosives; and (3) construction materials such as aggregate. Lists of all equipment and materials are given in Tables B.2 and B.4, respectively. It should be noted that for each of the three technology periods a separate set of equipment is specified, although this is not the case for labor and materials. This seems only logical in situations where new types of equipment appear; it is also thus in situations where a piece of equipment is apparently carried forward from one period to the next, in that it has likely undergone certain changes which have influenced its quality, productivity, and so forth, and it is thus a different piece of equipment than it was. In the case of labor and materials, this process of change over time is largely ignored, and the assumption made that the change in these resources has been of much less significance than that in equipment.

Resource productivities of the various technical packages available over time in the U.S. might most ideally be obtained from field observations of all packages at one point in time and space. This is obviously impossible, however, and even where some of the older methods might still be in use, as in certain developing countries, it is generally in conjunction with today's designs which raises a compatibility question, and the institutional and environmental conditions, which play an important role in resource productivity, are undoubtedly rather different. Since cross-sectional data is thus not available, historical has to suffice, although inherent in it are such problems as changes in resource quality, indexing difficulties, lack of detail, and questionable reliability.

In the course of searching for this data, various agencies such as the FHWA and U.S. Bureau of Labor Statistics, associations such as the Associated General Contractors of America, American Road Builders Association, and Construction Industry Manufacturers Association, and equipment manufacturers such as Caterpillar Tractor Company and John Deere were contacted. A thorough search of the literature was also undertaken, including the publications of various groups such as the FHWA, Transportation Research Board, National Cooperative Highway Research Program, American Association of State Highway and Transportation Officials, and American Society of Civil Engineers, the publications of the Engineering Experimental Stations of various universities such as Purdue and Iowa State, various books and handbooks pertaining to highways and their construction including those focusing on methods and costs, cost estimating, engineering, and equipment, and various journals such as Public Roads, Construction Methods and Equipment, and Highway and Heavy Construction. The single most useful source for the productivity data is probably the FHWA production studies noted above, although the various books and handbooks are also very valuable.

The productivities of the labor, equipment, and materials included in each technical package are usually derived from a variety of sources, generally at the activities level, under typical institutional and environmental conditions, for each stage of construction for the 1920's, 1950's, and 1970's. Section B.12 contains sample calculations of these productivity figures, demonstrating the estimation procedure and also giving an indication of the range in quality and detail found in the original data; Table B.1, then, in Section B.13 lists the full set of estimated resource requirements of each technical package for all stages and all three periods, as well as identifying the sources for each technical package. In order to remain consistent and logical throughout the course of deriving the various resource productivities, certain assumptions were made at the outset and as necessary throughout this phase of the work; some of the more important ones are touched upon here in the following brief discussion of each stage of construction, while a more complete discussion of them and the sources substantiating them can be found in Section B.11 and in the sample calculations of Section B.12. It should be noted that all assumptions and productivity estimations are made with the project-level analysis in mind.

Site preparation consists of brush, tree, and stump removal and burning of the debris and is measured in hectares or acres, generally including the road and borrow areas. The environmental condition of primary concern here is the amount of vegetation which is taken as medium. As in the spreading/compaction and surfacing stages, the width of the road may be a factor in resource productivity; in such cases, productivity data for the two road widths designed in Section 3.2 are calculated and averaged to get a figure relatively independent of road width.

Loosen and load constitute the first part of excavation/hauling, while load, haul, unload, and return constitute the second. The units of measure are bank cubic meters or bank cubic yards, and soil and haul distance and condition are the primary environmental factors. Ordinary/ common soil is assumed, which was later made more specifically silty clay, as this is one of only a few materials for which a relationship could be found in the literature between the amount of compaction and subgrade strength; these materials may be from cuts for the road itself or from borrow areas and may be going to the embankment or to spoil. As for the haul, the conditions are assumed to be average to good, and the distance is allowed to vary; in determining the haul distances for the two basic designs under various borrow situations given in Section 3.2, three groups of haul distances arose which in the stage-level analysis are represented by 6, 100, and 800 meter (20, 330, and 2625 foot) hauls.

Spreading/compaction is made up of the activities spread, compact, and finish, is also measured in bank cubic meters or bank cubic yards, and pertains to subgrade materials coming from cuts for the road or from borrow areas and going to fills for the embankment. In this stage, as in surfacing, the quality of the product may be dependent upon the the technology which produces it. Data on compaction for the 1920's is particularly sparse, but with the help of a British publication (70) relating material density to number of passes for a few materials and rollers, two levels of compaction could be derived for the 1920's horse-drawn roller: (1) 98 percent compaction which falls within the range 95-100 percent of the standard AASHO compaction, the customary level of compaction of subgrades and embankments today, and which represents a compacted to loose ratio of 65 percent, assuming a bank to loose ratio of 80 percent for this soil; and (2) 93 percent compaction which falls below that generally acceptable today and which represents a compacted to loose ratio of 69 percent. The productivity of the powered roller in the 1920's, as well as that of all 1950's and 1970's rollers, is estimated only at 98 percent compaction, or as falling within the 95-100 percent range, as this can reasonably be achieved by such equipment.

The activities involved in surfacing vary with the material, as do naturally the quality of the product and the set of technical packages used in its construction. Spreading, compacting, and finishing the gravel constitute gravel surfacing, which is measured in compacted cubic meters or compacted cubic yards. Although the degree of compaction might again be allowed to vary, compaction in the range of 100-105 percent standard AASHO, as is customary for gravel subbases, bases, and surfaces, can reasonably be achieved by all rollers in the study, and this variable is thus assumed constant. The construction of water-bound macadam consists of spreading very coarse crushed rock, compacting, spreading screenings, and sprinkling, compacting, and finishing; it is measured in compacted cubic meters or compacted cubic yards.

According to the sources discussing waterbound macadam in the 1920's (11, 29), which is when it was most commonly used, nearly a hundred passes are necessary in the final compaction activity in order to properly float the mixture of screenings and water between the crushed rock as a binder; unfortunately, there is no indication of the surface behavior if less compaction is used, so this parameter could not be varied. Double bituminous surface treatment involves sweeping the base, spreading the primer bitumen, binder bitumen, and quite finely crushed stone, compacting (very lightly), spreading binder bitumen and even finer crushed stone, and compacting (very lightly) and finishing; since this is, as its name suggests, simply a surface treatment, it is measured in square meters or square yards, having a finished thickness of only some 2.2 centimeters (7/8 inch). The activities involved in materials production and their transport to the site are included in the cost of the materials rather than as a surfacing activity, although these activities also warrant investigation as to how their technology has changed.

These particular surfaces were selected because they are reasonably flexible in terms of the variety of technical packages that can be used in their construction, they represent a reasonable range of surface materials although they tend toward the low standard end for the 1950's and 1970's, and they were in use in all three periods although water-bound macadam is no longer much used except perhaps as a base. The materials productivity is thus based on designs which pretty much span all three periods. It should also be noted that it is assumed that the same resource productivities apply whether the material is used as a surface, base, or subbase.

In addition to the stage-specific assumptions, some more generally applicable ones are also necessary. At least in part in order to avoid grossly different environmental and particularly institutional conditions, the study is limited to the U.S.; it thus seems appropriate, within reason, to assume that the health and nutritional conditions, work attitudes, and basic quality of the workforce are relatively uniform, the work is generally performed on a contract basis and payment of labor is by the hour, the equipment is reasonably fully utilized, and the climate is temperate. It is also assumed that the necessary amenities for labor and maintenance and repair facilities for equipment are available, and that the costs of these and of mobilization of labor and equipment essentially balance out for the two resources and are thus not explicitly included. Management is assumed to be average to good, working efficiency to be 80 percent (i.e., a 48-minute hour) when it is not specified for the particular operation, and supervision to be one supervisory person per a crew of ten or so unskilled men in situations where the workforce is predominantly unskilled laborers, mostly arising in the 1920's technical packages. Finally, the parameters of time to complete the job and project scale are not considered, as data are lacking and they are beyond the scope of this analysis.

At this point the resource productivities, in hours of labor or equipment per unit of output or quantity of material per unit of output, have been derived; what is still required for the determination of the unit costs of the various technical packages (i.e., dollars per unit of output) are the resource costs, in dollars per hour for labor and equipment or dollars per quantity of material. These costs are needed for a few points in time; more specifically, since the influence of resource prices and thus factor substitution on technology change is of interest in this study, sets of resource costs representative of each technology period are necessary. The prices of 1930, 1956, and 1974 are thus used throughout the analysis. The economic situation at the time of the 1920's technology makes selection of a year rather difficult; however, since equipment purchase costs are mostly available for 1930 and only an extrapolated form of the equipment index exists prior to 1929, 1930 seems an appropriate year, a time when prices were on the decline but had not yet reached the bottom. The year 1974 is selected as the most current year for which a full set of cost data would be available. Finally, 1956 is selected as being in a relatively similar position, some two-thirds of the way through the time span covered by the technology period. The difficulty, of course, is arriving at a full set of labor, equipment, and materials prices for these particular years, necessitating a further search of the literature and pursuit of various contacts in the field.

Equipment is the most difficult resource to price, its hourly price involving ownership costs of depreciation and interest, maintenance, and miscellaneous items such as insurance, tax, and storage and operating costs of fuel and lubrication. Hourly rates for equipment may be found throughout the literature in various forms (e.g., hourly ownership cost and fuel consumption), but because of the various assumptions hidden in such figures and the difficulty of adjusting them to various time periods, it was decided to estimate hourly equipment rates from scratch. This necessitated the collection of certain basic data about each piece of equipment, including investment cost, life in years, hours used per year, maintenance as a percentage of investment cost, and rate of fuel consumption, and certain assumptions such as the use of a capital recovery factor to arrive at interest and depreciation, selection of 5.5 percent of average annual investment as the charge for miscellaneous items, and estimation of lubrication as 35 percent of fuel cost. The basic data for each piece of equipment, with the possible exception of the rate of fuel consumption, by and large came from a single source for each technology period. The Associated General Contractors of America were responsible for the 1920's source (5), while Peurifoy authored both the 1950's and 1970's sources (66, 67); the data presented in each are similar enough in form to suggest that there may be a certain amount of coordination. Adjusting the hourly rate to various price periods simply involves adjusting the investment cost, interest rate, and fuel cost. Since each piece of equipment is taken as somewhat unique to its time period, its purchase price at the time of its use is inflated or deflated by means of an index. For the period 1929-1965, the U.S. Office of Business Economics index for private purchases of construction machinery (110) is directly used; the U.S. Bureau of Labor Statistics wholesale price index (91) for construction machinery and equipment is used to extrapolate this index forward from 1965, and the same index for industrial commodities to extrapolate it backward from 1929 resulting in an index covering the entire period 1913-1974. Interest rates for the three years are taken from the Federal Reserve Bulletin's statistical tables (26), while fuel is costed as a material. For further details on any aspect, see Section B.21.

The draft animal, a horse in this study, is part of many of the 1920's technical packages; although it is in essence a piece of equipment, it is treated separately here as its cost is derived somewhat differently. An investment cost and hourly rate including upkeep are obtained for the 1920's and are inflated as necessary using the U.S. Bureau of Labor Statistics wholesale price indexes (91).

Labor and materials are handled very similarly. Prices are obtained for each of the three periods with only occasional use of indexes (the wholesale price indexes of the U.S. Bureau of Labor Statistics [91, 96]), and the same basic source is used to price a particular item over as many periods as possible (e.g., materials quotations in the Engineering News-Record [25] are used to price all but a couple of the construction materials for all three periods). The primary sources include Engineering News-Record (25), U.S. Bureau of Labor Statistics (91, 96), Survey of Current Business (78) and one of its supplements (109), and certain of the sources for resource productivities especially for the 1930's prices (e.g., 29). The hourly rate for skilled and unskilled labor is that which the contractor pays out for union labor for 1956 and 1974; the same source was not available for 1930, however, and it seems likely that the wage rate which is used is a mix of union and nonunion rates. As for materials, wholesale prices are used, and the price for construction materials includes delivery as well as production. For further discussion of pricing the horse, labor, and materials see Sections B.22, B.23, and B.24, respectively.

As discussed in the methodology of the data analysis in Section 2.3, a wide range of economic conditions is needed in order to ascertain the set of efficient technical packages for each stage of construction, for each period and over all periods. The set of economic conditions developed for this purpose is given in Table 3.3. The figures for the U.S. for 1930, 1956, and 1974 and for a developing country today come directly from the tables and discussion in Section B.2. It should be noted that these conditions reflect a rather extreme case of a developing country. The wage rates reflect an abundance of unskilled labor and a relative shortage of skilled labor, while the interest rate suggests a lack of capital; the prices of heavy equipment (i.e., powered equipment or unpowered equipment attached, in some way, to powered equipment), equipment consumables, and materials assisting in construction suggest they are imported, while the price of light equipment (i.e., unpowered equipment or that which may be animal-powered) suggests it is locally produced, and that of the horse that it is relatively available. The set of miscellaneous conditions exists for the purpose of developing alternative combinations and conditions within the four groups of factors; the interest rate and labor wages represent an even more extreme case of a developing country. It might also be noted that construction materials are missing from the list in Table 3.3; these materials are not needed for the stage-level analysis, as materials productivity is assumed to be constant over all relevant technical packages,

Table 3.3: The set of economic conditions used in the efficiency analysis at the stage level (Source: Section B.2).

Resource	Units	Economic Conditions				
		United States			Developing	Miscellan-
		1930	1956	1974†	Country	eous
1. Labor - skilled	$/hr	0.88	3.17	9.86	0.20	0.75
- unskilled	$/hr	0.46	2.36	7.88	0.05	0.01
2. Interest Rate	%	5.0	4.5	11.5	20.0	30.0
3. Equipment - light	index	30.1	89.7	176.3	15.0	-
- heavy	index	30.1	89.7	176.3	350.0	-
Coal	$/ton	4.00	8.91	32.97	40.00	-
Gasoline	$/gal	0.194	0.25	0.426	2.00	-
Diesel Fuel	$/gal	0.091	0.15	0.355	1.50	-
Dynamite	$/lb	0.206	0.248	0.321	0.500	-
Fuse	$/100 ft	0.71	1.22	3.44	4.00	-
Caps	$/100 count	1.08	1.85	5.22	6.00	-
Kerosene	$/gal	0.057	0.103	0.232	0.700	-
4. Horse	$/hr	0.12	0.22	0.44	0.05	-

Note: Light equipment is unpowered equipment or that which may be towed by horses, while heavy equipment is powered or unpowered equipment which is somehow attached to powered equipment. The ratio of the index given in this table to that at the time a particular piece of equipment was in use is used to inflate or deflate the investment cost of that particular piece of equipment at the time of its use.

and comparisons among various types of surfaces are relatively meaningless at the stage level since their quality varies.

3.13 Alternative Technical Packages and Their Costs

As a first step in the analysis of the alternative technical packages and their costs, Figure 3.1 presents a graphical representation of some of the results. For each stage of construction and each technology period, the amount of investment in 1974 dollars and the amount of labor required to achieve a certain rate of production is plotted for each technical package. The labor component is measured in terms of unskilled men which is derived by summing over the number of skilled men, weighted by the ratio of skilled to unskilled wages for the period of the technology, and the number of unskilled men; the rate of production is expressed in basically arbitrary hourly units, being, for example, 100 bank cubic meters per hour for excavation/hauling and spreading/compaction. Here, as throughout the remainder of the analysis, various haul distances, levels of compaction, and surfacing materials are handled separately, as these parameters affect the resource productivities and thus costs. Such a pictorial representation of the alternative technical packages is useful in terms of developing a general impression of how technology has changed. Moreover, if it can reasonably be assumed that investment is an appropriate measure of capital, as is often done in the economic literature and as is discussed further for the case at hand in Section 4.11, then these graphs are production isoquants, depicting the set of efficient technical packages for each stage of construction for

Figure 3.1a: Labor and capital requirements of each technical package for site preparation at the rate of 1 hectare per hour, for each technology period (source: Table B.6).

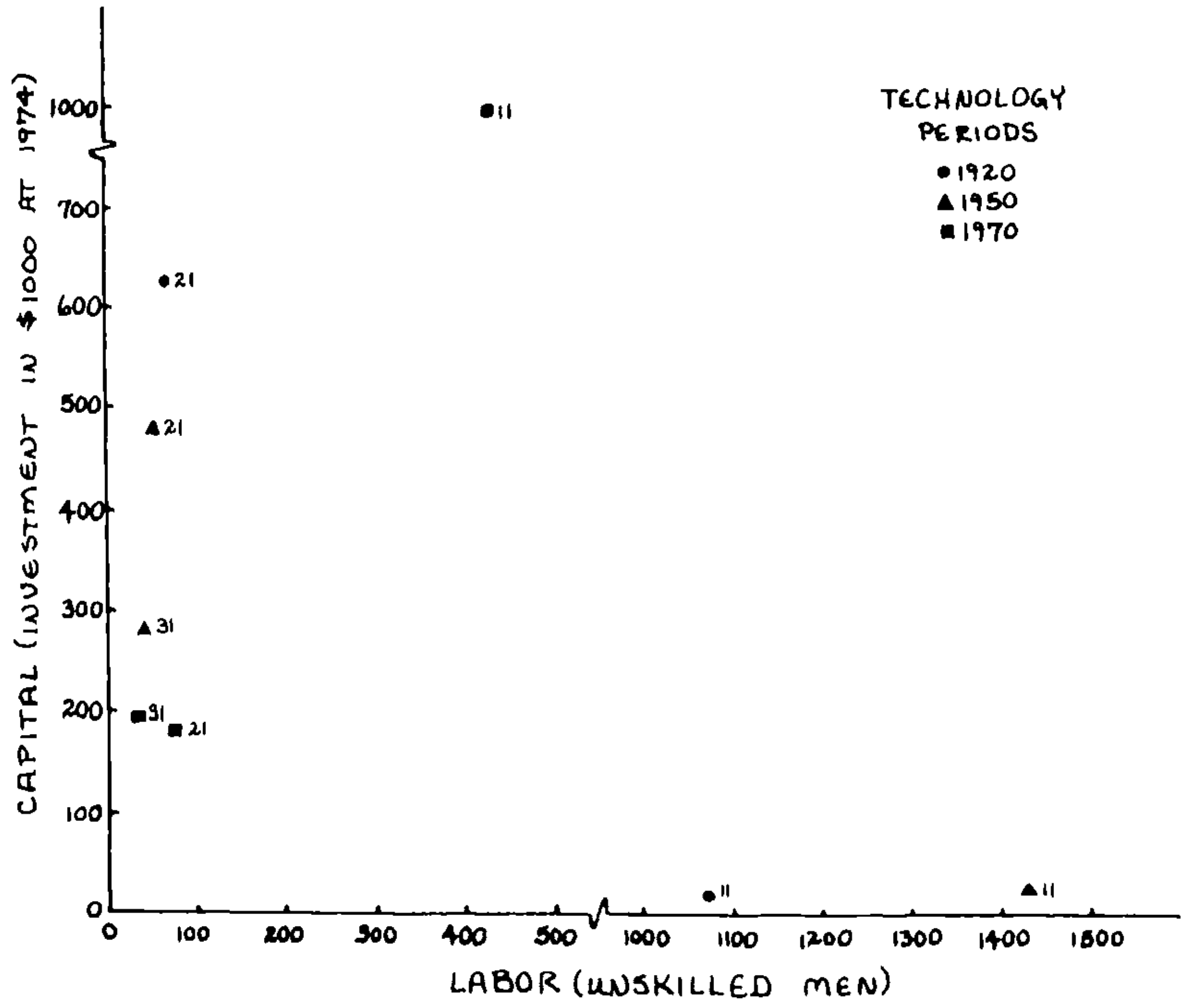


Figure 3.1ba: Labor and capital requirements of each technical package for excavation/hauling at 6 meters at the rate of 100 bank cubic meters per hour, for each technology period (source: Table B.6).

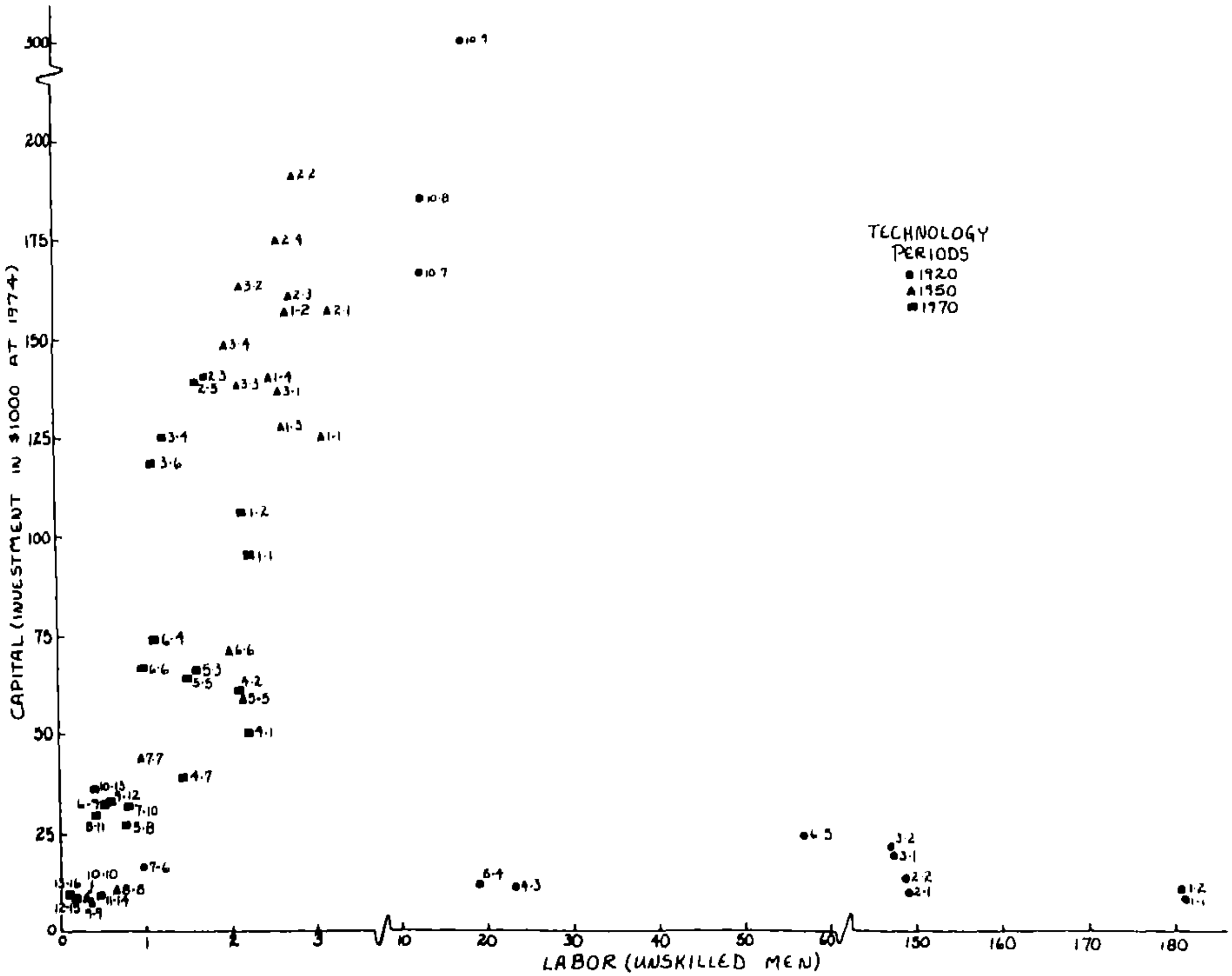


Figure 3.1bb: Labor and capital requirements of each technical package for excavation/hauling at 100 meters at the rate of 100 bank cubic meters per hour, for each technology period (source: Table B.6).

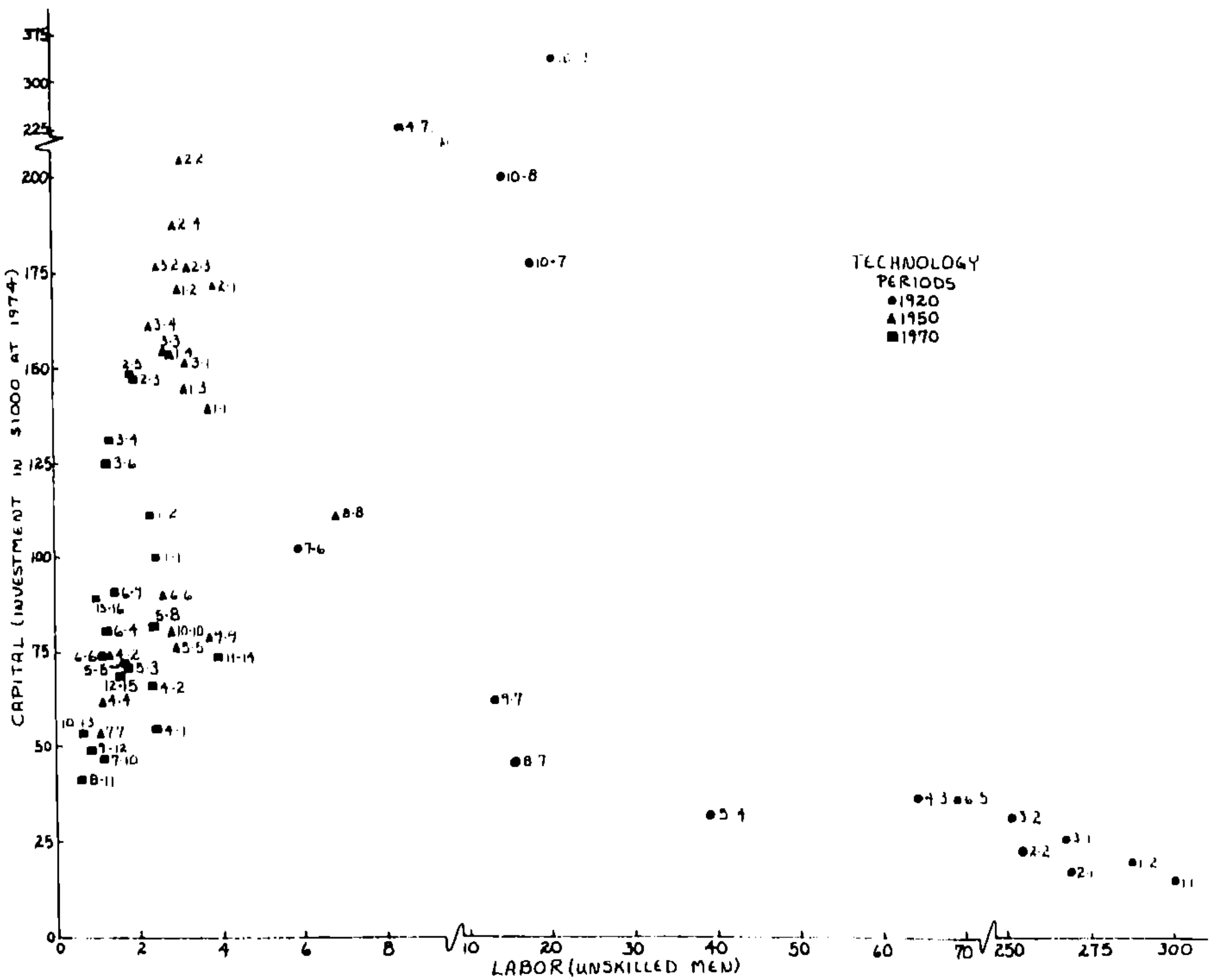


Figure 3.1bc: Labor and capital requirements of each technical package for excavation/hauling at 800 meters at the rate of 100 bank cubic meters per hour, for each technology period (source: Table B.6).

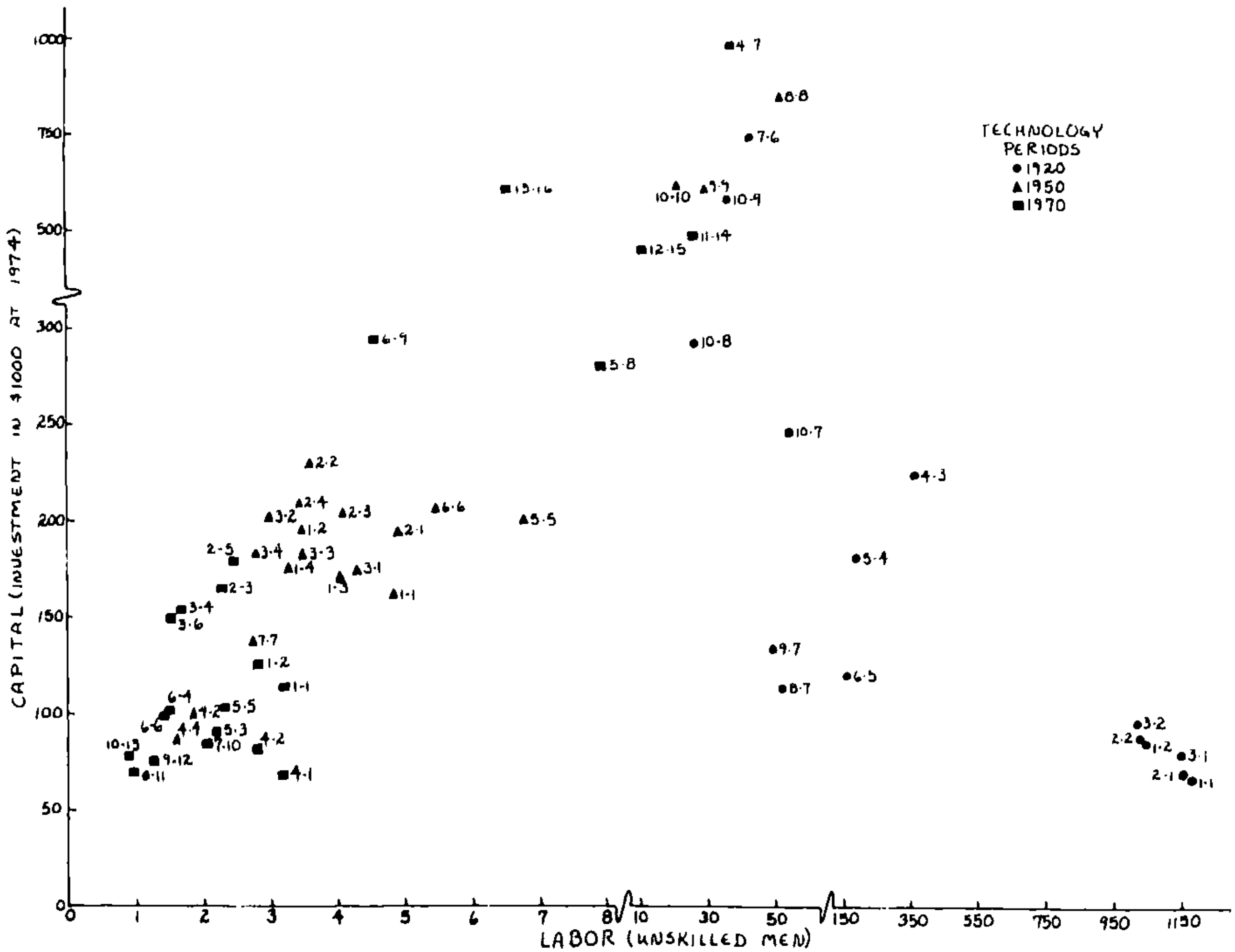


Figure 3.1c: Labor and capital requirements of each technical package for spreading/compaction at the rate of 100 bank cubic meters per hour, for each technology period (source: Table B.6).

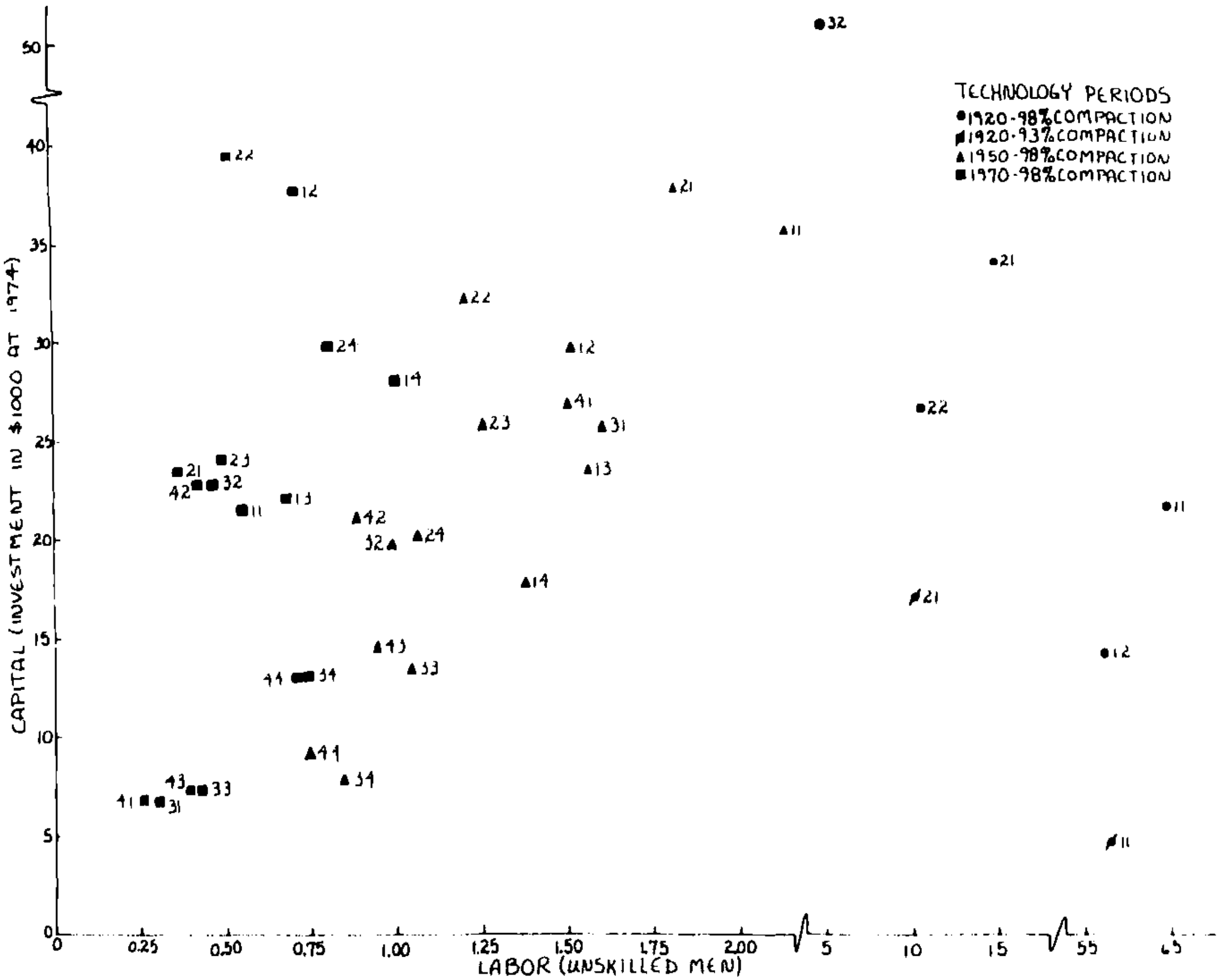


Figure 3.1d: Labor and capital requirements of each technical package for gravel surfacing at the rate of 100 compacted cubic meters per hour, for each technology period (source: Table B.6).

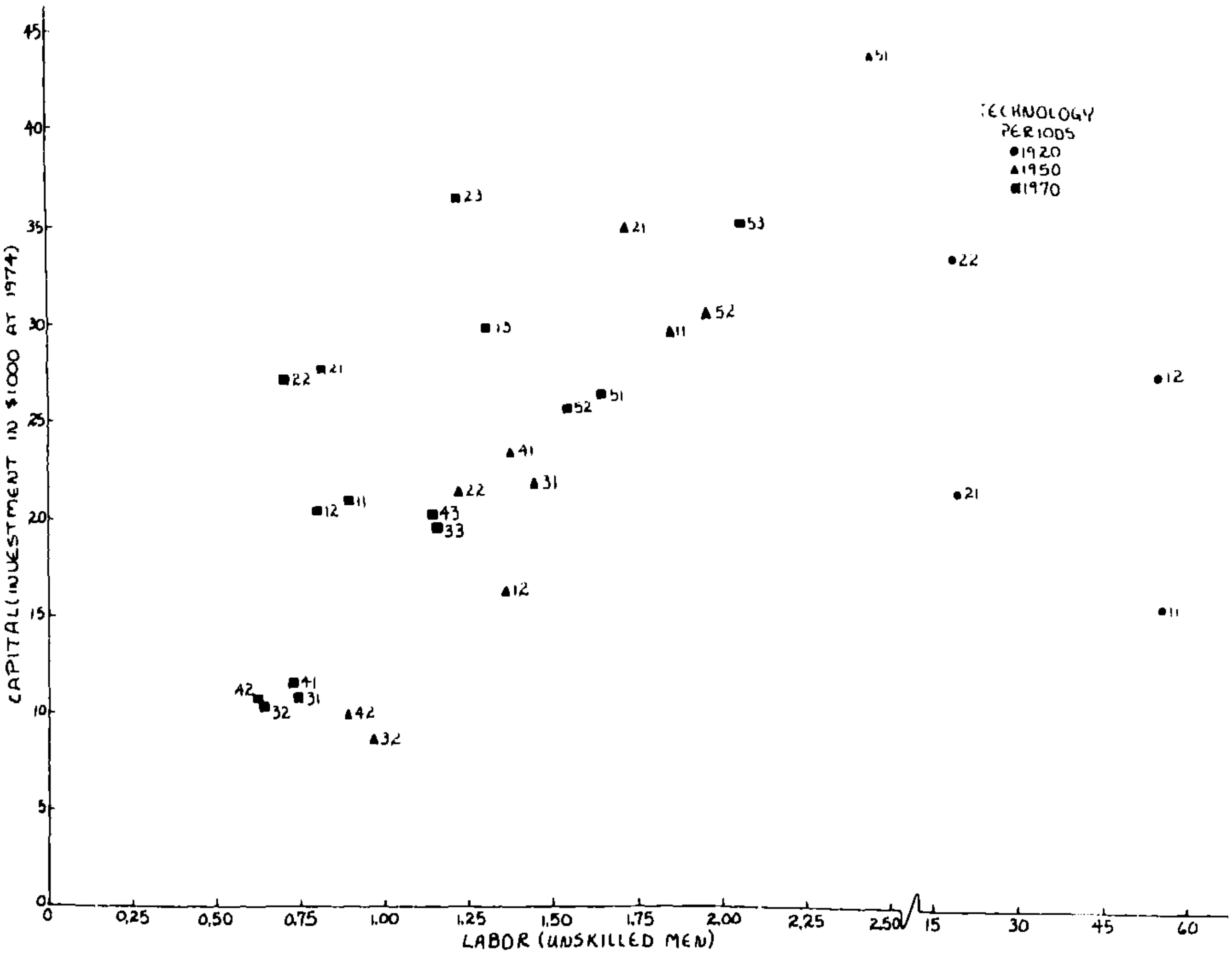


Figure 3.1e: Labor and capital requirements of each technical package for waterbound macadam surfacing at the rate of 100 compacted cubic meters per hour, for each technology period (source: Table B.6).

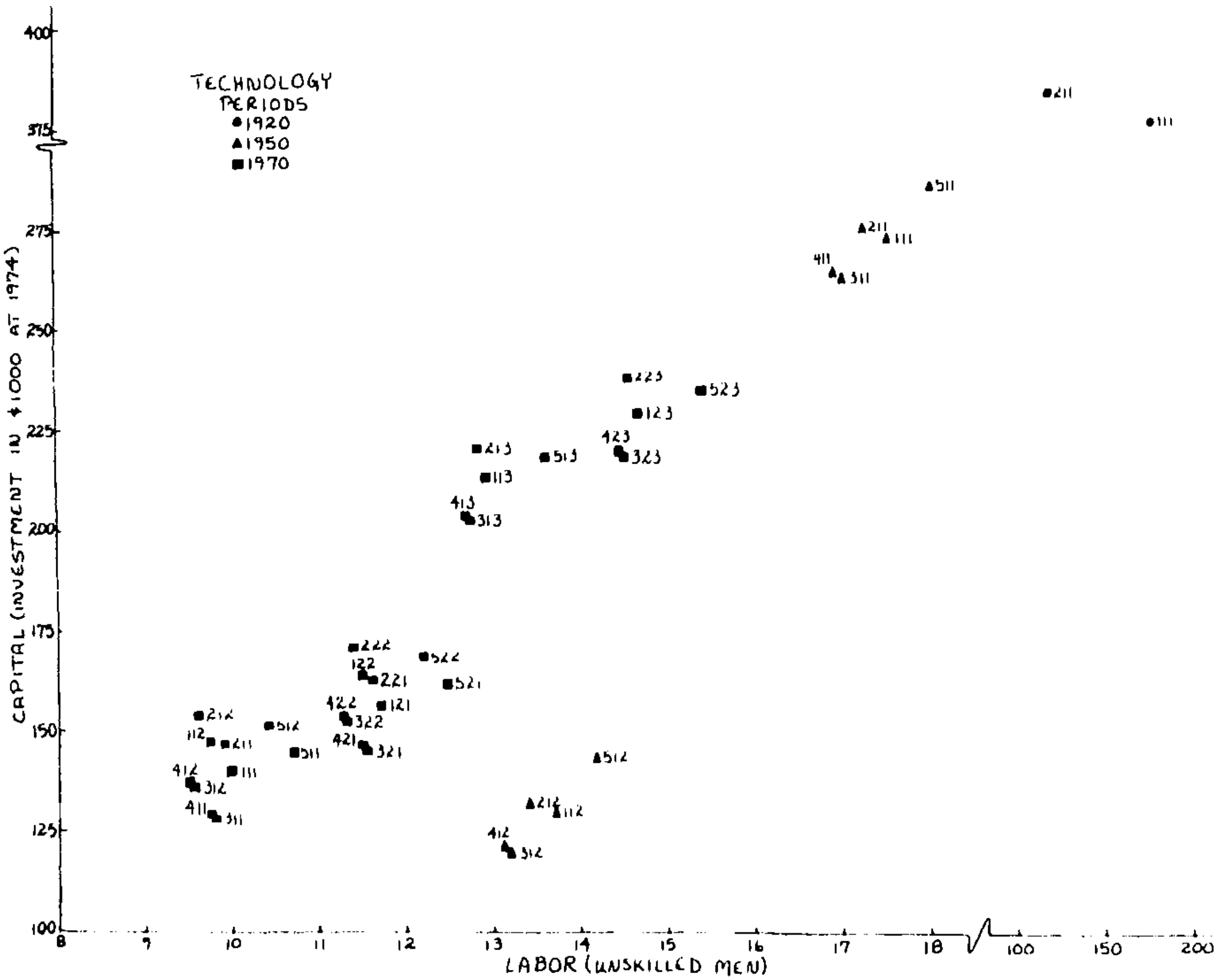
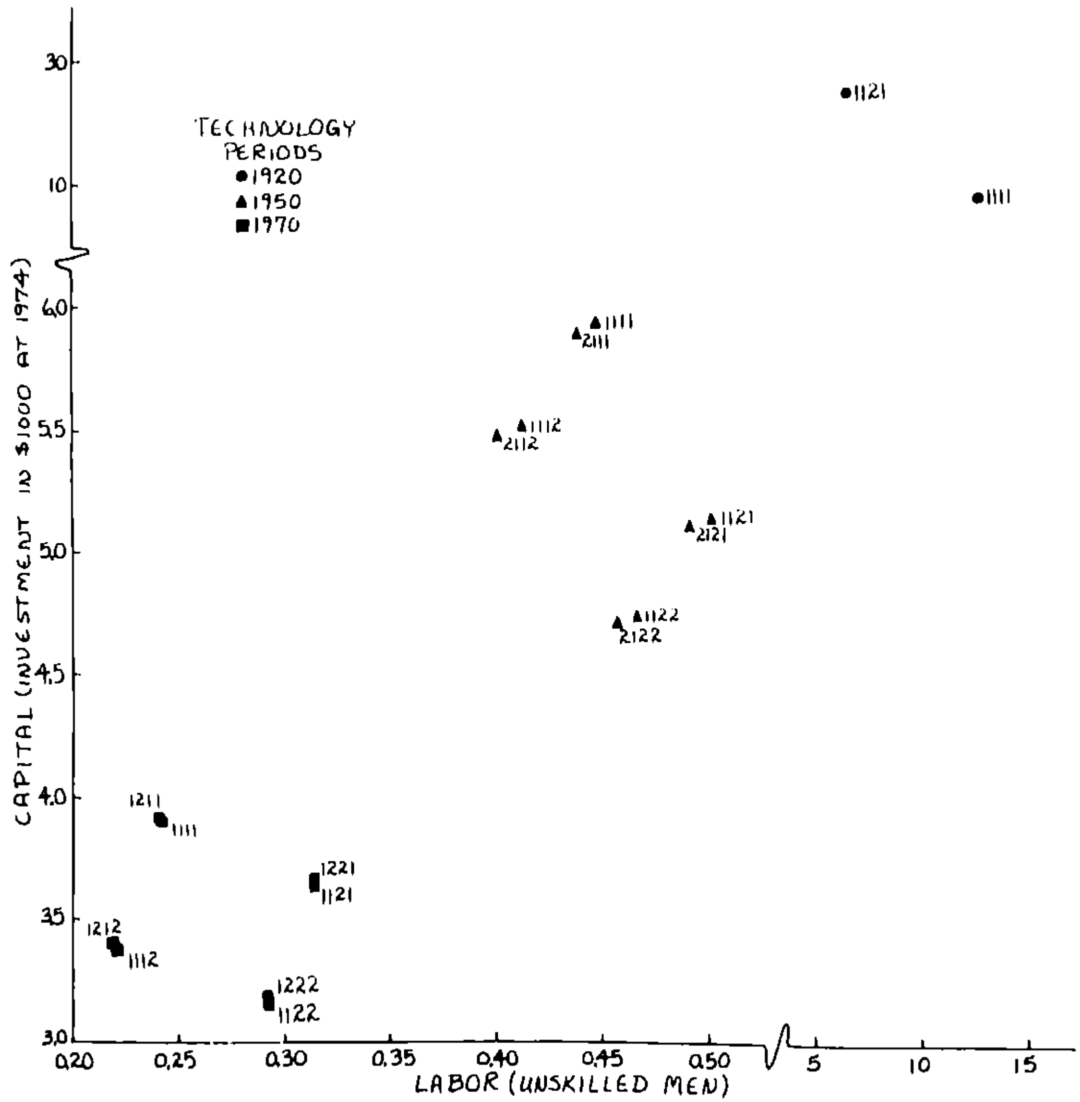


Figure 3.1f: Labor and capital requirements of each technical package for double bituminous surface treatment over gravel at the rate of 100 square meters per hour, for each technology period (source: Table B.6).



each technology period and over all periods; Table 3.4 summarizes these graphs by presenting the efficient set so determined in list form.

In situations where the lifetime, maintenance as a percentage of investment cost, and fuel consumption vary considerably among the different pieces of equipment, as is particularly the case for the 1920's (see Table B.2), a perhaps more reliable measure of capital is its hourly ownership and operating cost; a numerical, as opposed to graphical, efficiency analysis of the sort outlined in Section 2.31 thus becomes necessary. The results of this are included here as Table 3.5, where the set of efficient technical packages is given for each stage, for each technology period and over all periods. It should be noted, however, that this efficient set is restricted to those technical packages which arise as least cost under some reasonable mix of the conomic conditions given in Table 3.3, and it may not thus be all-inclusive.

Four hundred possible combinations of economic conditions arise from the four groups of resources, each with four or five economic conditions. Certain combinations are, of course, not plausible, including for example:* (1) 1974 labor and 1930 equipment; (2) 1956 labor, miscellaneous interest rate, and 1930 equipment; and (3) miscellaneous labor and 1930 equipment; only three of the technical packages, which show up as being least cost under some of the four hundred combinations, appear only under such implausible combinations and are thus eliminated from the efficient set. Each of the technical packages in Table 3.5 thus

*Resource groups not included in the combination listed may take any value.

Table 3.4: Graphical efficiency analysis results -- the set of efficient technical packages for each stage of construction, from among those available in each technology period alone and in all periods combined (source: Figure 3.1 and Table B.6).

Stage	Technology Period					
				All Periods		
	1920	1950	1970	1920	1950	1970
Site Preparation	11,21	11,31	21,31	11	-	21,31
Excavation/Hauling						
-6M	1-1,4-3,5-4,7-6	9-9,10-10	12-15,13-16	-	9-9	12-15,13-16
-100M	1-1,5-4,7-6,8-7	7-7	8-11	1-1,5-4	-	8-11
-800M	1-1,8-7,10-8	4-4	4-1[a],8-11,10-13	1-1	-	4-1[a],8-11,10-13
Spreading/Compaction						
-93%	11,21	-	-	-	-	-
-98%	12,22,32	34,44	31[a],41	-	-	31[a],41
Gravel Surfacing	11,21,22	32,42	32,42	-	32	32,42
Waterbound Macadam Surfacing	111,211	312,412	311,312,411,412	-	312,412	311,312,411,412
Double Bituminous Surface Treatment over Gravel	1111,1121	2112,2122	1112,1122,1212,1222	-	-	1112,1122,1212, 1222

[a]These technical packages are barely efficient in that the investment costs of 800M exc/haul tp 8-11 and of 98% spr/comp tp 41 are only very slightly higher than those of tp 4-1 and tp 31, respectively, although their labor requirements are significantly less.

Table 3.5: Numerical efficiency analysis results -- the set of efficient technical packages for each stage of construction, from among those available in each technology period alone and in all periods combined.

	Technology Period					
				All Periods		
Stage	1920	1950	1970	1920	1950	1970
Site Preparation	11,21	31	31	11	-	31
Excavation/Hauling						
-6M	1-1,4-3,5-4,7-6	9-9,10-10	12-15,13-16	5-4	9-9	13-16
-100M	1-1,1-2,5-4,7-6,8-7,9-7	7-7	8-11	1-1,1-2,5-4,8-7	-	8-11
-800M	1-1,1-2,2-1,2-2,6-5,8-7, 9-7,10-8	4-4	8-11	1-1,1-2,2-1,2-2,8-7	-	8-11
Spreading/Compaction						
-93%	11,21	-	-	-	-	-
-98%	11,21,12,22,32	33,34,43,44	41	21	-	41
Gravel Surfacing	11,21,12,22	32,42	31,41	21	-	31,41
Waterbound Macadam Surfacing	111,211	312,412	311,411	-	-	311,411
Double Bituminous Surface Treatment over Gravel	1111,1121	2112,2122	1112,1121,1122	-	-	1112,1121,1122

arises under one or more sets of conditions constituting a reasonable scenario such as: (1) the U.S. in 1974, 1956, or 1930 or some slight variation (e.g., 1974 conditions except developing interest rate, 1956 conditions except 1930 interest rate and/or labor, or 1930 conditions except 1956 interest rate and/or developing horse and/or labor); (2) a reasonably typical developing country or some slight variation (e.g., 1930 or miscellaneous labor, miscellaneous interest rate, and/or 1974 equipment); (3) the U.S. in the future as labor continues to increase in cost relative to other resources (e.g., 1956 conditions except 1974 labor or 1930 conditions except 1956 labor); (4) a reasonably advanced developing country (e.g., 1930 labor, 1974 interest rate, 1956 equipment, and 1930, 1956, or developing horse); and (5) a capital-rich developing country with somewhat of a labor shortage (e.g., 1930 or 1956 labor and interest rate and 1974 or developing equipment) or with an abundance of unskilled and shortage of skilled labor (e.g., developing or miscellaneous labor, 1930, or 1956 interest rate, and 1974 or developing equipment). It is interesting to note that, except in a few cases, the most labor-intensive technical packages of the 1920's given in Table 3.5 arise only under the conditions given in (2) above with a 1956 or 1974 horse, suggesting the importance of the draft animal in raising crew productivity.

In order to begin to address the issue of efficiency and substitution and their role in technology change, it is necessary to apply, to the resource requirements of each of the technical packages in each technology period, the factor prices at each of the price periods; the set of unit costs, which constitute the results of this, are given in Table B.5.

Table 3.6, then, presents a subset of these results: the set of least-cost, and thus best-practice, technical packages for each stage of construction, at the prices of 1930, 1956, and 1974, in each of the 1920's, 1950's, and 1970's technology periods. Technical packages with unit costs within ten percent of that of the least-cost technical package are also included in Table 3.6 in order to allow for reasonable error, accounting for those cases where more than one technical package is listed for a particular technology and price period. Generally, a second technical package is the most that is necessary to include, with the exception of the waterbound macadam surfacing and double bituminous surface treatment stages; these two stages involve a greater number of major activities or tasks for which different resource packages can be specified, and thus each activity or task potentially has a lesser part in the whole, and correspondingly, a change in its resource package potentially has a lesser impact on total unit cost. All further analyses involving the best-practice packages include those which appear as least-cost at the prices of the period coincident with that of the technology; in cases where more than one package is involved, the data for the various packages is averaged as necessary for the analysis.

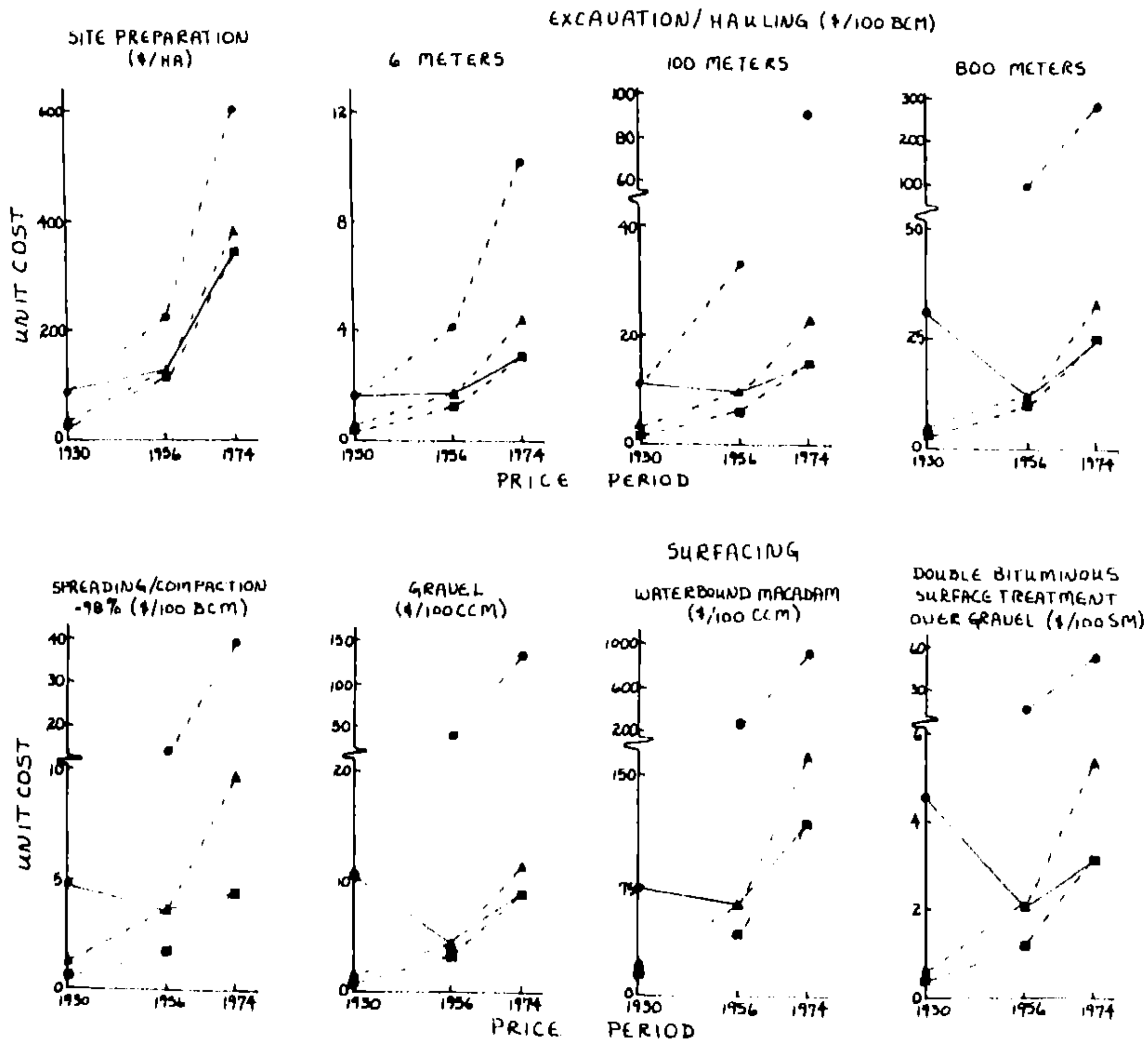
Figure 3.2 is presented to give some indication of the magnitude of technology change in unit cost terms. Figure 3.2a consists of plots, for each stage of construction, of the unit costs of the best-practice technical packages of each technology period at the prices of 1930, 1956, and 1974, indicating the transition in costs that actually occurred as well as that which would have occurred had technology not changed as it

Table 3.6: The set of least-cost technical packages for each stage of construction, at the prices of 1930, 1956, and 1974, from among those available in each technology period (source: Table B.5).

	Technology Period		
Stage	1920	1950	1970
Site Preparation	21	31	31
Excavation/Hauling			
-6M	7-6	9-9,10-10/10-10,9-9/10-10,9-9	13-16,12-15/13-16/13-16
-100M	7-6,9-7/7-6/7-6	7-7,4-4	8-11
-800M	10-8	4-4	8-11
Spreading/Compaction			
-93%	21	-	-
-98%	32	44/44,34/44,34	41,31
Gravel Surfacing	22	42,32	31,41
Waterbound Macadam Surfacing	211	412,312,212,112,512	311,411,111,211
Double Bituminous Surface Treatment over Gravel	1121	2122,1122,2121,1121,2112,1112/ 2122,1122,2112,1112,2121,1121, 2111,1111/2112,2122,1112,1122, 2111,2121,1111,1121	1122,1222,1112,1121,1212, 1221,1111,1211/1112,1212, 1111,1211,1122,1222,1121/ 1112,1212,1111,1211

Note: The slashes separate the packages which appear as least-cost at 1930/1956/1974 price periods; if there are no slashes, then the same packages appear as least-cost at each price period. The least-cost technical packages of the 1970's are least-cost among all technical packages at all three price periods. Least-cost includes those packages within 10 percent of the least-cost package, the order of the listing being from the lowest to highest in cost.

Figure 3.2a: Unit costs of the best-practice technical packages of each technology period for each stage of construction, at the prices of 1930, 1956, and 1974 (source: Table B.5).



(Figure 3.2a continued)

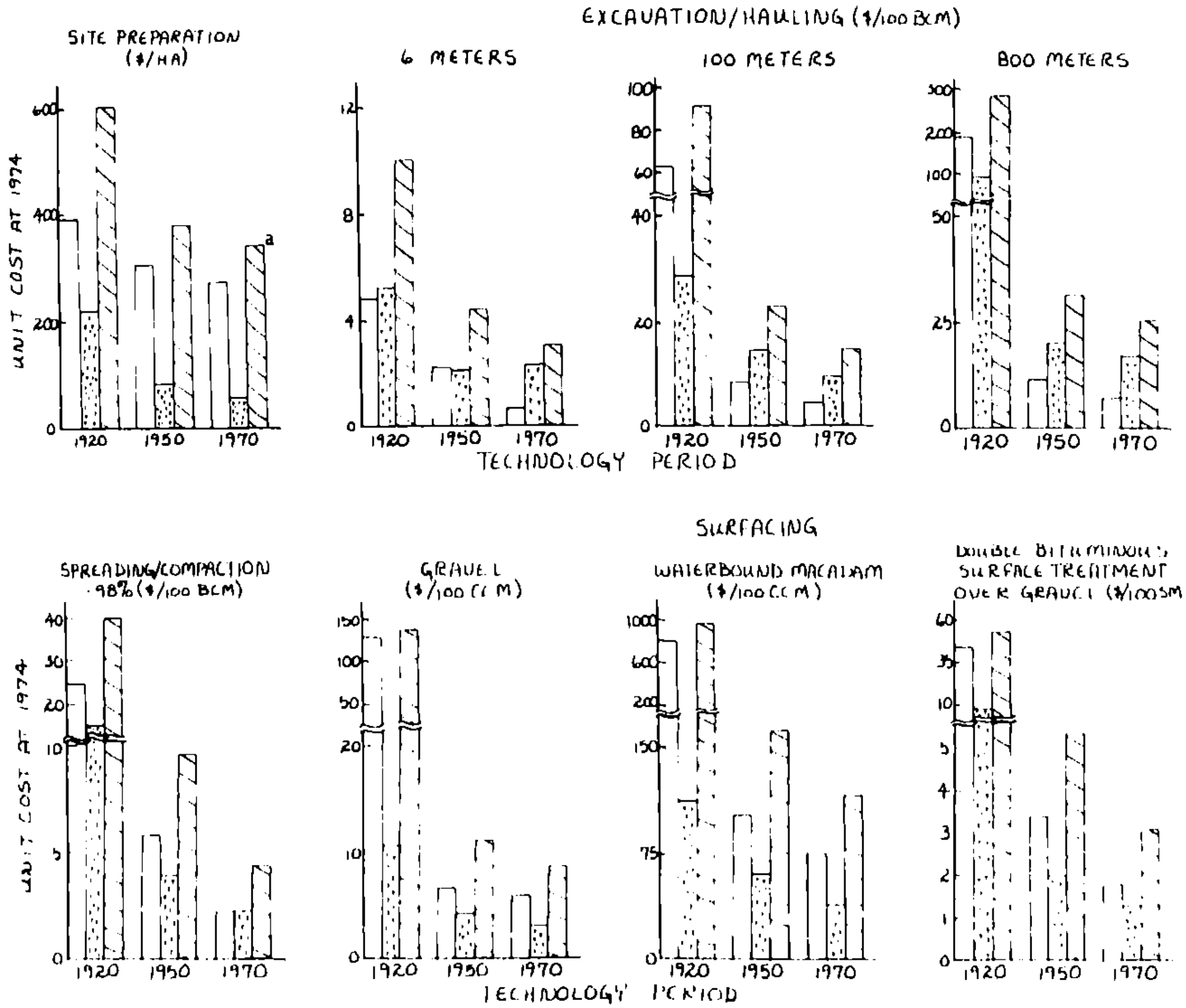
Note: Technology periods: ● 1920, ▲ 1950, ■ 1970.

——Transition in costs that actually occurred.

- - -Transition in costs that would have occurred had technology not changed.

Best-practice packages are those which appear as least-cost, or within 10 percent of it, at the prices of the period coincident with that of the technology; where more than one package is involved, the data for the various packages is averaged.

Figure 3.2b: Labor and capital components of the unit costs of the best-practice technical packages of each technology period for each stage of construction, at the prices of 1974 (source: Table B.5).



(Figure 3.2b continued)

<u>Note</u>: Unit costs: ☐ labor, ⬚ capital, ▧ total.

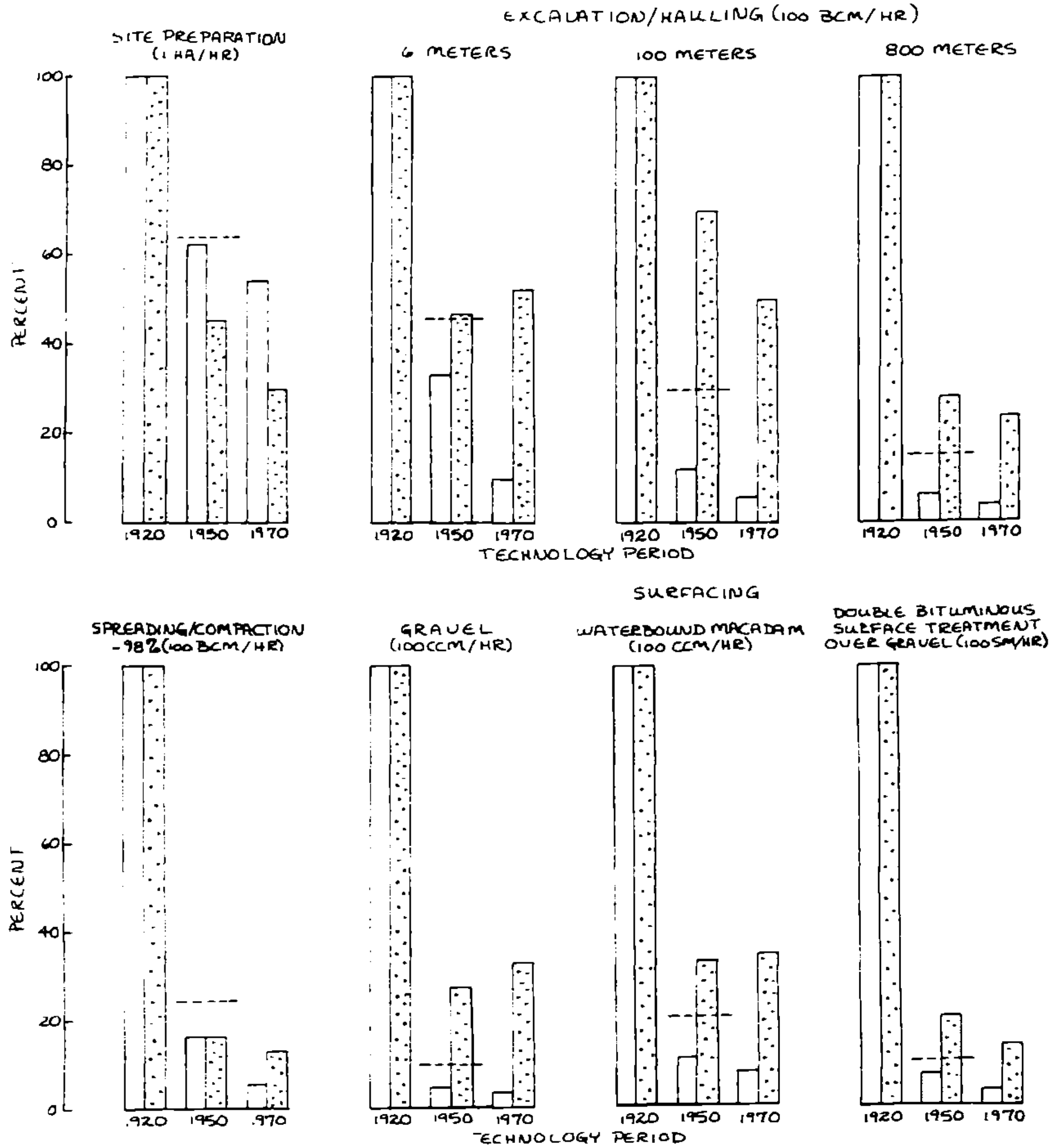
Best-practice packages are those which appear as least-cost, or within 10 percent of it, at the prices of the period coincident with that of the technology; where more than one package is involved, the data for the various packages is averaged.

[a]Includes $19.09 of materials.

did. In order to investigate labor and capital shares of the unit costs, Figure 3.2b presents bar charts, again for each stage, of the labor and capital components, in terms of 1974 unit costs, of the best-practice packages in each period. In an effort to avoid the biases introduced by the use of a particular set of factor prices and to focus more directly on changes in quantities of resources, Figure 3.3 uses labor measured in units of unskilled men and capital in 1974 investment dollars required for a particular rate of production; Figure 3.3a presents the labor and capital requirements of the best-practice packages of each of the three technology periods as a percentage of those of the 1920's, while Figure 3.3b does the same using the 1950's as the base.

Returning to the questions of efficiency and substitution and their role in technology change brings up Tables 3.6 and 3.7. Table 3.6 gives an indication of the extent of substitution, brought about by changes in factor prices, in technology change, as it gives the best-practice packages for each technology period at the prices of 1930, 1956, and 1974. In order to investigate the role of efficiency in technology change, a method based on that of Salter (73), as discussed in Section 2.31, is used to separate the impact of efficiency from that of bias, technology change being represented by movements among the best-practice packages over time. Table 3.7 presents the results of this analysis; the figures represent the percentage change (decrease [-] or increase [+]) in the quantity of labor and of capital, required for the various stages of construction, which can be attributed to efficiency and to

Figure 3.3a: Labor and capital requirements of the best-practice technical packages of each technology period as a percentage of those of the 1920's, for each stage of construction (source: Table B.6).



(Figure 3.3a continued)

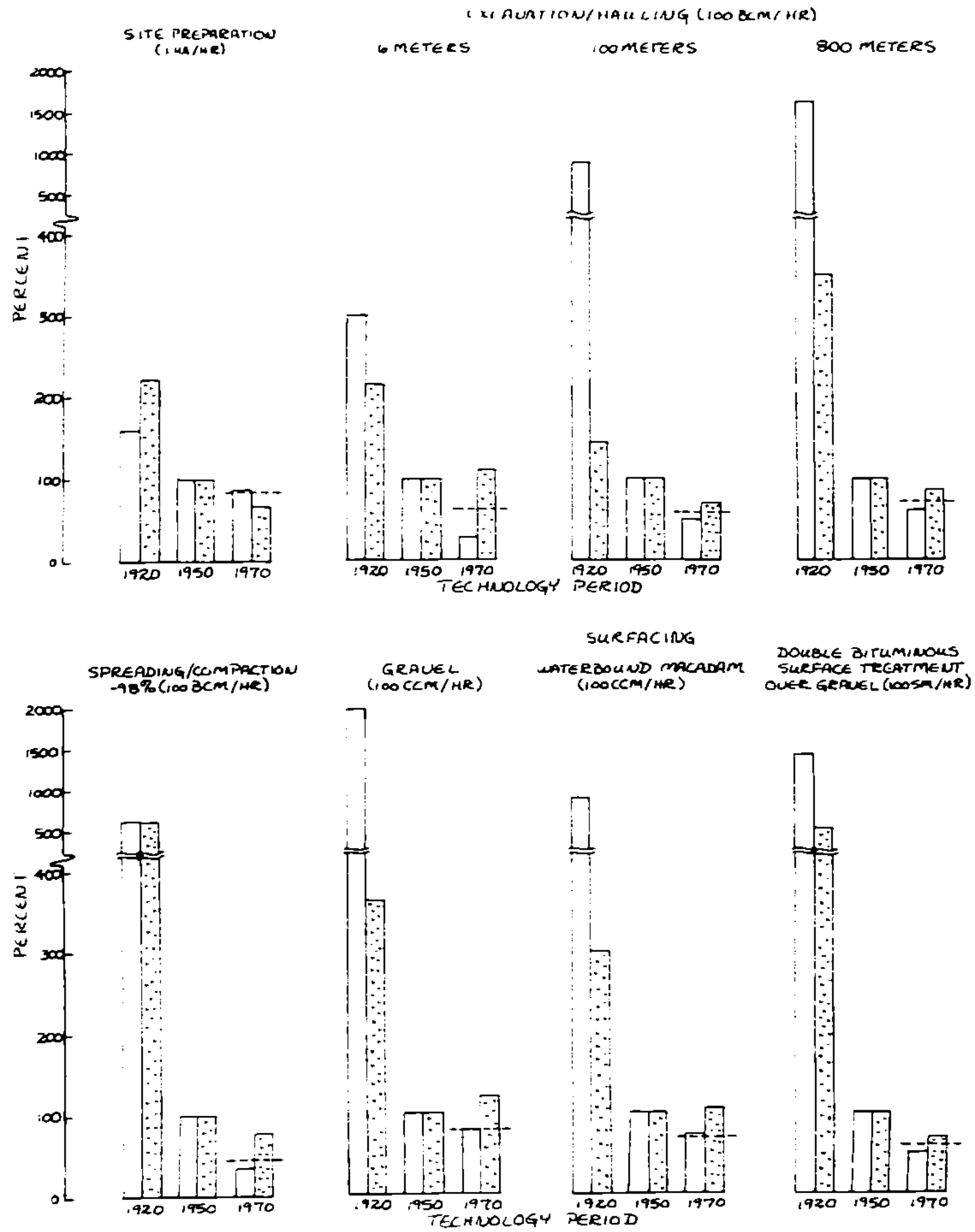
Note: ☐ Percent of 1920's labor, where labor is measured in unskilled men required for the given rate of production.

▒ Percent of 1920's capital, where capital is measured in investment, in 1974 dollars, required for the given rate of production.

---- Indicates the level to which the quantities of labor and capital of the 1950's, relative to those of 1920's, fell due to efficiency; the further drop, generally of labor, below this line and rise, generally of capital, above it represents the changes due to bias (from Table 3.7).

Best-practice packages are those which appear as least-cost, or within 10 percent of it, at the prices of the period coincident with that of the technology; where more than one package is involved, the data for the various packages is averaged.

Figure 3.3b: Labor and capital requirements of the best-practice technical packages of each technology period as a percentage of those of the 1950's, for each stage of construction (source: Table B.6).



(Figure 3.3b continued)

Note: ☐ Percent of 1950's labor, where labor is measured in unskilled men required for the given rate of production.

▨ Percent of 1950's capital, where capital is measured in investment, in 1974 dollars, required for the given rate of production.

---- Indicates the level to which the quantities of labor and capital of the 1970's relative to those of the 1950's fell due to efficiency; the further drop, generally of labor, below this line and rise, generally of capital, above it represents the changes due to bias (from Table 3.7).

Best-practice packages are those which appear as least-cost, or within 10 percent of it, at the prices of the period coincident with that of the technology; where more than one package is involved, the data for the various packages is averaged.

Table 3.7: Distribution of the percentage change in the quantity of labor and capital required by the best-practice packages, for each stage of construction, in the 1920's to the 1950's and the 1950's to 1970's transitions (source: Tables B.5 and B.6 and Figure 3.3).

Stage and Resource	Distribution of the Percentage Change: $100 \cdot (Resource_{50} - Resource_{20}) / Resource_{20}$				$100 \cdot (Resource_{70} - Resource_{50}) / Resource_{50}$			
	Total[a]	Efficiency[b]	Bias[b]	Salter's Bias[b]	Total[a]	Efficiency[b]	Bias[b]	Salter's Bias[b]
Site Preparation								
Labor	-37.8	-36.2	-1.6	+7.23	-13.2	-14.9	+1.7	+3.01
Capital	-55.0	-36.2	-18.8	-20.4	-32.6	-14.9	+17.7	-19.4
Excavation/Hauling								
-6M Labor	-67.1	-54.3	-12.8	-19.3	-70.4	-38.2	-32.2	-144.
Capital	-53.4	-54.3	+0.9	+25.2	+12.0	-38.2	+50.2	+128.
-100M Labor	-88.2	-69.9	-18.3	-169.	-48.6	-41.8	-6.8	-22.6
Capital	-30.4	-69.9	+39.5	+197.	-28.5	-41.8	+13.3	+17.1
-800M Labor	-93.8	-85.1	-8.7	-166.	-40.8	-32.3	-8.5	-23.5
Capital	-71.6	-85.1	+13.5	+189.	-16.4	-32.3	+15.9	+17.9
Spreading/Compaction								
-98% Labor	-83.6	-75.7	-7.9	-0.607	-64.9	-55.3	-9.6	-42.8
Capital	-83.4	-75.7	-7.7	+1.30	-21.3	-55.3	+34.0	+81.5
Gravel Surfacing								
Labor	-94.9	-89.9	-5.0	-87.5	-20.0	-19.7	-0.3	-13.3
Capital	-72.5	-89.9	+17.4	+355.	+21.0	-19.7	+40.7	+37.2
Waterbound Macadam Surfacing								
Labor	-88.5	-78.9	-9.6	-41.3	-27.0	-29.2	+2.2	-11.1
Capital	-66.5	-78.9	+12.4	+149.	+5.0	-29.2	+34.2	+33.4
Double Bituminous Surface Treatment over Gravel								
Labor	-92.9	-88.7	-4.2	-46.3	-48.8	-41.5	-7.3	-9.55
Capital	-79.6	-88.7	+9.1	+143.	-31.5	-41.5	+10.0	+23.2

(Table 3.7 continued)

[a]From Figure 3.3.

[b]Equations for calculating these values are given and discussed in Section 2.31. Calculation of columns 2 and 6, efficiency, and columns 4 and 8, Salter's bias, are based on Salter's work, while columns 3 and 7 are the difference between the total percentage change from Figure 3.3 and that due to efficiency.

bias, in the transition from the 1920's to 1950's and in that from the 1950's to 1970's. It should be noted that Salter's measure of bias is an indication of what would happen, in terms, for example, of reducing labor and augmenting capital, if it could be done, and not of what actually happened; columns 3 and 7 of Table 3.7, then, combine the efficiency results with the data in Figure 3.3 to derive the actual percentage change in inputs due to bias.

This thus completes the presentation of the results of the stage-level analysis. Further discussion of these results and their implications, as well as some limited sensitivity testing of them, is left to Chapter 4.

3.2 Project Designs and Costs

Highway construction and use are not independent, making it important to extend the stage-level analysis to the project-level and to look at some alternative project designs as well as construction technologies. Differences among designs lie primarily in the quality of the final product and in the quantities of the various stages in the overall project. In the course of the stage-level analysis, meaningful comparisons could not be made among the various surfaces because the nature of the surface itself, both in terms of the material and in its level of compaction and general quality of construction (although the latter parameter is assumed constant), affects the quality of the final product. Somewhat similarly, the degree of compaction in the spreading/compaction stage potentially interacts with the other stages of construction in terms of project quantities and/or affects the quality of the final product. Site preparation and excavation/hauling, on the other hand, have no impact on the quality of the final product, as a cubic meter of excavation/hauling is the same regardless of how it is done. Noteworthy in the case of excavation/hauling are the variety of possible haul distances, a condition which varies widely among projects, and the range of possible construction scenarios, in terms of line hauling and borrowing, which affects the quantity of site preparation as well as the set of haul distances. Maintenance and user costs over the life of the project for a particular traffic profile serve as a very convenient, and measurable, indicator of the quality of the final product. The data required for the project-level analysis thus consists of the construction quantities and least-cost technical packages (and thus unit costs from the stage-level analysis) at various technology and price periods, for the various stages of construction of a representative set of alternative projects; also needed are the maintenance and user costs associated with these projects.

3.21 Selection of Projects

In investigating the interaction of design and technology in highway construction and use, three groups of projects are of interest, as indicated in Table 3.8. Before proceeding, the numbering scheme of the projects might be mentioned. The L and H indicate the level of design standards, which will be discussed shortly; the first digit represents the surfacing materials, the second the subgrade strength and surface

Table 3.8: A list of the projects considered in the analysis and their basic characteristics.

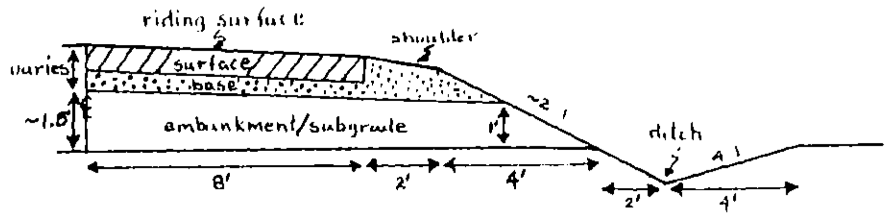
Project Number	Design Standards/ Initial Traffic (ADT)	Subbase/Base/ Surface Materials	Subgrade Strength (%CBR)/%CBR for which Surface Designed	Line Hauling/ Sideborrowing/ Pit Borrowing
L 114	low/80	-/-/gravel	7.0/7.0	short/-/near
L 214	low/80	-/gravel/wbm	7.0/7.0	short/-/near
L 314	low/80	-/gravel/dbst	7.0/7.0	short/-/near
H 215	high/400	-/gravel/wbm	7.0/7.0	long/-/near
H 315	high/400	-/gravel/dbst	7.0/7.0	long/-/near
H 415	high/400	gravel/wbm/dbst	7.0/7.0	long/-/near
L 314	low/80	-/gravel/dbst	7.0/7.0	short/-/near
L 324	low/80	-/gravel/dbst	3.5/3.5	short/-/near
L 334	low/80	-/gravel/dbst	3.5/7.0	short/-/near
H 315	high/400	-/gravel/dbst	7.0/7.0	long/-/near
H 325	high/400	-/gravel/dbst	3.5/3.5	long/-/near
H 335	high/400	-/gravel/dbst	3.5/7.0	long/-/near
L 311	low/80	-/gravel/dbst	7.0/7.0	short/ 1 side/-
L 314	low/80	-/gravel/dbst	7.0/7.0	short/-/near
L 315	low/80	-/gravel/dbst	7.0/7.0	long/-/near
H 312	high/400	-/gravel/dbst	7.0/7.0	short/2 sides/near
H 313	high/400	-/gravel/dbst	7.0/7.0	long/2 sides/near
H 315	high/400	-/gravel/dbst	7.0/7.0	long/-/near
L 316	low/80	-/gravel/dbst	7.0/7.0	short/-/far
L 317	low/80	-/gravel/dbst	7.0/7.0	long/-/far
H 317	high/400	-/gravel/dbst	7.0/7.0	long/-/far

(Table 3.8 continued)

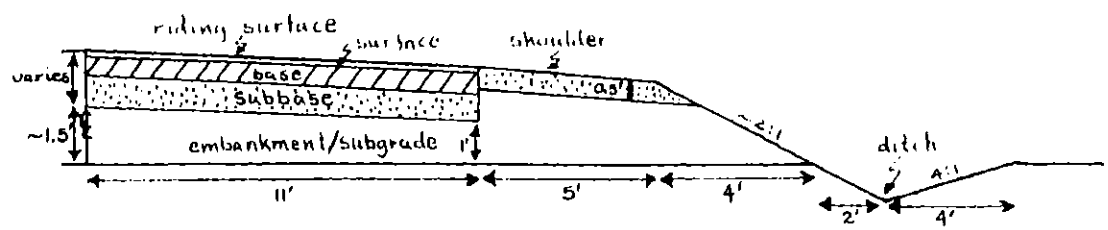
<u>Note</u>: Design standards and traffic profile details:

	Low Standard	High Standard
Design Speed	25 mph	60 mph
Maximum Grade	9 %	4 (some 6) %
Minimum Radius of Curvature	230 feet	1,300 feet
Minimum Length of Vertical Curves	400 feet	600 feet
Initial Traffic	80 ADT	400 ADT
Truck Percentage	20 %	30 %
Annual Growth Rate Over 15 Years	10 %	10 %

Low Standard Cross Section:



High Standard Cross Section:



design combination, and the third the excavation/hauling scenario. One numerical parameter is varied in each set of projects while the others are held constant, for the low and high standard design alternatives.

In the first group of projects, the surfacing material is allowed to vary, the surfaces being well-graded gravel (p L114), waterbound macadam with the gravel as a base (p L214, H215), double bituminous surface treatment with the gravel as a base (p L314, H315, and double bituminous surface treatment with the waterbound macadam as a base and the gravel as a subbase (p H415). As indicated in Section 3.12, these particular surfaces were selected because of their use in all three technology periods, being reasonably common as surfaces in the 1920's while more recently being used on relatively low volume, rural roads, and because of their flexibility in terms of being able to be constructed using alternative technical packages. Construction, maintenance, and user costs may be expected to vary among these projects.

In the second project group, the degree of compaction of the subgrade is allowed to vary and with it the design of the surface. Three combinations occur: (1) a 7 percent California Bearing Ratio* (CBR)

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*CBR is a measure of the strength of the subgrade and can be expressed as a function of the soil type, its density, and its moisture content, but as noted in Section 3.12 such data seems to be available for only a few materials, one being silty clay. A soaked CBR of 7 percent corresponds to compaction in the range of 95 to 100 percent of the standard AASHO compaction of silty clay within $\pm$ 2 percent of the optimum moisture content (i.e., the 98 percent compaction case), while a soaked CBR of 3.5 percent corresponds to 91 to 96 percent compaction of the same (i.e., the 93 percent compaction case) (116). It might further be noted that these are relatively low CBR values, resulting in the need for rather thick surfacing layers.

with a suitable surface thickness (p L314, H315); (2) a 3.5 percent CBR with a suitable surface thickness (p L324, H325); and (3) a 3.5 percent CBR with a surface thickness suitable for a 7 percent CBR (p L334, H335). A comparison of the first two cases yields insight into the trade-off in construction costs between the compacting and affected activities and the surfacing activities, while the maintenance and user costs may be expected to be the same. Comparison of the last case with each of the first two yields insight into the trade-off between construction costs now, in terms of the compacting and affected activities or the surfacing activities, and maintenance and user costs later.

In the third group of projects, the scenario for the excavation and hauling tasks is allowed to vary. It is assumed that all fill material for the embankment comes from cuts for the road (termed line haul) and from borrow areas. Assuming borrowing from alongside the road is possible, various scenarios arise: (1) short line haul with sideborrow on one side (p L311); (2) short line haul with sideborrow on both sides and near pit borrow as necessary (p H312); (3) long line haul with sideborrow on two sides and near pit borrow as necessary (p H313); (4) short line haul with near pit borrow (p L314); and (5) long line haul with near pit borrow (p L315, H315). Assuming borrowing can only be done at some distance from the road (e.g., 305 meters or 1000 feet) as is more common today, a couple scenarios arise: (1) short line haul with far pit borrow (p L316); and (2) long line haul with far pit borrow (p L317, H317). Maintenance and user costs may be expected to be constant over these projects, with the trade-offs showing up in the construction costs.

Also varying in each of these project groups are the design standards and traffic. While it seemed desirable at the outset to use design standards commensurate with each technology period, this proved to be unfeasible due to a paucity of design data for the 1920's (about all that could be found were cross sections indicating road width and surface thickness); instead, it was decided to use today's designs for two-lane, low volume, rural roads. As it is desirable to actually build rather different roads for different design standards, rolling terrain with reasonably steep grades is selected, with the road crossing it in going from point A to point B. Two sets of design standards at reasonably opposite ends of the spectrum, as given in the note to Table 3.8, are defined with the help of such sources as the American Association of State Highway Officials (4), Oglesby and Altenhofen (59), and Vance (112). The low standard design has a 4.88 meter (16 foot) surface and two 0.61 meter (2 foot) shoulders, grades up to 9 percent, and a design speed of some 40 kilometers per hour (25 miles per hour); thus it essentially follows the contour of the land, with cuts and fills primarily resulting from the ditches and the 0.30 meter (1 foot) embankment, respectively. The high standard design, on the other hand, had a 6.71 meter (22 foot) surface and two 1.52 meter (5 foot) shoulders, grades up to 4 percent (a few up to 6 percent to avoid excessive cuts), and a design speed of some 97 kilometers per hour (60 miles per hour); it cuts through the terrain with very large cuts and fills, resulting in some thirty-five times the cut and five times the fill quantities of the low standard design. In overall length, the two roads are about the same, being 17.0 kilometers (10.6 miles) and 16.6 kilometers (10.3 miles), respectively. In line with these two design standards and their various surfaces, two sets of traffic are specified; an initial average daily traffic (ADT) of 80 with 20 percent trucks is used for the low standard design, and one of 400 with 30 percent trucks for the high standard, each with a 10 percent annual growth rate over the 15 year life of the road (reaching 334 ADT and 1671 ADT, respectively).

3.22 Estimation of Project Quantities and Costs

It was observed in the introduction to Section 3.2 that one of the primary differences among projects is in the quantities of each stage in the overall project. For each project in Table 3.8, then, Table 3.9 presents the full set of quantities for each stage of construction, including the various haul distances, compaction percentages, and surfacing materials encountered in the analysis; sizeable differences are evident. The derivation of these quantities is briefly touched upon here, leaving the more complete discussion to Section C.1.

In the inital stages of development of the project-level analysis, an effort was made to find a simple, two-lane, rural road, crossing rolling terrain with a minimum of artificial influences affecting its alignment, which has been constructed and for which the plans, quantity estimates, and so forth were still available. This alone proved

Table 3.9: Quantities of each stage of construction for each project.

Project Number	Site Preparation (HA)	Excavation/hauling[a] (100 BCM) Ditch	6M	9M	60M	100M	165M	500M	800M	Spreading/ Compaction (100 BCM) 98%	93%	Surfacing Gravel (100CCM)	Water-bound Macadam (100CCM)	Double Bituminous Surface Treatment (100SM)
L 114	28.7	94.8	S 392	-	L 37.5	-	-	P 577	-	710	-	333	-	-
L 214	28.7	94.8	S 392	-	L 37.5	-	-	P 577	-	710	-	207	126	-
L 314	28.7	94.8	S 392	-	L 37.5	-	-	P 577	-	710	-	339	-	829
H 215	35.9	92.5	-	S 3800	-	-	P 931	L 2460	-	3490	-	282	170	-
H 315	35.9	92.5	-	S 3800	-	-	P 931	L 2460	-	3490	-	452	-	1110
H 415	35.9	92.5	-	S 3800	-	-	P 931	L 2460	-	3490	-	282	170	1110
L 314	28.7	94.8	S 392	-	L 37.5	-	-	P 577	-	710	-	339	-	829
L 324	28.5	94.8	S 390	-	L 37.5	-	-	P 536	-	-	668	526	-	829
L 334	28.5	94.8	S 390	-	L 37.5	-	-	P 536	-	-	668	339	-	829
H 315	35.9	92.5	-	S 3800	-	-	P 931	L 2460	-	3490	-	452	-	1110
H 325	34.9	92.5	-	S 3780	-	-	P 728	L 2460	-	-	3280	634	-	1110
H 335	34.9	92.5	-	S 3780	-	-	P 728	L 2460	-	-	3280	452	-	1110
L 311	34.7	47.4	S 489	B 625	L 37.5	-	-	-	-	710	-	339	-	829
L 314	28.7	94.8	S 392	-	L 37.5	-	-	P 577	-	710	-	339	-	829
L 315	28.5	94.8	S 352	-	-	- -	-	L 75.7 P 539	-	710	-	339	-	829
H 312	56.7	-	-	B 937 S 6240	L 330	-	P 2220	-	-	3490	-	452	-	1110
H 313	44.3	17.6	-	B 631 S 3930	-	P 375	-	L 2460	-	3490	-	452	-	1110
H 315	35.9	92.5	-	S 3800	-	-	P 931	L 2460	-	3490	-	452	-	1110
L 316	28.7	94.8	S 392	-	L 37.5	-	-	-	P 577	710	-	339	-	829
L 317	28.5	94.8	S 352	-	-	-	-	L 75.7	P 539	710	-	339	-	829
H 317	35.9	92.5	-	S 3800	-	-	-	L 2460 P 931	-	3490	-	452	-	1110

[a]For excavation/hauling - S = spoil
L = line haul
P = pit borrow
B = sideborrow

to be nearly impossible. With the additional condition that it be a project where different design standards and alignments had been considered and worked up or where such was even possible, it quickly became unfeasible, and it was decided to start from scratch.

On a U.S. Geological Survey topographic map of some rolling terrain, two points about 16 kilometers (10 miles) apart are selected, and a few possible alignments for each of the two design standards are planned, assuming no intermediate controls such as townships and quarries. Upon reviewing the wide variety of methods available for estimating earthwork quantities, which range from very rough to very detailed, it is decided to use one of the intermediate methodologies, a modified version of the one point model, in view of the geological data available (the topographic map with 6.1 meter [20 foot] contours) and the data pertaining to the alignment required by the Highway Cost Model (HCM) for estimating maintenance and user costs and surface conditions. The one point model simply computes the area of the cross section at each station (spaced every 60 meters [200 feet] along the route) and uses the average end area technique to compute the volumes, requiring only the centerline height difference between the terrain and road profile; due to the rolling terrain condition, side slope is also taken into account in calculating cross-sectional areas and finally volumes of earthworks. For the purposes of the study at hand, the intermediate alignment, in terms of road length and earthwork quantities, for both the low and high standard designs is selected; the details of these alignments, as required by the HCM, are given in Section C.1, along with further details pertaining to laying out the route and estimating the earthwork quantities.

Given the basic earthwork quantities in terms of cut and fill volumes* for the two design standards, the distribution of cut between fill and spoil and of fill between cut and borrow remains to be determined along with the haul distances. This requires knowledge of the excavation/hauling scenarios of interest. Rather than going to a method as sophisticated as mass-haul diagrams, it is decided to simply review the cut and fill volumes given at 60 meter (200 foot) intervals along each road with two line haul distances (60 meters [200 feet] and 500 meters [1640 feet]) in mind, estimating the percentages of cut which can go to fill. The remainder of the fill, then, must come from borrow, the actual haul distances varying with the assumption as to the type of borrow, side or near or far pit, and the quantity and distribution of the material involved. In the low standard case, for example, the remaining fill is reasonably distributed along the road and thus can all be sideborrowed. In the high standard case, however, the remaining fill is large in quantity and unevenly distributed, and thus it is assumed sideborrow would be done to a limited distance from the road and then near pit borrow would begin as needed. In the near pit borrow scenario, the low standard design is penalized by a long haul distance, because a certain minimum size pit is assumed,

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*Cut for the low standard road is 17,100 bank cubic meters, while fill is 57,700 compacted cubic meters; for the high standard road, cut is 589,000 bank cubic meters, and fill is 283,000 compacted cubic meters.

as is required by some equipment and by common sense, making the haul along the road quite long. As for the quantity of spoil and its haul distance, the remaining cut and the top six inches on the roadbed including the ditches and on all borrow areas go to spoil, with the haul distance being a weighted average. In order to limit the full set of haul distances thus derived to a reasonable number and to leave an allowance for underestimating, some limited grouping and general rounding up is done, resulting in the set of distances given in Table 3.9. Section C.12 contains a fuller discussion of the derivation of these excavation/hauling estimates.

The volume of spreading/compaction is simply taken as the quantity of fill material, under the assumption that compaction is done only in fill areas. The factor for converting compacted to bank measure varies with the level of compaction, being 1.23 for 98 percent compaction and 1.16 for 93 percent compaction.

As in the case of topsoil removal which goes to spoil, the roadbed including the ditches and all borrow areas must be cleared of brush and trees. The quantity of site preparation thus consists of these areas plus an additional 1.5 meters (5 feet) on either side of the road and an additional 10 percent on the pits, as an allowance for brush encroachment and working space.

Gravel and waterbound macadam surfacing are measured in volumetric units as a function of the surface design in terms of layer thickness, the road cross section, and the length of the route; double bituminous surface treatment is measured in units of area as a function of the road cross section and length. Gravel shoulders are assumed in all cases, with a thickness equivalent to that of the surfacing materials for the low standard road since the shoulders are so narrow, and a fixed thickness of 15.2 centimeters (6 inches) for the high standard route. Section C.12 contains the final set of equations used in these calculations.

The surface design requires knowledge of the traffic expected over the design life of the road, the strength of the subgrade (i.e., its CBR), and the layer coefficients of the materials being used, which serve as indicators of the structural support value of the materials in the overall surface. It was decided at the outset to use the Transport and Road Research Laboratory's (TRRL's) design procedure (79), rather than that of the American Association of State Highway and Transportation Officials (AASHTO) (3), as TRRL's surface deterioration models (80) are used in the HCM. This results in somewhat lower standard surfaces (i.e., thinner layers) than might be expected from an AASHTO-based design, which is probably not unreasonable for low volume, rural roads.

Actually only the thickness of the gravel layer has to be designed, as the waterbound macadam is assumed to be 15.2 centimeters (6 inches), since this represents standard design practice at the time of its use and even today, and the double bituminous surface treatment has a thickness determined primarily by the size of the crushed stone used instead of the amount, with 2.2 centimeters (7/8 inch) being a common thickness.

Given the traffic in terms of the cumulative number of standard axles (8200 kilogram [18 kip] loads) over the project life and the subgrade CBR, the gravel thicknesses are designed with the help of a chart provided by TRRL (79). For the two cases of the properly designed surface over a 3.5 percent CBR (p L324, H325), however, the modified structural number* is used to design the gravel layer, such that the properly designed roads with the 7 percent (p L314, H315) and 3.5 percent (p L324, H325) CBR's have the same modified structural number; this is done under the assumption that two such roads should behave the same, which is also the basis of TRRL's use of the modified structural number to determine paved road deterioration. As for layer coefficients for the various materials, figures are derived with the help

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*The structural number (SN) of a pavement is defined by an empirical relationship between the thicknesses and material coefficients of its various layers as follows:

$$SN = \sum_{i=1}^{n} a_i t_i$$

where n = number of layers
a_i = material coefficient of layer i
t_i = thickness of layer i (inches)

The modified structural number (SN') incorporates the subgrade strength in terms of CBR into the measure as follows:

$$SN' = SN + 3.51(\log_{10}CBR) - 0.85(\log_{10}CBR)^2 - 1.43$$

SN', then, is used as an index of the strength of the surface (3, 80).

of AASHTO (30) TRRL (80), and Yoder and Witczak (117), among others; these and the layer thicknesses are given in Section C.11, along with further details about the surface designs. Waterbound macadam presents some problems in that no deterioration model can be found for it; this is resolved by using a modified version of TRRL's model for double bituminous surface treated roads, as this seems reasonable in light of descriptions in the literature of the surface and of its behavior and maintenance.

Given the quantities of each stage in each project, what is still required for the derivation of the construction costs of the projects are the technical packages to be used, and thus their unit costs, from the stage-level analysis. It is assumed that each of the projects is only a small part of a much larger project, and thus no constraints are placed on the selection of technical packages in terms of their having to be used long enough to warrant their being brought to the site without incurring some penalty charge. The selection of technical packages is, therefore, largely stage and economic conditions specific and not really project specific. Table 3.10, then, gives the least-cost technical packages for each of the 1920's, 1950's, and 1970's technology periods as well as those over all technology periods at the prices of 1930, 1974, and developing countries. As in the stage-level analysis, packages within 10 percent of the least-cost one are also included, with the data being averaged as necessary for the analysis. Also, in the case of the 1930 and 1974 pricing periods, these are the

Table 3.10: Least-cost technical packages for each stage of construction, for each technology period alone and over all periods, at the prices of 1930, 1974, and developing countries (source: Tables 3.6 and B.5).

Stage	1930,1974 Prices[a]			Developing Countries Prices			
	1920's Technology	1950's Technology	1970's Technology	1920's Technology	1950's Technology	1970's Technology	All Technologies 1920/1950/1970
Site Preparation	21	31	31	11	31	31	11/-/-
Excavation/ Hauling[b]							
Ditch	5-4	11-0	14-0	5-4,4-3	11-0	14-0	5-4,4-3/-/-
6M-S	7-6	10-10,9-9	13-16	5-4,4-3	9-9	12-15,13-16	5-4,4-3/-/-
9M-B	7-6	10-10,9-9	13-16,12-15	5-4,4-3	9-9,10-10	12-15	5-4,4-3/-/-
-S	7-6	10-10,9-9	13-16,12-15	5-4,4-3	9-9,10-10	12-15	5-4,4-3/-/-
60M-L	7-6	7-7[4-4][c]	8-11	5-4[8-7]	7-7,9-9, 10-10[4-4]	8-11	5-4[8-7]/-/-
100M-P	7-6,9-7	7-7,4-4	8-11	8-7	7-7,4-4	8-11	8-7/-/-
165M-P	9-7	7-7,4-4	8-11	8-7	7-7,4-4	8-11	8-7/-/-
500M-P	10-8	4-4	8-11	8-7	4-4	8-11	8-7/-/-
-L	-[d]	7-7[4-4]	8-11	6-5[8-7]	7-7[4-4]	8-11	6-5[8-7]/-/-
800M-P	10-8	4-4	8-11	8-7	4-4	8-11	8-7/-/-
Spreading/ Compaction							
98%	32	44,34	41,31	21	44,43,34,33	41,31	21/-/-
93%	31[e]	-	-	21	-	-	21/-/-
Surfacing							
Gravel	22	42,32	31,41	21	32,42	31,41	21/-/-
Waterbound Macadam	211	412,312,212, 112,512	311,411, 111,211	211,111	412,312, 112,212	311,411,111	-/-/311,411,111
Double Bituminous Surface Treatment Over Gravel	1121	2122,1122,2112, 1112,2121,1121, 2111,1111	1112,1212, 1111,1211	1111	2122,1122, 2121,1121	1122,1121, 1222,1221	-/-/1122,1121,1222, 1221
Double Bituminous Surface Treatment Over Waterbound Macadam	1121	2122,1122,2112, 1112,2121,1121, 2111,1111	1112,1212, 1111,1211	1111	2122,1122, 2121,1121	1122,1222, 1121,1221	-/-/1122,1222,1121, 1221

(Table 3.10 continued)

Note: Unit costs for these packages are found in Table B.5; where more than one package falls in the least-cost set (including the least-cost package and those within 10 percent), the average cost of the packages is used.

[a]These are the least-cost technical packages at the prices of the period coincident with that of the technology, as were used in the stage-level analysis of best-practice packages. The 1970's least-cost set is also least-cost over all technology periods at these prices.

[b]For excavation/hauling - S = spoil
B = sideborrow
L = line haul
P = pit borrow

[c]The package within the square brackets is the least-cost package for the haul distance, but as it cannot be used in such a line hauling activity, the next least-cost, technically feasible package is used.

[d]The design standard affects package selection - low standard 7-6 [10-8]
high standard 60% 10-8, 40% 7-6

[e]Only two 1920's technical packages were developed for the 93% compaction case, tp 11 and tp 21, neither of which cost less at 1930 or 1974 prices than the least-cost 98% compaction package, tp 32. A new technical package, tp 31, was thus created, using the spreading technique of tp 32 (12 ft blade grader [403] and 76 hp tractor [632]) and the compacting technique of tp 21 (2.5 ton roller [501] and horse), at a cost of $4.52/100BCM at the prices of 1930; it could not compete with tp 32 at the prices of 1974, however, so there is no 93% compaction considered for that price period.

least-cost technical packages at the prices of the period coincident with that of the technology, as were used in stage-level analyses of the best-practice packages.

Only a couple of situations arise in which the project can be said to influence the choice of technical packages. One involves the elevating grader (1920 tp 8-7; 1950 tp 4-4) which cannot be used for line haul or hauls under 60 meters (200 feet) or so; the second involves the use of a power shovel (1920 tp 10-8) in line haul, which is impossible in the low standard case due to the generally shallow depth of the cuts, but which is possible for an estimated 60 percent of the line haul work in the high standard case. In each of these cases, the next least-cost, technically feasible technical package is used, and that which could not be used is indicated in square brackets.

In order to complete the construction costs and bring them more in line with the maintenance and user costs, overhead and profit is included at 20 percent of total direct costs (i.e., labor, capital, and materials) (7, 28, 92). Minor structures are still left out, however, as they represent such a small share of total costs, and it is assumed that no major structures are necessary.

As for the quality of the final product, maintenance and user costs over the life of the project are used. As discussed in Section 2.22, the HCM is one of the models which investigates trade-offs among construction, maintenance, and user costs of alternative designs, with the construction technology being implicit in the rather aggregate cost data used in the analysis. Since it integrates many of the existing methodologies of evaluating alternative designs in terms of the three costs, it seems an appropriate tool to use in deriving maintenance and user costs, although its data requirements are quite substantial. The majority of its requirements in terms of road characteristics, such as alignment, cross section, and surface design, and traffic profile are indicated throughout the discussion above; what remains consists of maintenance policies and unit costs and vehicle characteristics, costs, and utilization. Before proceeding, it should be noted that today's maintenance policies and technologies and vehicle transport technologies are assumed, although significant changes have occurred over time; maintenance itself is still often a relatively labor-intensive activity and has considerable potential for labor-capital substitution, presenting yet another interesting area for research. Furthermore, it is important to bear in mind that the final maintenance and user costs are simply intended as reasonable indicators, not absolute measures, of the quality of the final product; the degree of accuracy and detail desired in this phase is, therefore, much less stringent than that in the construction phase, the primary focus of the research.

With regard to maintenance policies, the personnel associated with the HCM served as a primary source of information based on their experience in applying the model; Harger (31) also proved to be useful in the particular case of waterbound macadam surfacing. Maintenance policies had to be developed and tested, using the HCM, for each subgrade/surface combination, the objective being to minimize maintenance and user costs and to end up with all of the roads in reasonably poor condition at the end of 15 years, the assumed design life, such that their salvage values would be low and reasonably comparable so as to justify their being ignored. It was quickly learned that the two sets of properly designed roads on different subgrade CBR's (p L314 and L324; p H315 and H325) exhibited the same behavior, and thus have the same maintenance and user costs, so the two on the poor subgrade (p L324, H325) were eliminated from further testing. The high standard design generally requires more maintenance than the low due to its traffic volume, while the improperly designed roads on the 3.5 percent CBR's (p L334, H335), not surprisingly, require more still. The final set of maintenance policies is given and discussed in Section C.21.

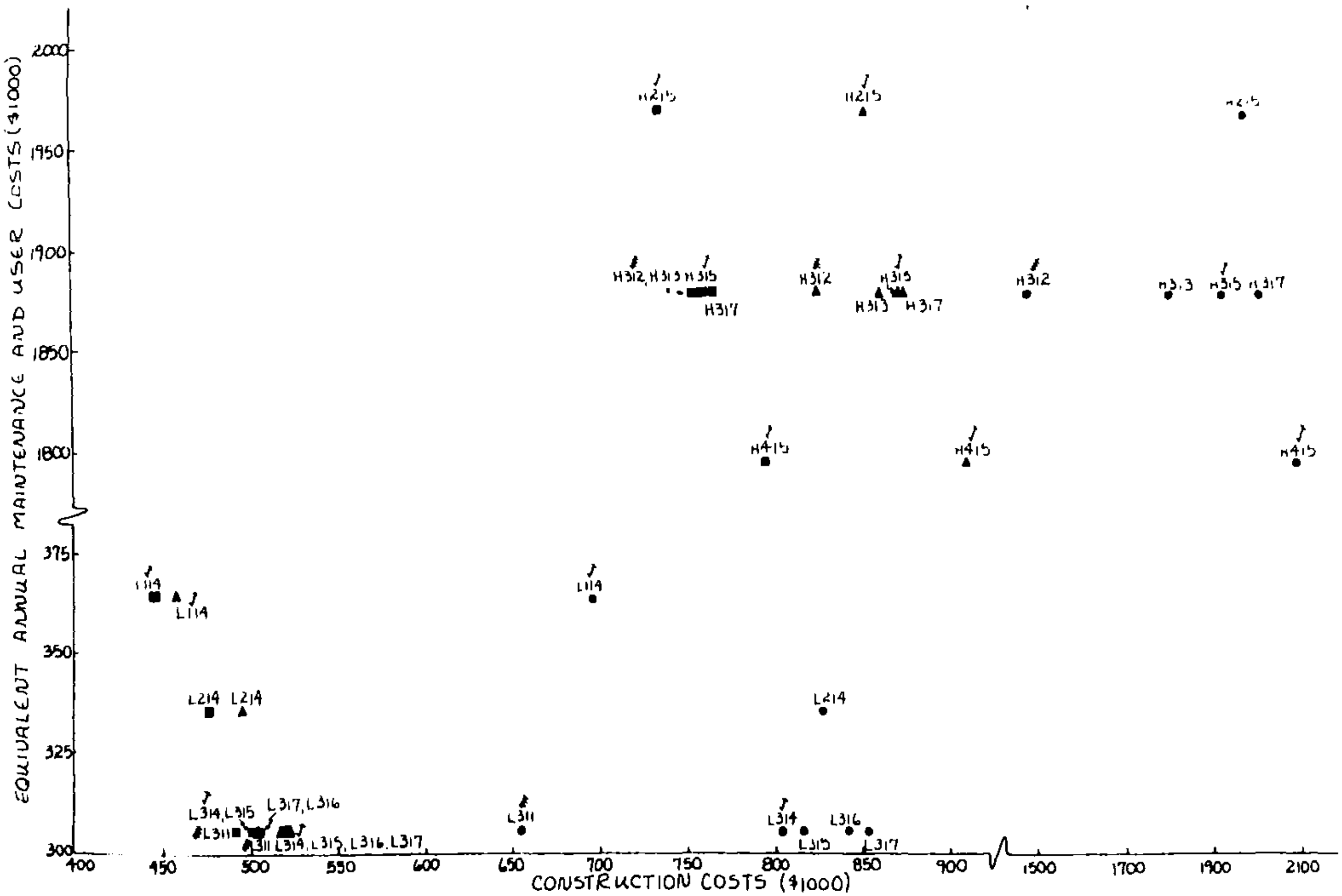
Unit costs of each maintenance activity in the various policies is also needed. With the help of such sources as maintenance studies (34, 35), studies of alternative design standards (36, 59), and engineering texts (31), one or more sets of productivity data, generally in a crew format with materials requirements specified as well, are found for each maintenance activity. These are then priced at 1974, using equipment rental rates (54, 113), along with the labor and materials costs used in the construction phase of the study. Using the FHWA highway maintenance and operation cost index (68, 102), these prices can be indexed back to 1930. An indexing factor is also derived for developing conditions, on the basis of the relative trends exhibited in the stage-level construction costs and a comparison of Ethiopian (55) and U.S. maintenance costs. Table C.2 contains the full set of maintenance unit costs.

Vehicle characteristics, costs, and utilization constitute the final set of data needed for the project-level analysis. As in the case of maintenance policies, one set of vehicle characteristics and utilization data is used, although costs are required for all price periods. Four vehicle types, a car, a single-unit truck, and two semi-trailer combinations, are selected on the basis of their representativeness of the range of vehicles and the availability of data. The basic data required consists, for example, of fuel type, brake horsepower, maximum load, annual utilization in hours, and normal life in years; cost data is needed for such items as tires, insurance, registration, maintenance labor, and drivers. The primary sources for this data include Winfrey (115), Anderson, et al (61), Claffey (60), U.S. Federal Highway Administration (99), U.S. Bureau of Labor Statistics (94), and U.S. Interstate Commerce Commission (106). By and large, the 1974 cost data is readily available from these sources, although the U.S. Bureau of Labor Statistics labor wage and wholesale price indexes (91) are occasionally needed to update items. Since the HCM does not consider congestion or accidents, these items are ignored, as are overhead costs and value of time savings due to a lack of data. Unit costs at 1930 are generally 1974 prices indexed back with various sections of the U.S. Bureau of Labor Statistics wholesale and consumer price indexes (90, 91), except for labor costs which are handled more directly by means of a U.S. Bureau of Labor Statistics bulletin (95). As for developing countries' prices, vehicle cost figures are developed in line with the set of economic conditions used in the construction cost phase, keeping in mind the vehicle information that is available in a few developing country case studies (10, 55, 62, 64). Fur further details on the vehicle characteristics, utilization, and cost data used in the analysis, see Section C.22.

3.23 Alternative Projects and Their Costs

Combining the project quantities with the unit costs of the least-cost technical packages for various technology and price periods and the various maintenance and user cost data via the HCM for the appropriate price periods yields the project-level results, as given in Table C.5, for each project under various technology and price conditions. As an initial step in the analysis of the interaction of design and technology in highway construction and use, Figure 3.4 presents a graphical representation of some of these results. For each project and each technology period, the maintenance and user costs incurred over the life of the project, expressed in terms of equivalent annual costs, are plotted against the construction costs. As these are value rather than quantity-based measures, various economic conditions need to be considered; 1974 and 1930 costs are used to represent U.S. conditions over the period of interest, while developing conditions are used to broaden the analysis and to indicate the sensitivity of the results to economic conditions. In developing equivalent annual maintenance and user costs, a discount rate is required; with the help of the Federal Reserve Bulletin (26), one which is roughly representative of the rate at which long-term bonds are floated is estimated for the three price conditions.

Figure 3.4a: Construction costs and lifetime maintenance and user costs, expressed in equivalent annual cost terms, of each project/technology combination at each design standard/traffic volume, for all project groups and all technology periods, at the prices of 1974 (source: Table C.5).

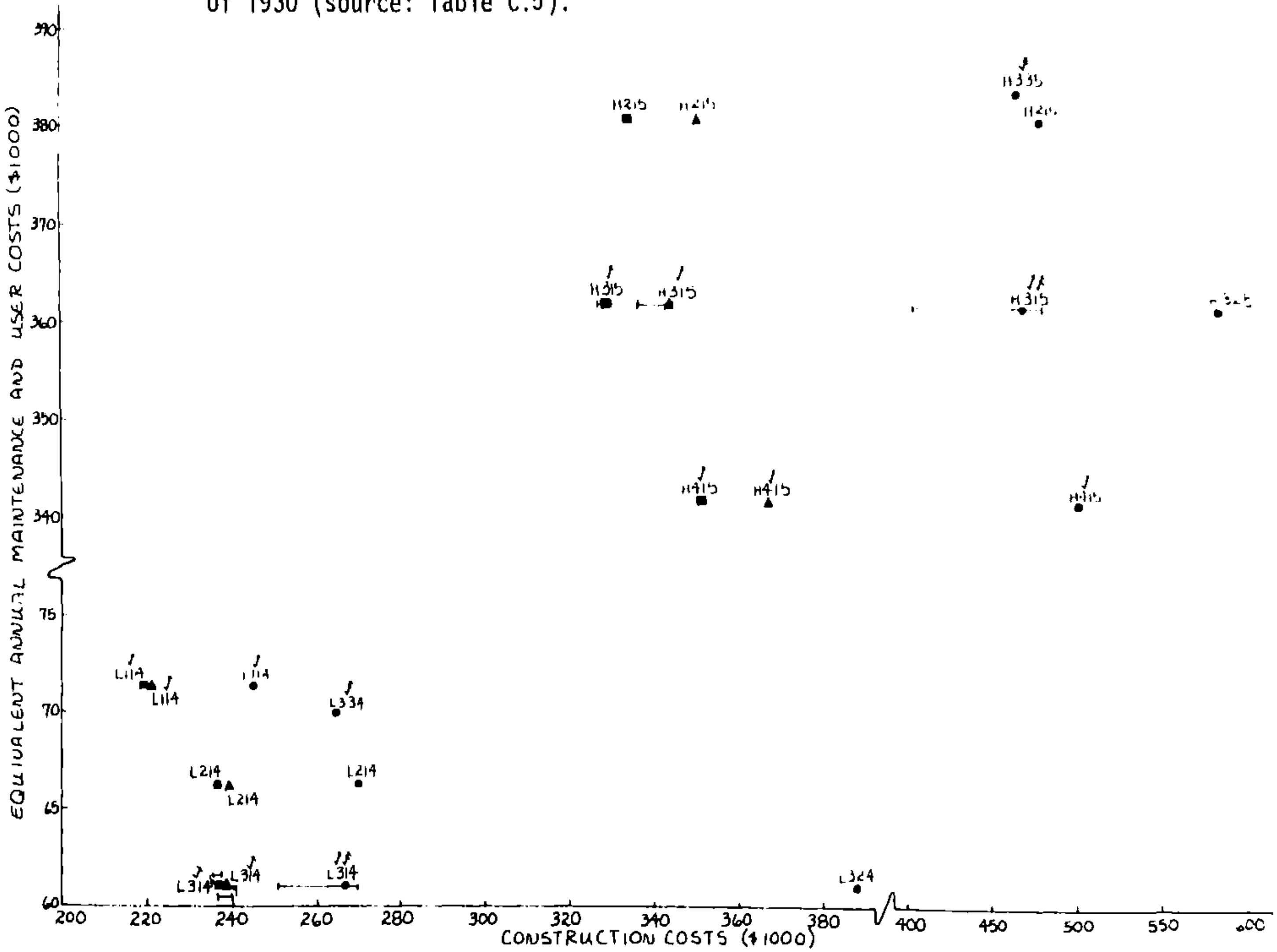


(Figure 3.4a continued)

Note: Technology periods: ● 1920, ▲ 1950, ■ 1970.

√ Indicates an efficient project alternative, for a particular project group (√ surface materials; √ excavation/hauling scenarios), design standard, and technology period.

Figure 3.4b: Construction costs and lifetime maintenance and user costs, expressed in equivalent annual cost terms, of each project/technology combination at each design standard/traffic volume, for all project groups and all technology periods, at the prices of 1930 (source: Table C.5).



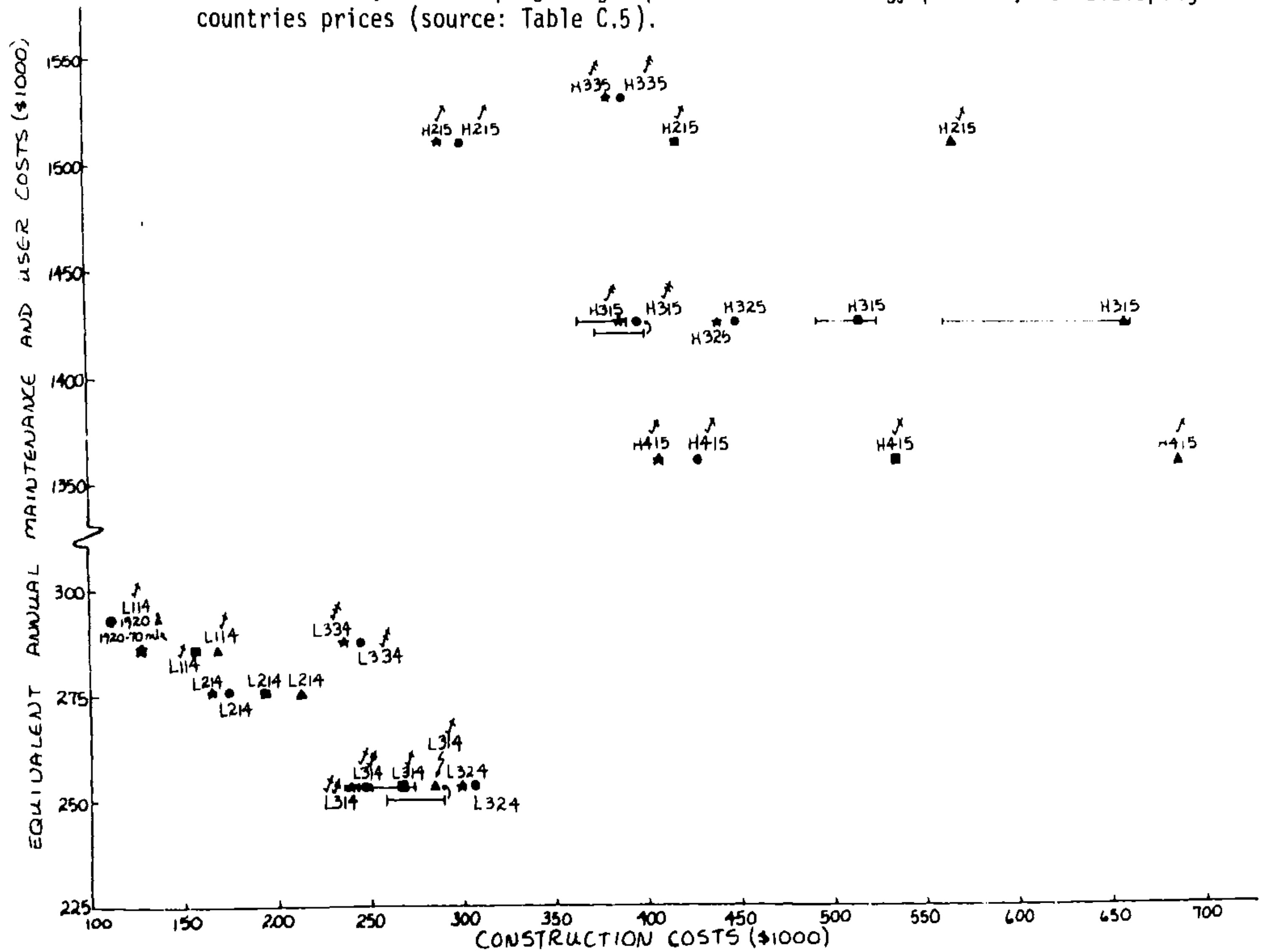
(Figure 3.4b continued)

<u>Note</u>: Technology periods: ● 1920, ▲ 1950, ■ 1970.

✓ Indicates an efficient project alternative, for a particular project group (✓̸ surface materials; ✓̸̸ subgrade strength/surface design), design standard, and technology period.

⊢—⊣ Indicates the range of construction costs of the alternative excavation/hauling scenarios, for a particular design standard and technology period.

Figure 3.4c: Construction costs and lifetime maintenance and user costs, expressed in equivalent annual cost terms, of each project/technology combination at each design standard/traffic volume, for all project groups and all technology periods, at developing countries prices (source: Table C.5).



(Figure 3.4c continued)

Note: Technology periods: ● 1920, ▲ 1950, ■ 1970, ★ 1920-70 mix.

✓ Indicates an efficient project alternative, for a particular project group (✓* surface materials; ✓* subgrade strength/surface design), design standard, and technology period.

⊢—⊣ Indicates the range of construction costs of the alternative excavation/hauling scenarios, for a particular design standard and technology period.

In the developing conditions case (Figure 3.4c), four technologies are indicated, where the fourth is a combination of the least-cost technical packages of all three technology periods (only the 1920's and 1970's actually contribute to the set [see Table 3.10]), and is thus the overall least-cost set of packages for developing conditions. In the 1974 and 1930 cases (Figures 3.4a and 3.4b, respectively), the 1970's technical packages are least-cost over those of all technology periods. It might also be observed that the alternative subgrade strength/surface design projects (p L314, L324, L334, H315, H325, H335) appear only at 1930 and developing prices, since at 1974 prices the least-cost 1920's technical package which compacts to 98 percent (tp 32) is actually less costly than is the package which compacts to only 93 percent (tp 31*); the difference between the 1930 and 1974 cases likely arises as a result of the relative capital intensities of the two packages. Finally, maintenance and user costs do not vary over the various excavation/hauling scenarios at a single design standard (p L311, L314, L315, L316, L317 and p H312, H313, H315, H317), and thus in the 1930 and developing cases, only the range of construction costs of these projects is given at the appropriate maintenance and user cost level. Such a pictorial representation as these graphs is useful in terms of developing a general feeling of how the technologies and designs interact in the various project groups. Moreover, these graphs are in essence production isoquants, depicting the trade-off

*See footnote to Table 3.10.

between current and future expenditures in highway construction and use resulting from the design and technology mix; check marks by the project numbers indicate those combinations which are efficient in each group of projects at each design standard, for each technology period and over all periods.

Somewhat in line with the stage-level analysis, the next step consists of narrowing the sets of efficient projects to the least-cost sets under various price conditions. In order to further investigate the trade-offs among the various components of total project costs, the least-cost projects are thus identified for each of several cost items as appropriate; these include: (1) partial construction costs, which include only the cost of labor and capital used in construction, although site preparation materials (amounting to, at most, 4 percent of this cost item) are also included in the few cases where the site preparation packages use them; (2) total construction costs, including the cost of labor, capital, materials, and overhead and profit for all stages of construction except minor and major structures; (3) maintenance costs incurred over the life of the project, expressed in net present value terms using the same discount rate as above; (4) user costs incurred over the life of the project, similarly expressed; and (5) total project costs, the sum of the last three items. The results of this analysis for each project group and design standard are presented in Table 3.11 for the various price and technology periods; as previously, least-cost is defined as including all projects within 10 percent of the least-cost one.

Table 3.11a: Least-cost projects at each design standard from among the surface materials alternatives, under various technology and price conditions, for the various cost components (source: Table C.5).

Design Standard/ Price Period/ Technology Period	Construction Costs		Operation Costs[b]		Total Project Costs[b]
	Partial[a]	Total	Maintenance	User	
Low Standard Design					
1930 Prices					
1920	L114	L114,L314,L214	L314	L314,L214	L314,L214,L114
1950	L114	L114,L314,L214	L314	L314,L214	L314,L214
1970	L114,L314	L114,L214,L314	L314	L314,L214	L314,L214
overall[c]	L114,L314 @ 1970	L114,L214,L314 @ 1970,50	-	-	L314,L214 @ 1970,50,20
1974 Prices					
1920	L114	L114	L314	L314,L214	L314,L214
1950	L114	L114,L214	L314	L314,L214	L314,L214
1970	L114,L314	L114,L214	L314	L314,L214	L314,L214
overall[c]	L114,L314 @ 1970	L114 @ 1970,50 L214 @ 1970	-	-	L314@1970,50,20 L214@1970,50
Developing Prices					
1920	L114	L114	L314	L314,L214	L314,L214,L114
1950	L114,L314	L114	L314	L314,L214	L314,L214,L114
1970	L114,L314	L114	L314	L314,L214	L314,L214,L114
1920-70 mix	L114	L114	L314	L314,L214	L314,L214,L114
overall[c]	L114@mix,1920	L114@mix,1920	-	-	L314,L214,L114 @mix,1920,70,50

(Table 3.11a continued)

Design Standard/ Price Period/ Technology Period/	Construction Costs		Operation Costs[b]		Total Project Costs[b]
	Partial[a]	Total	Maintenance	User	
High Standard Design					
1930 Prices					
1920	H315,H215,H415	H315,H215,H415	H415	H415,H315,H215	H415,H315,H215
1950	H315,H215	H315,H215,H415	H415	H415,H315,H215	H415,H315,H215
1970	H315	H315,H215,H415	H415	H415,H315,H215	H415,H315,H215
overall[c]	H315 @ 1970	H315,H215 @ 1970,50 H415 @ 1970	-	-	H415,H315 @ 1970,50,20 H215 @ 1970,50
1974 Prices					
1920	H315,H215,H415	H315,H215,H415	H415	H415,H315,H215	H415,H315,H215
1950	H315,H215	H215,H315,H415	H415	H415,H315,H215	H415,H315,H215
1970	H315	H215,H315,H415	H415	H415,H315,H215	H415,H315,H215
overall[c]	H315 @ 1970	H215,H315,H415 @ 1970	-	-	H415 @ 1970,50,20 H315,H215 @ 1970,50
Developing Prices					
1920	H315	H215	H415	H415,H315,H215	H415,H315,H215
1950	H315,H215,H415	H215	H415	H415,H315,H215	H415,H315,H215
1970	H315,H215,H415	H215	H415	H415,H315,H215	H415,H315,H215
1920-70 mix	H315	H215	H415	H415,H315,H215	H415,H315,H215
overall[c]	H315 @ mix,1920	H215 @ mix,1920	-	-	H415,H315 @ mix, 1920,70,50 H215 @ mix,1920

(Table 3.11a continued)

<u>Note</u>: Least-cost includes those projects within 10 percent of the least-cost project, the order of the listing being from the lowest to highest in cost.

[a]Include cost of labor and capital used in construction, although site preparation materials ($\leq$ 4% of this cost item) are also included in the few cases where they are used.

[b]Expressed in net present value terms, the discount rate varying with the price period.

[c]Looking across all technology periods, for a particular price period and cost component, this is the least-cost set of project/technology combinations.

Table 3.11b: Least-cost projects at each design standard from among the subgrade strength/surface design alternatives, under various technology and price conditions, for the various cost components (source: Table C.5).

Design Standard/ Price Period/ Technology Period	Construction Costs		Operation Costs[b]		Total Project Costs[b]
	Partial[a]	Total	Maintenance	User	
Low Standard Design					
1930 Prices					
1920	L334,L314,L324	L334,L314	L314,L324	L314,L324,L334	L314,L334
Developing Prices					
1920	L334,L324,L314	L334,L314	L314,L324	L314,L324,L334	L314,L324
1920-70 mix	L334,L324,L314	L334,L314	L314,L324	L314,L324,L334	L314,L324
overall[c]	L334,L324,L314 @ mix	L334,L314 @mix,1920	-	-	L314,L324 @ mix, 1920
High Standard Design					
1930 Prices					
1920	H335,H325,H315	H335,H315	H315,H325	H315,H325,H335	H315,H325,H335
Developing Prices					
1920	H335,H325,H315	H335,H315	H315,H325	H315,H325,H335	H315,H325,H335
1920-70 mix	H335,H325,H315	H335,H315	H315,H325	H315,H325,H335	H315,H325,H335
overall[c]	H335 @mix,1920 H325,H315 @ mix	H335,H315 @mix,1920	-	-	H315,H325,H335 @ mix, 1920

Note: See note and footnotes in Table 3.11a. The 93% compaction case (i.e., CBR of 3.5%) is only considered for the horse-drawn roller in the 1920's, as the powered rollers are able to achieve 98% compaction (i.e., CBR of 7.0%) with relative ease; at the prices of 1974 the horse-drawn roller, even at 93% compaction, cannot compete in unit cost terms with the powered roller at 98% compaction.

Table 3.11c: Least-cost projects at each design standard from among the alternative excavation/hauling scenarios, under various technology and price conditions, for the various cost components (source: Table C.5).

Design Standard/ Price Period/ Technology Period	Construction Costs		Total Project Costs[b]
	Partial[a]	Total	
Low Standard Design			
1930 Prices			
1920	L311	L311,L314,L315,L316,L317	L311,L314,L315,L316,L317
1950	L311	L311,L314,L315,L316,L317	L311,L314,L315,L316,L317
1970	L311	L311,L314,L315,L317,L316	L311,L314,L315,L317,L316
overall[c]	L311 @ 1970	L311 @ 1970,50,20 L314,L315,L317,L316 @ 1970,50	L311,L314,L315,L317,L316 @ 1970,50,20
1974 Prices			
1920	L311	L311	L311,L314,L315,L316,L317
1950	L311	L311,L314,L315,L316,L317	L311,L314,L315,L316,L317
1970	L311	L311,L314,L315,L317,L316	L311,L314,L315,L317,L316
overall[c]	L311 @ 1970	L311,L314,L315,L317,L316 @ 1970,50	L311,L314,L315@1970,50,20 L317,L316 @ 1970,50
Developing Prices			
1920	L311,L314,L315	L311,L314,L315,L316,L317	L311,L314,L315,L316,L317
1950	L311	L311,L314	L311,L314,L315,L316,L317
1970	L311	L311,L314,L315,L317,L316	L311,L314,L315,L317,L316
1920-70 mix	L311,L314	L311,L314,L315,L316,L317	L311,L314,L315,L316,L317
overall[c]	L311,L314 @ mix	L311 @ mix,1920,70,50 L314,L315,L316,L317 @ mix,1920	L311,L314,L315,L316,L317 @ mix,1920,70,50

(Table 3.11c continued)

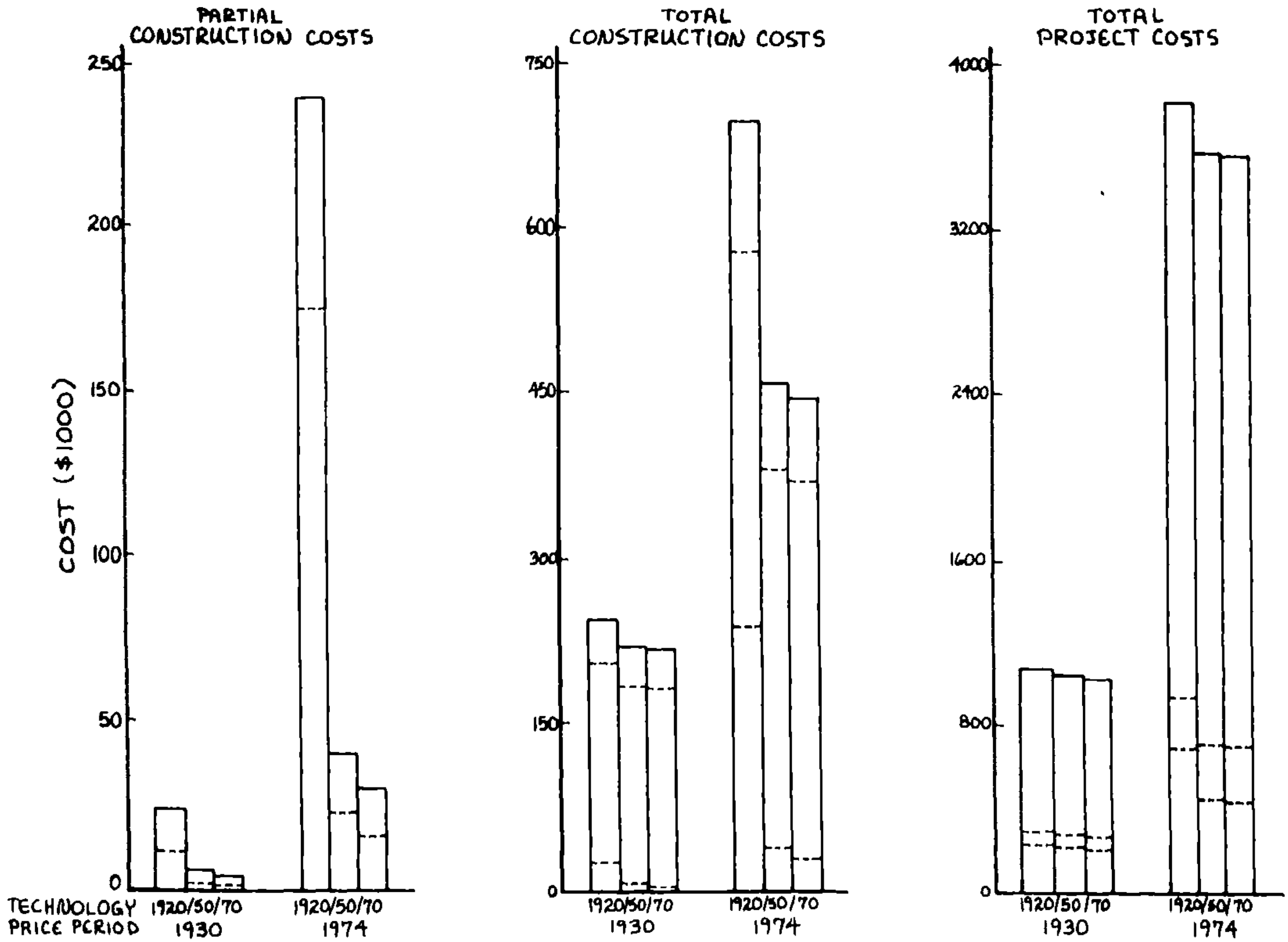
Design Standard/ Price Period/ Technology Period	Construction Costs		Total Project Costs[b]
	Partial[a]	Total	
High Standard Design			
1930 Prices			
1920	H312	H312	H312,H313,H315,H317
1950	H312	H312,H313,H315,H317	H312,H313,H315,H317
1970	H312,H313,H315	H312,H313,H315,H317	H312,H313,H315,H317
overall[c]	H312,H313,H315 @ 1970	H312,H313,H315,H317 @ 1970,50	H312,H313,H315,H317 @ 1970,50,20
1974 Prices			
1920	H312	H312	H312,H313,H315,H317
1950	H312	H312,H313,H315,H317	H312,H313,H315,H317
1970	H312,H313,H315,H317	H312,H313,H315,H317	H312,H313,H315,H317
overall[c]	H312,H313,H315, H317 @ 1970	H312 @ 1970,50 H313,H315,H317 @ 1970	H312,H313,H315,H317 @ 1970,50,20
Developing Prices			
1920	H312	H312,H315,H313,H317	H312,H315,H313,H317
1950	H312	H312	H312,H313,H315,H317
1970	H312,H313	H312,H313,H315,H317	H312,H313,H315,H317
1920-70 mix	H312	H312,H315,H313,H317	H312,H315,H313,H317
overall[c]	H312 @ mix	H312,H315,H313,H317 @ mix, 1920	H312,H315,H313,H317 @ mix, 1920,70,50

Note: See note and footnotes in Table 3.11a. Variation of the excavation/hauling scenario affects only construction costs; maintenance and user costs are thus not included separately in the table,as they are the same across all projects at a particular design standard.

Figure 3.5 is presented to give some indication of the relative magnitudes of these various cost items for a couple of projects under various price and technology conditions over time in the U.S. For a low standard, gravel surfaced road (p L114) and a high standard, double bituminous surface treated road (p H315), then, the partial construction, total construction, and total project costs are plotted with their various component parts indicated. The construction cost items vary with the technology and price period, while all other costs vary only with the price period. It might also be noted that, much as in Figure 3.2 in the stage-level analysis, this figure indicates the transition in costs that actually occurred, as well as that which would have occurred had construction technology not changed as it did, although in this case maintenance and transport technology are still assumed constant at the level of today. It should also be remembered that partial construction costs represent only best-practice technical packages, accounting in part for their rather small share of total construction costs.

This completes the presentation of the project-level results; further discussion of these results and their implications, as well as the limitations of the analysis, is taken up in Chapter 4.

Figure 3.5a: Various components of project costs for a low standard, gravel road (p L114), under various technology and price conditions (source: Table C.5).



(Figure 3.5a continued)

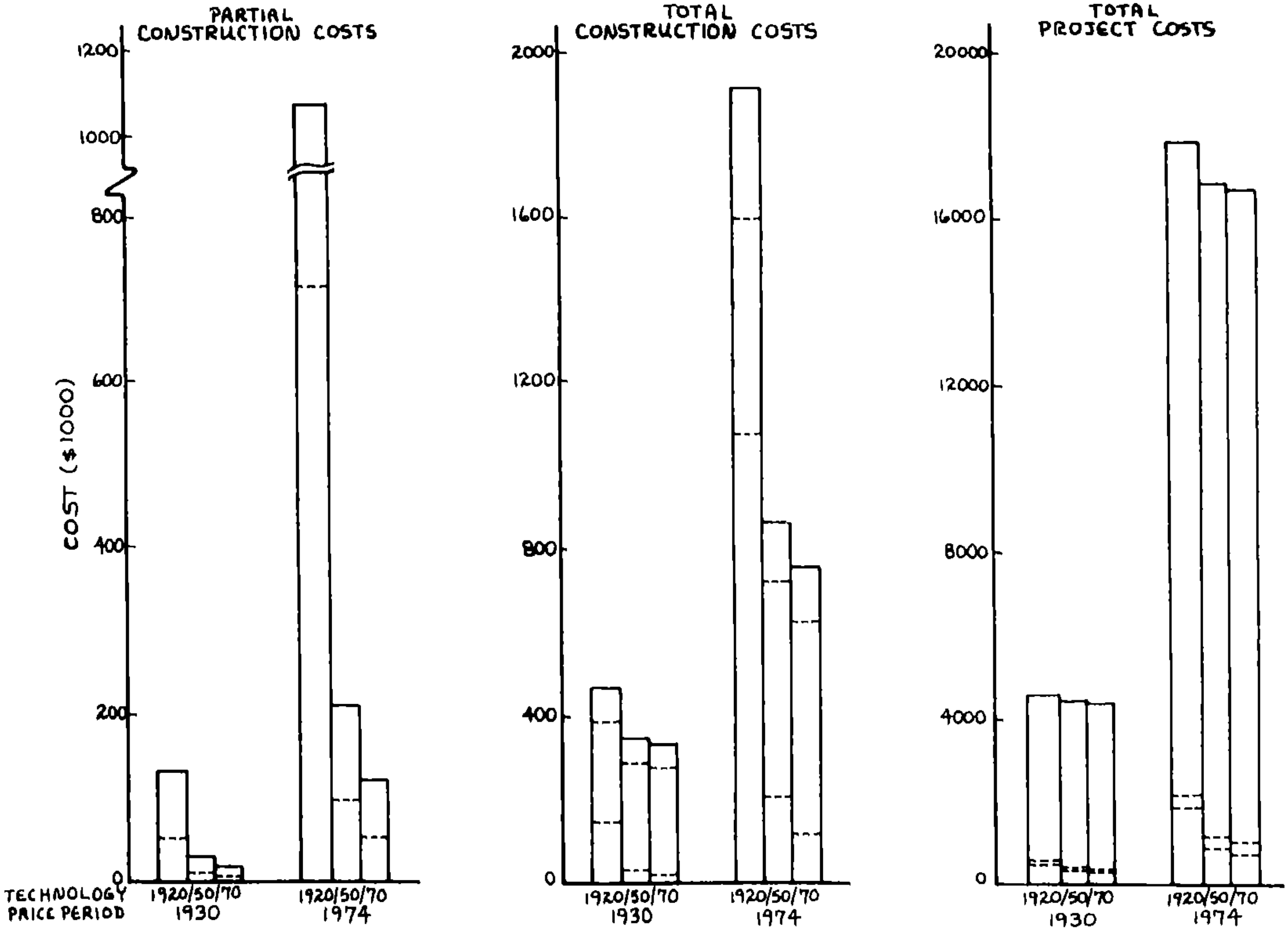
<u>Note</u>:

Partial construction costs: The lower portion of the bar chart represents the cost of labor and the upper portion that of capital, although site preparation materials ($\leq$ 4% of partial construction costs) are also included here in the few cases (1970's technology) where they are used.

Total construction costs: The lower portion of the bar chart represents the cost of labor and capital, the middle portion that of materials and the upper portion that of overhead and profit.

Total project costs: The lower portion of the bar chart represents the total cost of construction, while the middle and upper portions respectively represent the maintenance and user costs incurred over the life of the project; these two latter costs are expressed in net present value terms, the discount rate varying with the price period.

Figure 3.5b: Various components of project costs for a high standard, double bituminous surface treated road on a gravel base (p H315), under various technology and price conditions (source: Table C.5).



Note: See note in Figure 3.5a.

CHAPTER 4

DISCUSSION OF THE RESULTS

In much the same way that Chapter 3 presents the results, this chapter discusses them, devoting one section to the stage and one to the project-level analysis. Section 4.1 focuses on the change in highway construction technology over time and its implications for the future; in the course of the discussion, changes in the nature of the technical packages, the various sets of efficient technical packages, and the role of efficiency and substitution in technology change are considered and evaluated. Section 4.2 then focuses on the interaction of design and technology in highway construction and use; projects involving various surfacing materials, subgrade strengths, and methods of borrowing earthwork materials are considered and compared within their respective groups, accompanied by a discussion of the limitations of the analysis and implications of the results.

4.1 Change in Highway Construction Technology Over Time

In the analysis of technology change in highway construction, the first logical step is a qualitative investigation of how the technical packages, in terms of the resources constituting them, have changed (see Table 3.1 and Figure 3.1; Tables B.1 and B.2 might also be helpful). In the 1920's, small capacity, unpowered equipment operated largely by unskilled laborers with horses or mules as a source of power and a few skilled men acting in a supervisory role is most common, while in the

1950's the use of much larger capacity, powered equipment operated largely by skilled laborers with occasional unskilled assistants is the rule. The transition to the 1970's is not so great, primarily involving the introduction of still more powerful, larger capacity equipment as well as a few new types.

Both relatively labor-intensive (tp 11) and capital-intensive (tp 21, 31) technical packages exist for site preparation in all periods. Information on site preparation for highways is sparse, however, necessitating some limited use of data pertaining to building construction and road maintenance, particularly for the labor-intensive packages in the 1950's and 1970's; this perhaps, in part at least, explains their poor performance relative to that of the 1920's. As for the capital-intensive packages, that of the 1920's is replaced by larger bulldozers and/or additional items of equipment in the 1950's and 1970's, with significant decreases in investment and relatively small, if any, decreases in labor.

The progression of technology is well demonstrated by the technical packages for excavation/hauling, the stage of construction which seems to have received the most attention in the literature. The technical packages of the 1920's represent a broad range of capital/labor ratios, from the highly labor-intensive handtools (tp 1-1, 1-2, 2-1, 2-2, 3-1, 3-2) through the horse-drawn scrapers (tp 4-3, 5-4, 6-5) and the horse or tractor-drawn elevating graders (tp 8-7, 9-7) to the highly capital-intensive bulldozers (tp 7-6) and power shovels (tp 10-7, 10-8, 10-9). In the 1950's and 1970's the span of capital/labor ratios is practically reduced to a single value, with the 1970's generally being somewhat more capital-intensive than the 1950's. The 0.2 to 0.5 cubic yard, horse-drawn scrapers (tp 4-3, 5-4, 6-5) of the 1920's are replaced by 6 to 15 cubic yard, power-driven scrapers (tp 5-5, 6-6, 7-7) in the 1950's, with a significant decrease in labor and some to no increase in investment (with increasing haul distance); 20 to 30 cubic yard scrapers (tp 9-12, 10-13) and 11.5 to 21.5 cubic yard elevating scrapers (tp 7-10, 8-11) take over in the 1970's, with decreases in both labor and investment. With a significant decrease in labor and a slight increase to a decrease in investment (with increasing haul distance), the larger 1950's elevating graders (tp 4-2, 4-4) replace those (tp 8-7, 9-7) of the 1920's; in the 1970's 1.75 to 5 cubic yard front end loaders (tp 4-1, 4-2, 4-7, 5-3, 5-5, 5-8, 6-4, 6-6, 6-9) come into being. Finally, the 60 horsepower bulldozer (tp 7-6) and 0.75 cubic yard power shovel (tp 10-7, 10-8, 10-9) of the 1920's are replaced by successively largerpieces in the 1950's (tp 8-8, 9-9, 10-10, 1-1, 1-2, 1-3, 1-4, 2-1, 2-2, 2-3, 2-4, 3-1, 3-2, 3-3, 3-4) and 1970's (tp 11-14, 12-15, 13-16, 1-1, 1-2, 2-3, 2-5, 3-4, 3-6), with decreases generally in both labor and investment. It might also be noted that, with the exception of the more capital-intensive technical packages, the labor force of the 1920's is largely unskilled with skilled men acting in a supervisory capacity, while that of the 1950's and 1970's is fully skilled.

In the above discussion, the piece of excavation equipment has been used as an identifier of the excavation/hauling technical package, and for those packages where the haul equipment is a separate item, it, too, has changed in much the same way; thus, the hand-powered equipment, 1.5 cubic yard, horse-drawn wagons, 5.0 cubic yard, tractor-drawn wagons, and 3.5 ton trucks of the 1920's are replaced by 8.5 to 15 bank cubic yard, tractor-drawn wagons and 10 to 20 ton trucks in the 1950's and 15 to 27 bank cubic yard wagons and 10 to 35 ton trucks in the 1970's. The impact of the haul vehicle on the performance of the overall package is naturally much greater at the longer haul distances; only in the case of front end loaders, however, does the haul mode seem to have a generally significant effect, in that they perform well doing their own haul for short distances but absolutely require a separate haul vehicle for long distances.

With the exception of the material being used, spreading/compaction and gravel surfacing are very similar stages in that they involve the same basic activities and technical packages, and they can thus be discussed together. The set of technical packages available is not so diversified as is that for excavation/hauling, and the two major activities, spread and compact, are pretty much independent, with the result that the equipment in neither really dominates the performance of the technical packages (as does the excavation equipment in excavation/hauling). As in the case of excavation/hauling, the 1920's technical packages span a broad range of capital/labor ratios, while those of the 1950's and 1970's fall within a very narrow range, the 1970's being noticeably more capital-intensive than the 1950's.

The handtools (spr/comp tp 11, 12; gravel tp 11, 12), horse-drawn blade graders (spr/comp tp 21, 22; gravel tp 21, 22), and tractor-drawn blade graders (spr/comp tp 32) of the 1920's are replaced by self-powered blade graders (spr/comp tp 31, 32, 33, 34, 41, 42, 43, 44; gravel tp 31, 32, 41, 42), bulldozers (spr/comp tp 11, 12, 13, 14, 21, 22, 23, 24; gravel tp 11, 12, 21, 22), and spreaders (gravel tp 51, 52) in the 1950's and again in the 1970's by somewhat larger and more powerful pieces, each time with some drop in labor but only a small, if any, drop in investment across similar types of spreaders. As for the compacting equipment, heavier versions of existing rollers and new types of rollers are introduced in each period. The 2.5 ton, horse-drawn rollers (spr/comp tp 11, 21; gravel tp 11, 21) and 6 ton, 3 wheel rollers (spr/comp tp 12, 22, 32; gravel tp 12, 22) of the 1920's are replaced by 8 to 12 ton, 3 wheel rollers (spr/comp tp 13, 23, 33, 43; gravel tp 11, 21, 31, 41, 51), tractor-drawn sheepsfoot rollers (spr/comp tp 11, 12, 21, 22, 31, 32, 41, 42), and 10 ton, pneumatic rollers (spr/comp tp 14, 24, 34, 44; gravel tp 12, 22, 32, 42, 52) in the 1950's, while in the 1970's the same or slightly larger 3 wheel (gravel tp 11, 21, 31, 41, 51), sheepsfoot (spr/comp tp 12, 22, 32, 42), and pneumatic rollers (spr/comp tp 13, 23, 33, 43; gravel tp 12, 22, 32, 42, 52) are used, and self-powered sheepsfoot (spr/comp tp 11, 21, 31, 41) and vibratory rollers (spr/comp tp 14, 24, 34, 44; gravel tp 13, 23, 33, 43, 53) are introduced; the effect of these changes on labor is always a decrease across similar rollers, but that on investment varies from some increase to some decrease, depending upon the particular roller being considered, the overall impression being that investment decreases only slightly if at all. As for the labor, the 1920's tends to be mixed although slightly heavier on the unskilled, while the 1950's and 1970's is skilled except for an occasional unskilled helper. In these two stages, as in the other surfacing stages, the width of the road, as designed in Section 3.2, may be having an effect on the relative performance of technical packages of the 1950's and 1970's which differ only in terms of the size of the spreading equipment; this is not felt to be serious enough, however, to affect the relative performance of various types of spreading and compacting equipment, which is of more interest in any case.

The range of capital/labor ratios for waterbound macadam surfacing is very limited for all three periods. In the 1920's, data for only two technical packages could be found, but these are both considerably more labor-intensive than are those of the 1950's and 1970's; the technical packages for the 1950's fall into two distinct groups depending upon the method of compaction, one being considerably less capital-intensive than the 1970's and the other about the same level of capital intensity. It should be noted that the equipment used in spreading the crushed stone and compacting the surface is the same as that for gravel, except for the 1920's where a heavier roller is used. Waterbound macadam surfacing is that stage of construction which requires a tremendous amount of compaction; it is thus not surprising that the compaction method has a primary influence on the overall behavior of the technical package, resulting in the packages falling into groups around this in the 1950's and around this and the method of spreading screenings in the 1970's. The technical packages of the 1920's involve hand or horse-powered equipment and unskilled men with skilled men as supervisors, with the exception of the 10 ton, 3 wheel roller. The transition to the 1950's involves, in addition to the equipment noted for gravel surfacing, the introduction of a truck-mounted spreader box (in all technical packages) instead of handtools for distributing screenings and the use of mostly skilled labor with unskilled men as assistants; this occurs with significant decreases in both labor and investment. As for the 1970's, the primary change, in addition to those for gravel surfacing, is the introduction of a gas spreader (tp 111, 112, 113, 211, 212, 213, 311, 312, 313, 411, 412, 413, 511, 512, 513) for distributing screenings; corresponding change in labor and investment varies widely with the particular roller and screenings spreader being considered.

As is the case in waterbound macadam surfacing, the range of capital/labor ratios in the double bituminous surface treatment stage is rather narrow for all three periods, the 1920's being considerably more labor-intensive than the 1950's and 1970's, which exhibit about the same level of capital intensity. Although alternative methods are used for the major activities in each period, the set of technical packages in each period is very close in performance, with the primary influence on their behavior coming from the spreading crushed stone and compacting the surface activities. The transition from the 1920's to the 1950's involves going from handtools to a truck-drawn (tp 1111, 1112, 1121, 1122) or self-powered broom (tp 2111, 2112, 2121, 2122), from a 600 gallon to a 1000 gallon bitumen distributor, from handtools (tp 1111) or a spreader box mounted on a 5 ton truck (tp 1121) to a spreader box mounted on a 10 ton truck (tp 1121, 1122, 2121, 2122) or a gas spreader (tp 1111, 1112, 2111, 2112), and from a 6 ton, 3 wheel roller to a 5-8 ton, tandem roller (tp 1111, 1121, 2111, 2121) or 10 ton, pneumatic roller (tp 1112, 1122, 2112, 2122); as for labor, it is quite mixed in both periods, with the 1920's tending toward more unskilled with a few supervisory types and the 1950's tending toward more skilled with some unskilled assistants. Particularly significant in this transition, however, is the sizeable drop in both labor and investment. As for the 1970's, the equipment is basically the same as or slightly larger and more powerful than that of the 1950's, but there is still a noticeable drop in both labor and investment over this period.

4.11 The Efficient Technical Packages

Given this broad overview of the full set of technical packages, it is now useful to narrow this to those which are efficient, those which produce the most output for the least input, for each stage of construction, for each technology period and over all periods. Two basic approaches to such an efficiency analysis, a graphical and a numerical one, are presented in Section 2.31, and their results are presented as Figure 3.1 and Table 3.4 and Table 3.5, respectively, in Section 3.13. Before discussing these results, it is important to look briefly at these two analytic approaches and consider their limitations and sensitivities in the case at hand.

The graphical approach involves plotting the labor and capital components of the various technical packages for each period which are required to produce a given rate or level of output. The first simplification is the omission of materials, since they are the same across all technical packages, with the exception of those for site preparation where their share is small enough to warrant their omission as a third dimension in the graphical analysis. The next difficulty is the units of measurement of the resources. Labor can be measured in physical units of unskilled men or unskilled man-hours, where before the skilled is added to the unskilled component, it is weighted by the skilled to unskilled wage ratio at the time of the technical package; the justification for this is the assumption that the wages reflect, in some sense, the relative quality or productive potential of skilled and unskilled laborers, thus necessitating the use of the wage ratio at the time the technical package itself was in use. The 1920's technical packages are the ones potentially most affected by this assumption, in that the 1930 wage ratio is 1.91 compared with 1.34 and 1.25 for 1956 and 1974, respectively. A comparison of the investment plots in Figure 4.1a, where the wage ratio corresponding to the period of the technology is used, and Figure 4.1b, where the 1974 wage ratio is used for both the 1920's and 1970's technical packages, suggests, moreover, that the 1920's technical packages at the 1974 wage ratio have naturally shifted closer to the 1970's technical packages, but their relative positions remain essentially unchanged, and the set of efficient packages is the same. The impact of the wage ratio on the overall results thus seems relatively minor, and that of the period of the technology is used.

Capital's measurement presents even more of a problem because its heterogeneous nature necessitates the use of value measures rather than

Figure 4.1a: Labor, in unskilled men where the skilled are weighted by the wage ratio at the time of the technology, and capital, in investment costs at 1974, required by each technical package for excavation/hauling at 100 meters at the rate of 100 bank cubic meters per hour, for the 1920's and 1970's technologies (source: Table B.6).

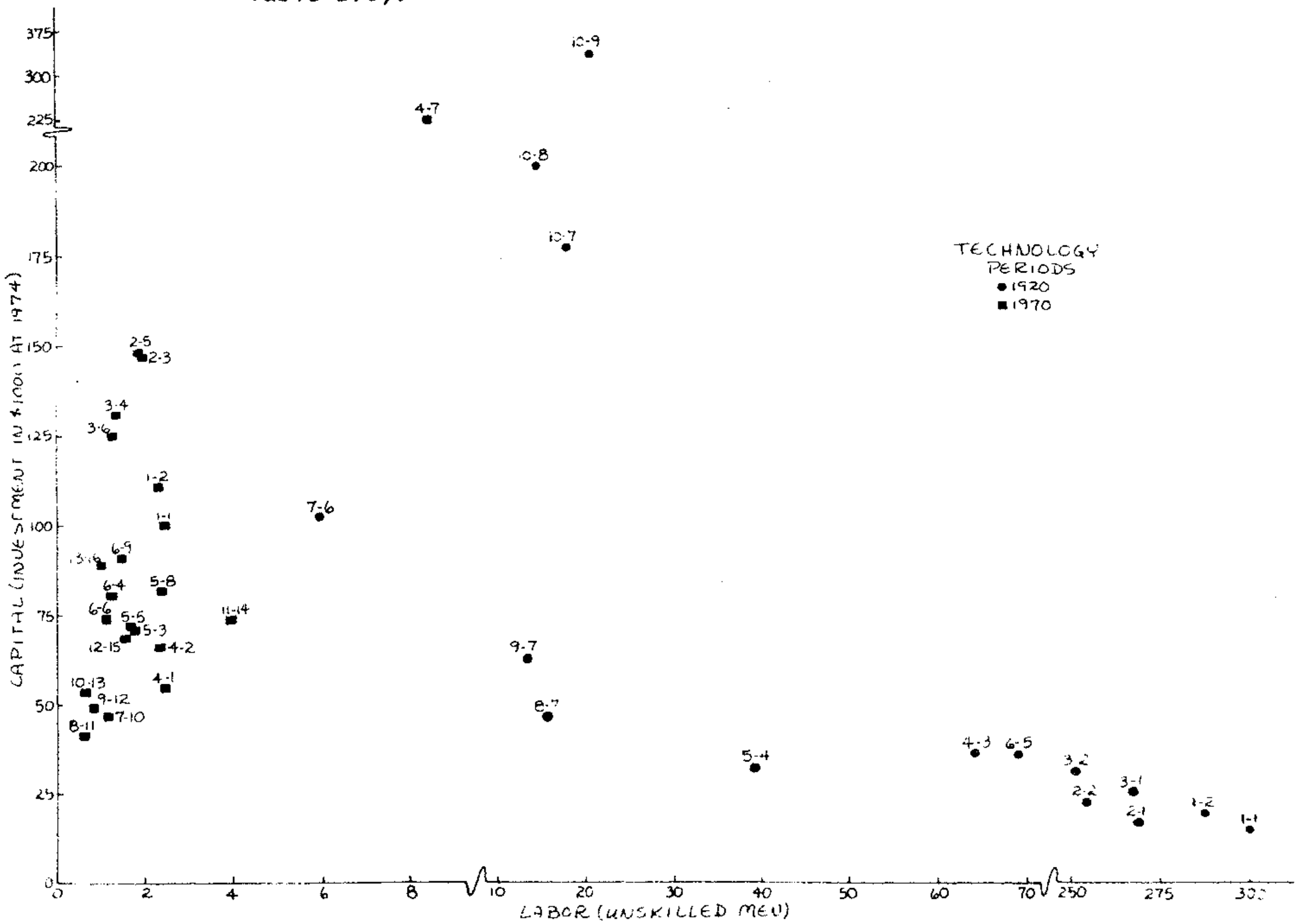


Figure 4.1b: Labor, in unskilled men where the skilled are weighted by the 1974 wage ratio, and capital, in investment costs at 1974, required by each technical package for excavation/hauling at 100 meters at the rate of 100 bank cubic meters per hour, for the 1920's and 1970's technologies (source: Table B.6).

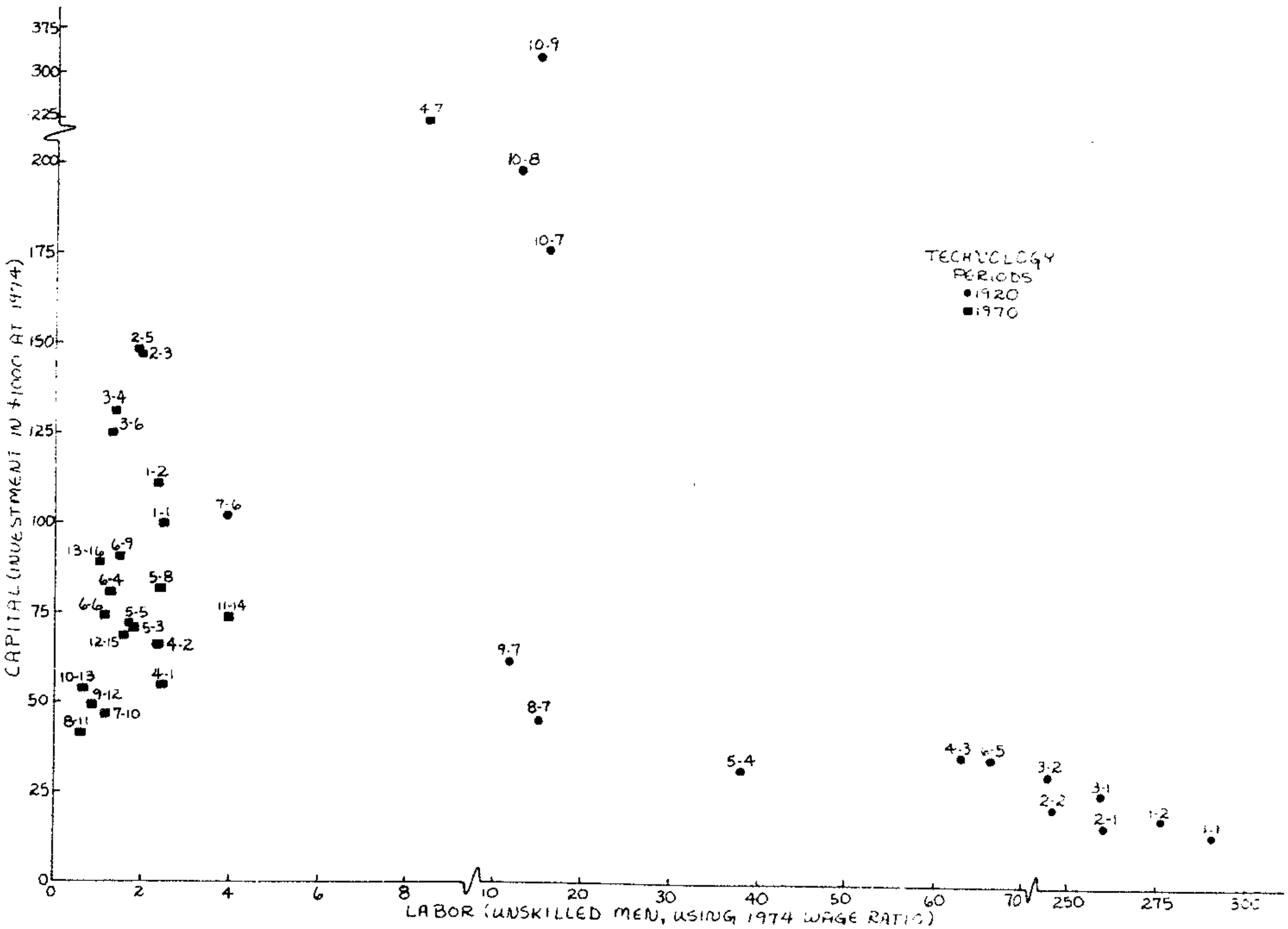


Figure 4.1c: Labor, in unskilled man-hours where the skilled are weighted by the wage ratio at the time of the technology, and capital, in depreciation costs at 1974, required by each technical package for 100 bank cubic meters of excavation/hauling at 100 meters, for the 1920's and 1970's technologies (source: Tables B.6 and B.7).

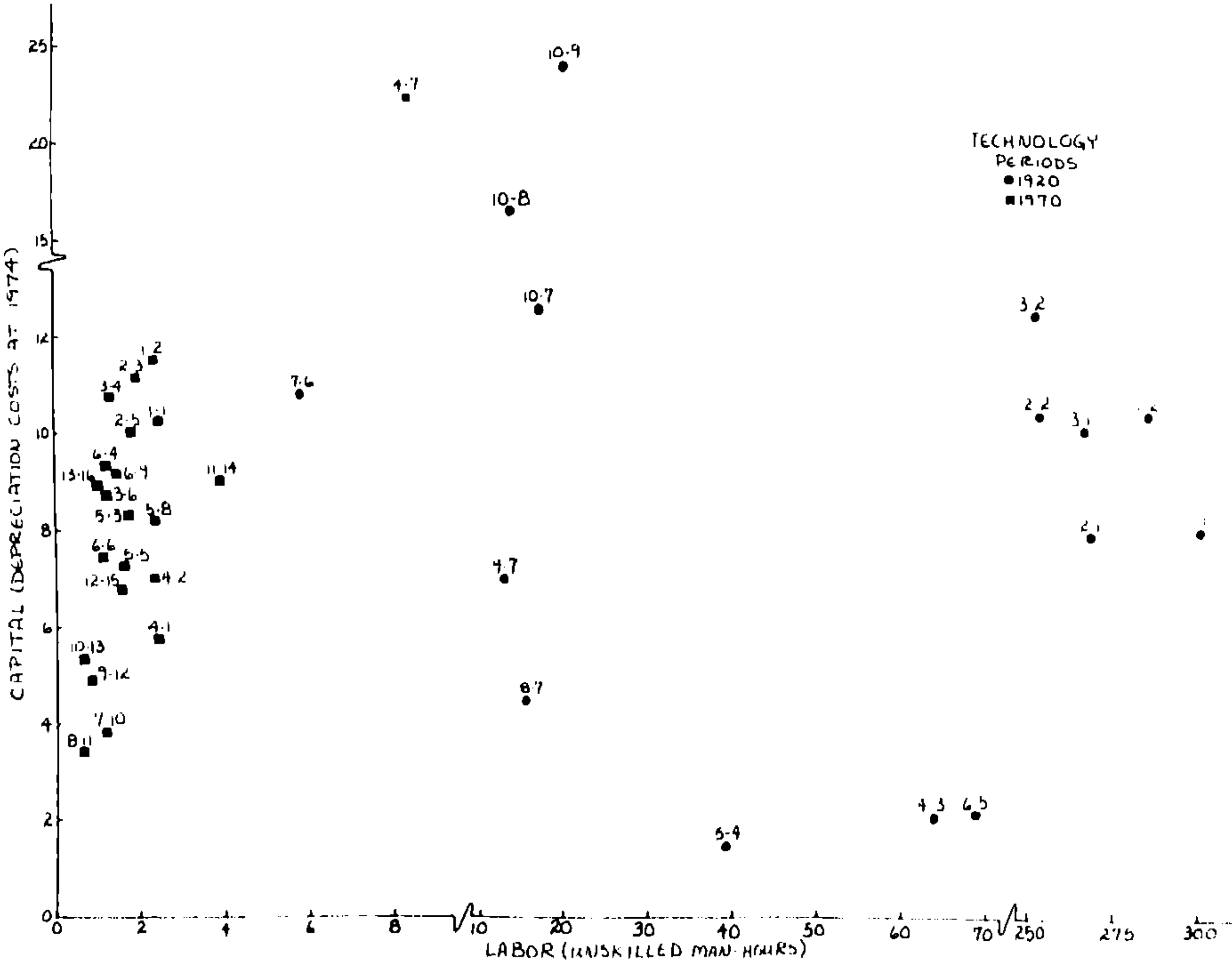


Figure 4.1d: Labor, in unskilled man-hours where the skilled are weighted by the wage ratio at the time of the technology, and capital, in ownership and operating costs at 1974, required by each technical package for 100 bank cubic meters of excavation/hauling at 100 meters, for the 1920's and 1970's technologies (source: Tables B.5 and B.6).

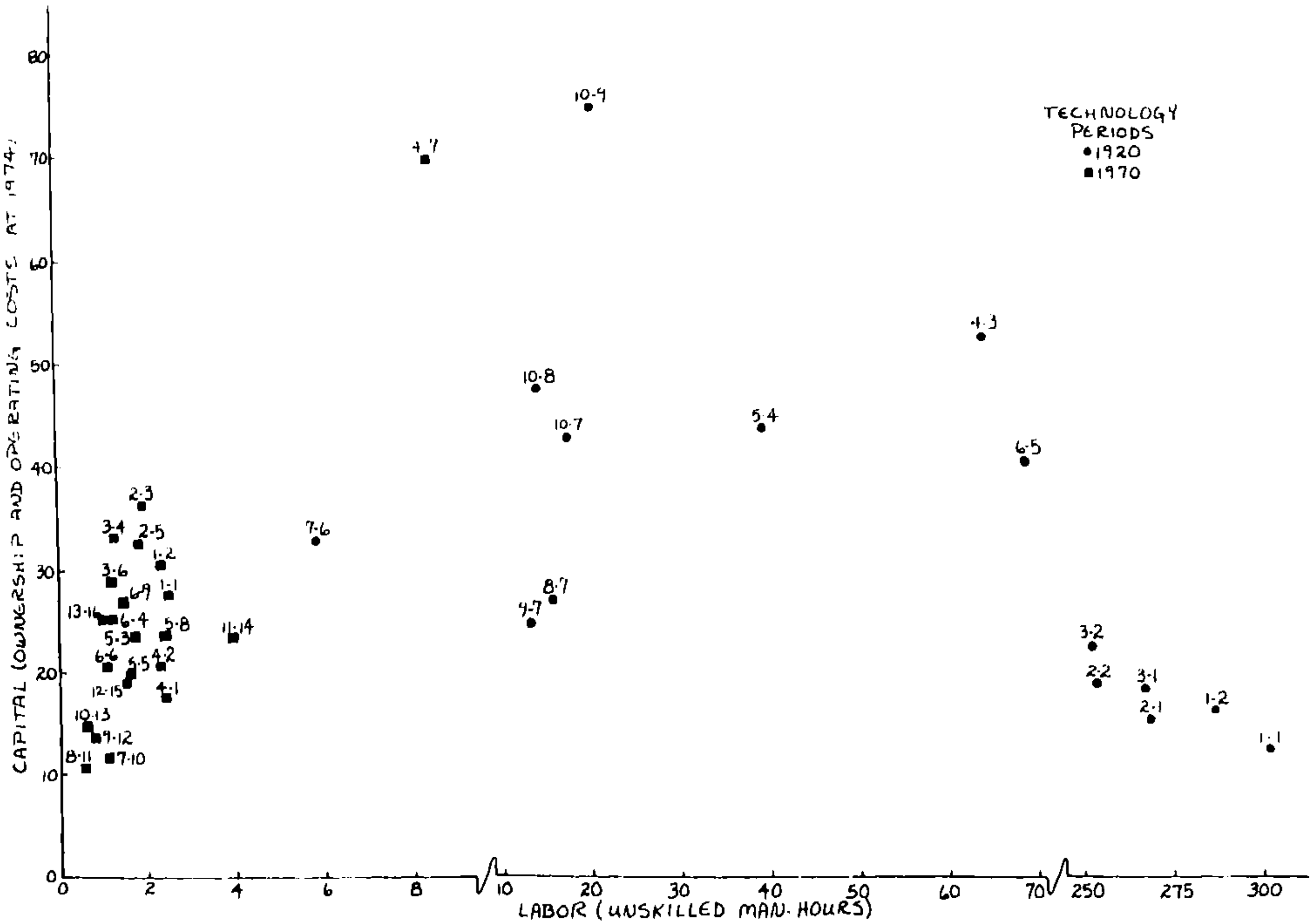


Figure 4.1e: Labor, in unskilled men where the skilled are weighted by the wage ratio at the time of the technology, and capital, in investment costs at 1930, required by each technical package for excavation/hauling at 100 meters at the rate of 100 bank cubic meters per hour, for the 1920's and 1970's technologies (source: Tables B.6 and B.7).

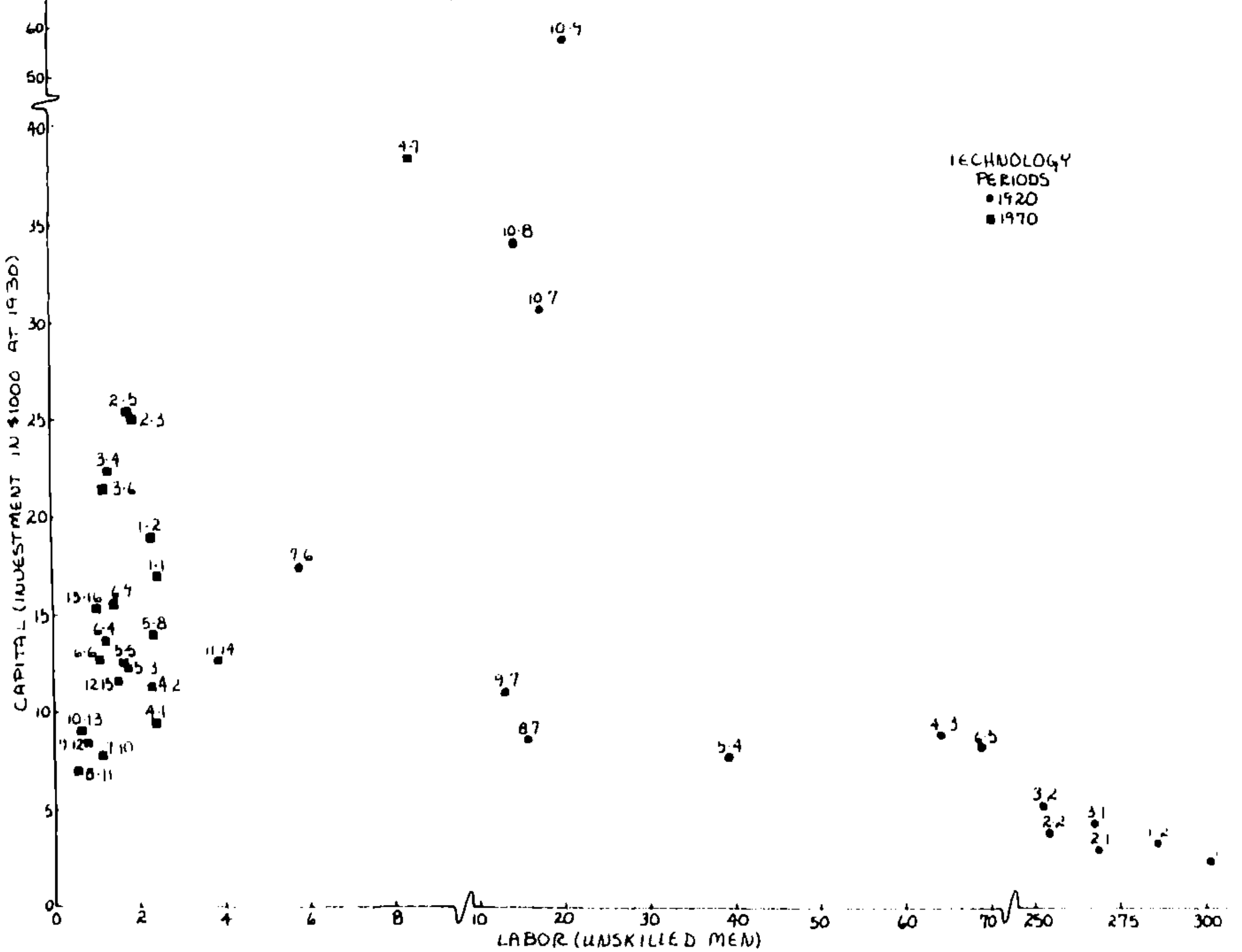
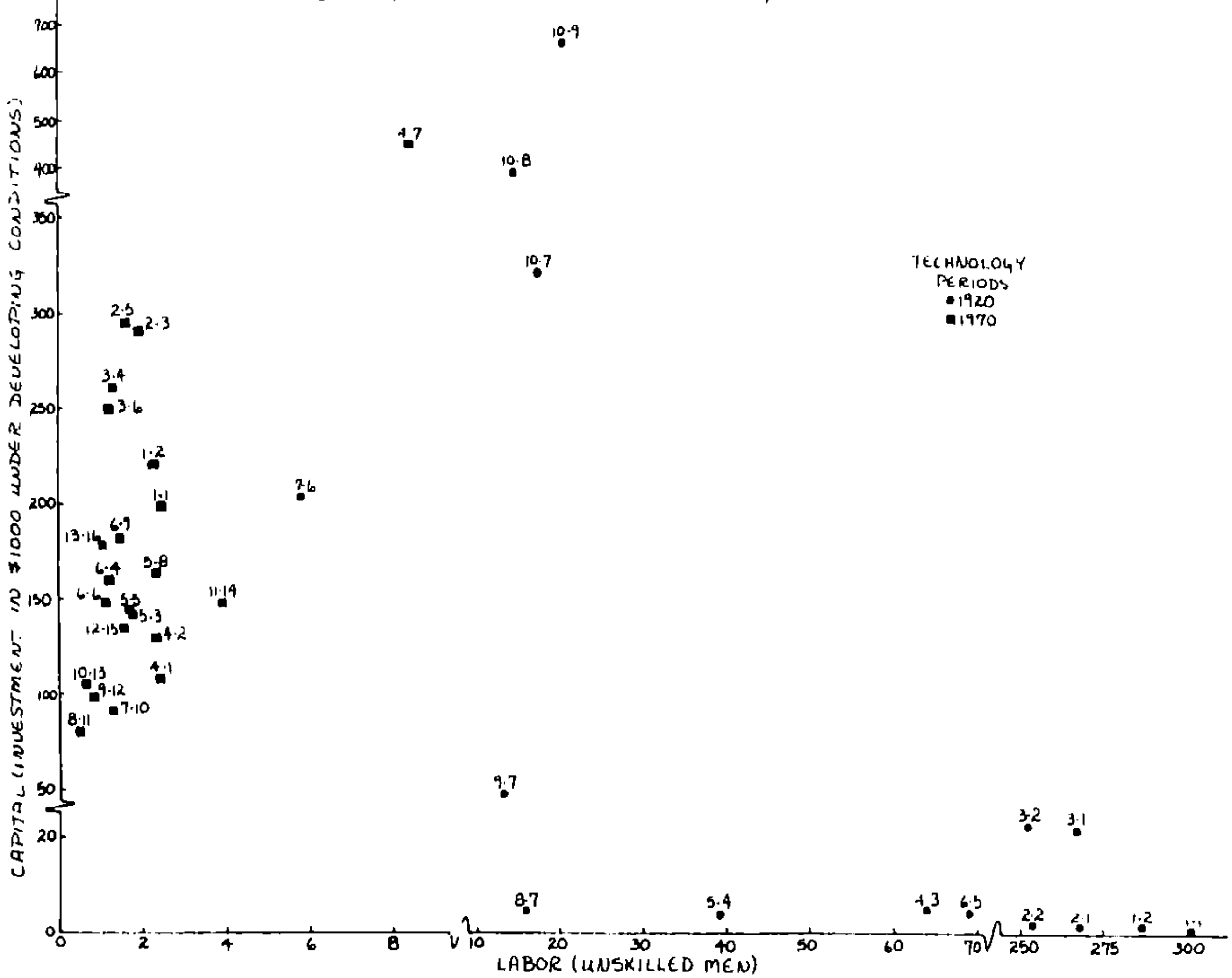


Figure 4.1f: Labor, in unskilled men where the skilled are weighted by the wage ratio at the time of the technology, and capital, in investment costs under developing conditions, required by each technical package for excavation/hauling at 100 meters at the rate of 100 bank cubic meters per hour, for the 1920's and 1970's technologies (source: Tables B.6 and B.7).



physical units. A rather natural measure of capital is its investment cost in that a primary concern in technology change and technology choice is expenditure now, as for capital, versus payments over time, as for labor and materials. This is particularly appropriate in cases where the equipment is quite uniform in terms of lifetime, maintenance as a percentage of investment cost, and fuel consumption, as is somewhat true for the 1950's and 1970's but is decidedly not the case for the 1920's. In order to ascertain the sensitivity of the results to the measurement of capital, a couple of different measures are tried for the 1920's and 1970's technical packages for excavation/hauling at 100 meters. Labor in all cases is measured in units of unskilled men per 100 bank cubic meters per hour or unskilled man-hours per 100 bank cubic meters. Figure 4.1a presents the standard investment plot of investment in 1974 dollars required to produce 100 bank cubic meters per hour; Figure 4.1c introduces the lifetime of the capital resource into its measure by using hourly depreciation costs in 1974 dollars (investment divided by lifetime in hours); finally Figure 4.1d brings in all of the parameters varying with the item of capital by using hourly ownership and operating costs in 1974 dollars.

The only really significant change in the 1920's technology in Figure 4.1c relative to 4.1a is the upward shift in the fully labor-intensive technical packages (tp 1-1, 1-2, 2-1, 2-2, 3-1, 3-2), reflecting the fact that the short lifetime of the handtools involved makes their low investment costs rather expensive in hourly depreciation terms. As for the 1970's some of the packages move slightly relative to one another, and some of the power shovels (tp 2-3, 2-5, 3-4, 3-6), in particular, shift downward due to their relatively long life, but there is no change in the set of efficient technical packages (tp 8-11), and the overall effect is not too significant. As for hourly ownership and operating costs as a measure, the major change in the 1920's technical packages is the upward shift of the horse-powered technical packages (tp 4-3, 5-4, 6-5, 8-7), suggesting that the upkeep of a horse is expensive although its investment cost is low and lifetime long relative to those of equipment; the handtools (tp 1-1, 1-2, 2-1, 2-2, 3-1, 3-2) have also shifted back to their old position, suggesting that the impact of their relatively short lifetime is neutralized by their relatively low maintenance and operating costs. Changes in the 1970's packages are limited to slight movements of the packages relative to one another, although it should be noted that the 1970's packages are generally lower relative to those of the 1920's, with the 1970 elevating scraper (tp 8-11) being lower in cost than all of the 1920's packages. In summary, it seems that investment is probably the most appropriate measure of capital, at least for a graphical representation, in that it focuses on the issue of present versus future costs and does not seem to somewhat arbitrarily eliminate technical packages from the efficient set, as do the hourly depreciation and ownership and operating cost measures.

Accepting this, the next question is the appropriate base period, the selection of which may also influence the results. Figures 4.1a, 4.1e, and 4.1f respectively present investment plots at the prices of

1974, 1930, and a typical developing country, the latter being included to see what occurs under more extreme conditions than the first two. Equipment investment changes by a factor of 5.86 between 1930 and 1974 while investment in a horse changes by a factor of 3.93; under developing conditions heavy equipment investment goes up by a factor of nearly two relative to 1974, while investment in light equipment and a horse are reduced by nearly a factor of two relative to 1930. The effect is as expected: (1) the 1970's are completely unaffected in terms of their relative positions, since practically all of the capital is heavy equipment; (2) the same is pretty much true for the 1920's packages at 1930 costs; and (3) the 1920's at developing country conditions are significantly affected, in that there is a large space between the largely heavy equipment packages involving the bulldozer (tp 7-6) and power shovel (tp 10-7, 10-8, 10-9) and the remaining largely light equipment packages. The set of efficient packages for each period, however, remains the same with but a few exceptions. The tractor-powered elevating grader (tp 9-7) is added to the 1920's efficient set at developing prices, due to its being partly light equipment; the fresno (1920 tp 5-4) is dropped from the overall efficient set at 1930 prices, due to the smaller change in the cost of the horse relative to that of equipment, while the horse-powered elevating grader (1920 tp 8-7) is added at developing prices, due to its being light equipment. In summary, the base period does not seem to have too significant an impact on the overall results, and 1974 seems as reasonable as any other year for use in pricing the investment plot.

The graphical analysis thus provides one means of identifying the efficient technical packages, but because of the measurement difficulties discussed above, particularly the sensitivity of the results to the method of measuring capital, a second means is seen as necessary, this being the numerical analysis. Holding the engineering variables (i.e., resource productivities and basic equipment characteristics) constant while varying the economic variables (see Table 3.3) over a wide range, the efficient technical packages are those which appear as least cost under at least one reasonable set of economic conditions. The first problem, of course, is developing a comprehensive set of economic conditions, such that the various combinations which can arise represent the majority of possible real world situations. Recognizing the difficulty of doing this with a reasonably sized set of conditions, it must be realized that the set of efficient technical packages is thus restricted by the particular conditions used in the numerical analysis; other packages might enter the efficient set if additional economic conditions were included or some enter and some leave the efficient set if the conditions were modified somewhat. This latter situation is particularly likely among those technical packages which are relatively close in cost, such as the handtools (tp 1-1, 1-2, 2-1, 2-2, 3-1, 3-2) in the 1920's and certain of the waterbound macadam surfacing and double bituminous surface treatment packages in the 1950's (wbm tp 112, 212, 312, 412, 512; most dbst tp's) and 1970's (wbm tp 111, 211, 311, 411; most dbst tp's). This brings up another difficulty with the numerical analysis. It is set up so as to identify only one technical package for each combination of economic conditions, even if the costs of others are in very close proximity; modification of this to include all packages within 10 percent, for example, might help alleviate some of the potential sensitivities of the results.

Between the graphical and numerical analyses, nevertheless, it seems quite possible to develop a reasonably reliable picture of the set of efficient technical packages for each stage of construction, for each period and over all periods. Most of the differences in the results of these two analyses, as given in Tables 3.4 and 3.5, arise as a result of the measure of capital selected in the graphical analysis. Several of the 1920's packages which arise only in the numerical analysis would arise in the graphical if it were done at developing rather than 1974 conditions; the remainder arise under economic conditions which depict reasonable scenarios, such as a typical developing country except for expensive light as well as heavy equipment and/or expensive beasts of burden, among others, as discussed in Section 3.13, but which are not represented by any of the capital measures considered above. The differences in the results of the 1950's and 1970's stem largely from the use of investment rather than hourly depreciation or ownership and operating cost as the measure of capital. For example, the investment required for a particular technical package may be relatively low, but its lifetime may also be relatively low and/or its fuel consumption high, resulting in high hourly costs; the outcome is that it looks efficient in the graphical analysis but does not appear as least cost in the numerical analysis. Another situation which occurs just a couple of times in the 1970's (exc/haul tp 4-1; spr/comp tp 31) is that a technical package shows up as efficient in the graphical analysis when, in fact, it is barely efficient, since its investment is essentially the same as that of another package which has significantly less labor; finally, the two extra site preparation packages for the 1950's and 1970's arise in the graphical but not in the numerical analysis because investment for the two packages is less than for package 31 each year, but labor is significantly more, and the economic conditions in the numerical analysis are never apparently such as to override the low productivity of the package relative to that of 31. As for the results of the analyses over all periods, the packages which appear naturally follow directly from those which appear in the individual periods, and similarly, the same basic explanations account for any differences in the results of the two analyses.

The set of efficient technical packages in the 1920's, then, is observed to span a broad range of capital/labor ratios and unit costs. The efficient sets in the 1950's and 1970's, on the other hand, are represented by only a few packages generally, with capital/labor ratios and/or unit costs in close proximity, sometimes so close that the packages are essentially indistinguishable; this closeness comes to a peak with the waterbound macadam surfacing and double bituminous surface treatment stages, where several technical packages (1950 wbm tp 112, 212, 312, 412, 512; 1970 wbm tp 111, 211, 311, 411; most 1950 dbst tp's; most 1970 dbst tp's) are within 10 percent in unit cost, making the efficiency analysis rather meaningless as the entire least-cost set is really efficient.

The efficient set for each stage of construction in the 1920's technology includes the full production set except for the excavation/hauling stage where certain representative technical packages are included; at 6 meters, handtools (tp 1-1), scrapers (tp 4-3, 5-4), and bulldozers (tp 7-6) are represented, at 100 meters, handtools (tp 1-1, 1-2), scrapers (tp 5-4), elevating graders (tp 8-7, 9-7), and bulldozers (tp 7-6), and at 800 meters, handtools (tp 1-1, 1-2, 2-1, 2-2), scrapers (tp 6-5), elevating graders (tp 8-7, 9-7), and power shovels (tp 10-8). This is not the case for the 1950's and 1970's where the efficient set consists of only a couple of technical packages and thus a couple of types or sizes of equipment, except for the double bituminous surface treatment stage where all packages are essentially included. Site preparation thus goes from handtools (tp 11) or a bulldozer (tp 21) in the 1920's to larger bulldozers in the 1950's (tp 31) and 1970's (tp 21, 31), although a handtools package (tp 11) also appears as graphically efficient in the 1950's. In excavation/hauling at 6 meters, successively larger bulldozers are used in the 1950's and 1970's, while at 100 meters scrapers take over, and at 800 meters an elevating grader takes over in the 1950's while the larger scrapers stay on in the 1970's. Finally in the spreading/compaction, gravel surfacing, and waterbound macadam surfacing stages, the handtools and early blade graders of the 1920's are replaced by larger, self-powered blade graders for spreading soil and aggregate (although, as noted above, any spreading tool can be used in waterbound macadam) and spreader boxes or gas spreaders for spreading screenings in the 1950's and 1970's; the horse-drawn and small, 3-wheel rollers of the 1920's, in turn, are replaced by larger, 3-wheel and pneumatic rollers in the 1950's and self-powered, sheepsfoot rollers in the 1970's for compacting soil and pneumatic rollers in the 1950's and larger, 3-wheel and pneumatic rollers in the 1970's for compacting aggregate.

More interesting, perhaps, than looking at the transition over time in the efficient sets of technical packages for each stage of construction is looking at the efficient set which arises when the technical packages of all periods are considered at once. The full set of efficient, 1970's technical packages are, not surprisingly, included in this set, but also included are certain of the more labor-intensive and animal-powered packages of the 1920's (at least through gravel surfacing), while only a couple of the 1950's packages are included. A reasonable explanation for the exclusion of the 1950's technical packages is that they are, by and large, very similar to those of the 1970's; their capital/labor ratios are about the same or only slightly less than those of the 1970's, especially compared with the 1920's-1970's gap, and the equipment involved is often just a little smaller or a slightly different type and somewhat less productive but still powered and requiring skilled labor. The technical packages of the 1920's which show up, on the other hand, are very different from those of the 1970's, being fully labor-intensive or at most labor assisted by horse-powered equipment. It is under developing conditions, then, that the 1920's packages arise as least cost. It might be noted, however, that (1) some of the most labor-intensive packages (exc/haul 6M tp 1-1;

spr/comp tp 11; gravel tp 11) which in the 1920's set arise under developing conditions with an expensive horse, (2) two of the horse-powered technical packages (exc/haul 6M tp 4-3; 800M tp 6-5) which in the 1920's set arise under developing conditions where light and heavy equipment are equally costly, and (3) all packages which involve any powered equipment (all remaining excluded technical packages) still cannot compete because of their very low productivity relative to that of the 1950's and 1970's packages. Although the 1920's technical packages for waterbound macadam surfacing and double bituminous surface treatment are labor-intensive relative to those of the 1970's, the gap is not so large as in the other stages and powered equipment is involved in all cases, resulting in their exclusion from the overall efficient set.

In summary, the results of the efficiency analysis demonstrate the existence of a production set that can be described as a production function for most stages of highway construction in the 1920's, the exceptions being site preparation, waterbound macadam surfacing, and double bituminous surface treatment. Only two packages are identified for each of these latter stages, as that was the limit of the available data, although it seems likely that other packages may have been in use. It might be noted at this point that much of the technology of surfacing is in the material being used, and that there is often not the variety of ways to produce a particular surface, especially the higher standard surfaces, as there is to do earthworks, for example. For the 1950's and 1970's, on the otherhand, there really are no production functions except maybe for site preparation, where three packages are identified, with two being efficient according to the graphical analysis. It is felt that this lack of production functions, however, does not stem from a lack of data, in that a reasonably large number of technical packages are identified for each stage, with a couple of different types as well as sizes of equipment, with the possible exception of double bituminous surface treatment for which at most two items of equipment are identified for each major activity. The implication, then, is that this lack depicts a real shortage of efficient alternatives and the focusing of the development of new technical packages on a particular capital/labor ratio.

As for the overall analysis, if one accepts the results of the numerical analysis or a combination of the two, then, once again production functions exist, with the exception of double bituminous surface treatment, but these are production functions with a large gap in the middle, going from the fully labor-intensive and animal-powered technical packages of the 1920's to the fully capital-intensive packages of the 1970's, with a couple having a 1950's package, much closer to the 1970's, in between. It is also expected that these 1920's packages will arise as least cost only under the rather extreme types of developing conditions outlined in this research. Nevertheless, there does at least seem to be some possibility of a few rather labor-intensive packages being efficient relative to today's technology.

4.12 The Best-Practice Technical Packages

In order to more directly investigate the issue of efficiency and substitution and their role in technology change, it is necessary to narrow the set of efficient technical packages in the 1920's, 1950's, and 1970's to the set of best-practice packages for each stage of construction at the prices of 1930, 1956, and 1974 as given in Table 3.6. This is done by applying the factor prices of each of these periods to the resource requirements of each technical package, the best-practice packages being those which are minimum cost, or at least within 10 percent of it, in terms of the production function and the relative factor prices. Movements over time of the best-practice package for a particular stage of construction, then, represent technology change.

Before proceeding to investigate technology change in some detail, it is useful to consider the magnitude of the change that has occurred over the years in terms of overall costs and factor inputs, the results being presented in Figures 3.2 and 3.3. Figure 3.2a shows the progression of the unit costs of each stage of construction over time, both as it actually occurred and as it would have occurred had technology not changed as it did. From the 1920's best-practice packages at 1930 prices to the 1950's packages at 1956 prices, the general trend in unit costs is steady to some decline, suggesting that the some four-fold increase in labor, nearly three-fold increase in equipment investment, and practically no to a two-fold increase in other items (e.g., fuel and interest) costs have been fully, or even more than fully, offset by the change in technology. Between the 1950's and 1970's, on the other hand, unit costs have roughly doubled, indicating that technology change has succeeded only in part in offsetting the better than three-fold increase in labor, two-fold increase in equipment investment, and two to three-fold increase in other items costs. In line with this is the broad divergence in unit costs of the 1920's and 1950's best-practice packages at the three price periods and the nuch narrower difference in those of the 1950's and 1970's packages. At the same time, it should be noted that the best-practice packages in the 1920's are the most capital-intensive ones of the efficient set.

The impact of technology change seems to be somewhat less in the cases of site preparation and excavation/hauling at 6 meters, as is further indicated by the somewhat narrower span in unit costs between the 1930's technology at the prices of 1956 and 1974 and the technologies which were actually used in those periods, than is the case for the other stages (see Figure 3.2a). This is not too surprising in that the technical packages for both of these stages are quite similar over all three periods, differing not in the type of equipment (largely bulldozers), but only in its size and productivity.

The excavation/hauling at 800 meters, gravel surfacing, and double bituminous surface treatment stages, on the other hand, exhibit a strong influence on the part of technology change between the 1920's and later period technologies, as is evident from Figure 3.2a. In the case of excavation/hauling, this is not surprising as both the excavation (power shovel versus elevating grader versus elevating scraper) and transport (5 cubic yard wagon towed by 20 horsepower tractor versus 15 cubic yard wagon towed by 185 horsepower tractor versus 21.5 cubic yard elevating scraper) equipment are vastly different in type, capacity, and speed over the three periods. This is a stage of highway construction in which truly significant advances have been made in technology.

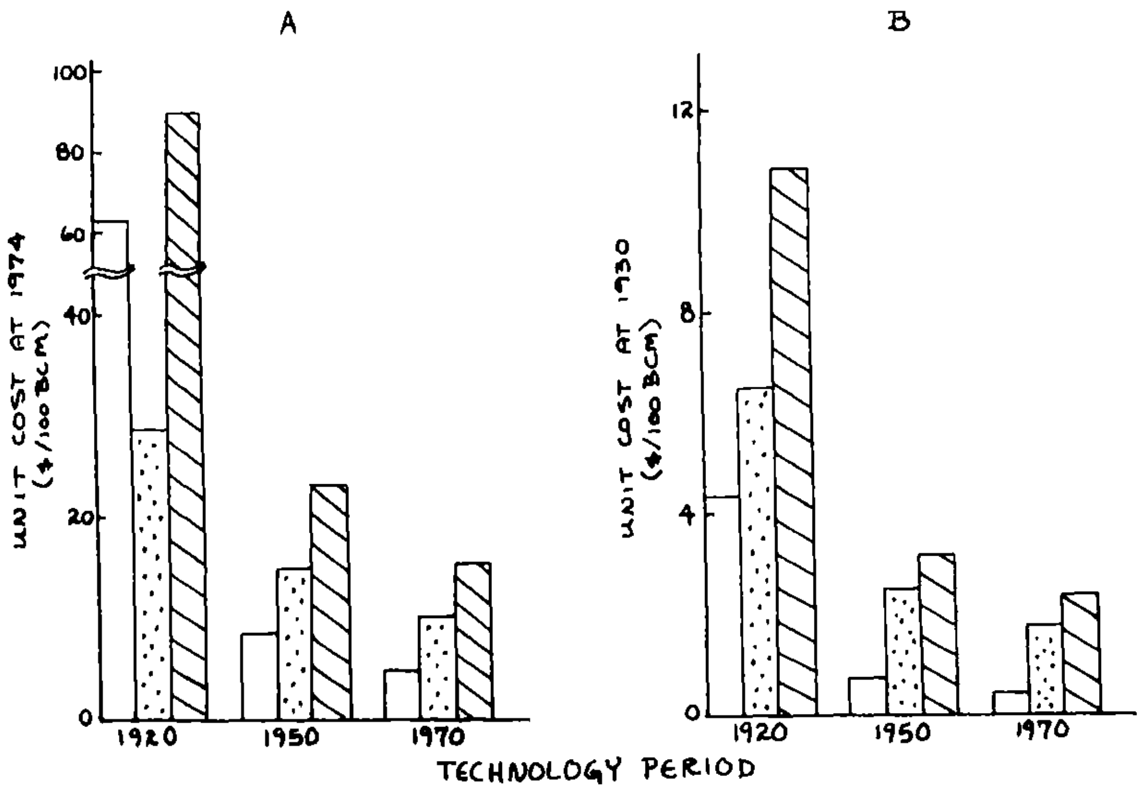
As for gravel surfacing, the difference lies primarily in the spreading equipment, going from a 5 foot, horsedrawn blade grader and handtools in the 1920's to 10 to 14 foot, self-powered blade graders in the 1950's and 1970's. Similar behavior might be expected in water-bound macadam surfacing, where the spreading equipment varies over a wide range (from 5 foot, horse-drawn blade graders in the 1920's to 10 to 14 foot, self-powered blade graders, 8 to 14 foot bulldozers, or gas spreaders in the 1950's and 1970's for the crushed stone; from handtools in the 1920's to spreader boxes in the 1950's to gas spreaders in the 1970's for screenings), but the domination of the compaction activity, where the equipment is more similar (10 ton, 3 wheel versus 10 ton, pneumatic versus 12 ton, 3 wheel rollers), overshadows this difference somewhat. As noted earlier, data on surfacing in the 1920's is somewhat sparse, and it is suspected that somewhat more advanced equipment may have existed for spreading aggregate as it did for spreading soil (e.g., the 12 foot blade grader towed by a 76 horse-power tractor-tp 32). In the case of double bituminous surface treatment, the technical packages over the three periods do not seem so far apart, going from hand to power-operated brooms, from 600 to 1000 or 1500 gallon bitumen distributors, from spreader boxes with 5 ton trucks to gas spreaders with 20 ton trucks or spreader boxes with 10 ton trucks, and from 3 wheel to pneumatic or tandem rollers; the effect of technology change, nevertheless, seems to be cumulative, although it should be noted that the really major differences in productivity are again in the spreading aggregate activity, where it is suspected that the productivity may be somewhat low for the 1920's due to a paucity of reliable data.

It is important to note, at this point, that much of the analysis of technology change in this section is done using the set of best-practice technical packages for each technology period. Quite justifiably, there is some concern that the magnitude of technology change and its effects might be somewhat overstated, in part because the best-practice rather than average-practice packages are being used, and also because one can feel somewhat more confident that the best-practice packages have truly been identified for the 1950's and 1970's than that the same has been done for the 1920's. At the same time, it should be noted, by looking at Figure 3.2a, that reasonably significant advances in technology are still evident in the pattern of unit costs over time for most stages of construction, even under the assumption that the productivity data for the 1920's are unfairly low relative to those of the 1950's and 1970's, and that they should thus be doubled, halving the unit costs of the 1920's best-practice packages. Site preparation and excavation/hauling at 6 meters are, to some extent, exceptions, but then doubling their 1920's productivities is also less justified, in that the packages of the 1920's in these two stages are so similar to those of the 1950's and 1970's that they are quite likely the truly best-practice ones.

In looking at what lies behind the trends in unit costs observed in Figure 3.2a, it is useful to look at the labor and capital shares of production. Figure 3.2b does this directly by presenting graphs of labor and capital shares of unit costs in 1974 dollars for the best-practice packages in each technology period. The use of a particular price period with all three technologies has certain difficulties, however, as demonstrated by Figure 4.2, part A, where 1974 unit costs are used, and part B, where 1930 prices are applied; a comparison of these two figures suggests that 1974 prices tend to overstate labor's share relative to that of capital while 1930 prices tend to understate it.

Figure 3.3 presents an alternative approach to looking at labor and capital shares in terms of the relative quantities of these resources required over time. Figure 3.3a, thus, presents the labor measured in unskilled men and capital measured in 1974 investment dollars required by the best-practice packages of each technology period as a percentage of those of the 1920's; Figure 3.3b does the same, using the 1950's as the base. Before deciding upon men and investment as the labor and capital measures, a wide variety of such measures were tried, as demonstrated in Figure 4.3. Comparison of the results produced by the various measures suggests that men and investment are the most reasonable pair to use, as they tend to understate the changes in capital, although at the same time, they slightly overstate the changes in labor. The only other measures of labor are 1930 and 1974 unit costs, and while one of these might be better in terms of changes in labor, they both seem to rather seriously overstate the changes in capital. Moreover, men and investment are the

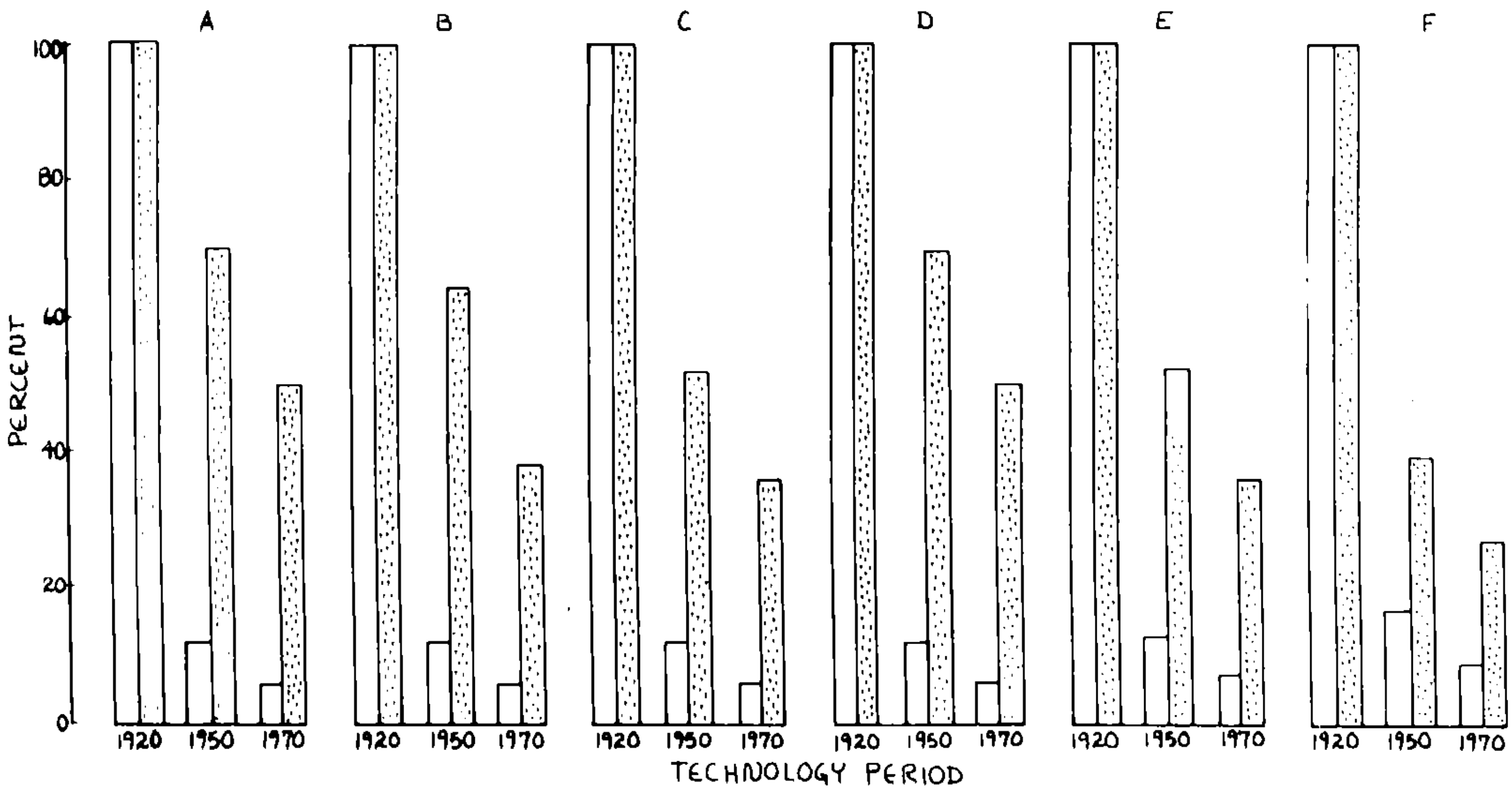
Figure 4.2: Labor and capital components of the unit costs of the best-practice technical packages of each technology period for excavation/hauling at 100 meters, at the prices of 1974 and 1930 (source: Table B.5).



Note: Unit costs: ☐ labor, ☐ capital, ☐ total.

Best-practice packages are those which appear as least-cost, or within 10 percent of it, at the prices of the period coincident with that of the technology; where more than one package is involved, the data for the various packages is averaged.

Figure 4.3: Labor and capital requirements of the best-practice technical packages of each technology period as a percentage of those of the 1920's, for excavation/hauling at 100 meters, using various measures of labor and capital (source: Tables B.5, B.6, and B.7).



(Figure 4.3 continued)

<u>Note</u>: □ percent of 1920's labor; ▨ percent of 1920's capital.

Units of measure:

Part	Labor Input	Capital Input	Product Output
A	unskilled men	investment costs at 1974	100 BCM/hr
B	unskilled man-hours	depreciation costs at 1974	100 BCM
C	unskilled man-hours	ownership and operating costs at 1974	100 BCM
D	unskilled men	investment costs at 1930	100 BCM/hr
E	labor costs at 1974	ownership and operating costs at 1974	100 BCM
F	labor cost at 1930	ownership and operating costs at 1930	100 BCM

Best-practice packages are those which appear as least-cost, or within 10 percent of it, at the prices of the period coincident with that of the technology; where more than one package is involved, the data for the various packages is averaged.

standardly accepted measures in the economic literature, and in the case of the best-practice technical packages, the use of investment as a capital measure is less serious, in that the equipment in the 1920's packages falls somewhat more in line with that ofthe 1950's and 1970's in terms of lifetime, maintenance as a percentage of investment, and fuel consumption.

In the overview of the production sets of the 1920's, 1950's, and 1970's at the beginning of Section 4.1, a general trend was observed of labor decreasing significantly in the transition among technologies, especially between the 1920's and 1950's, while investment behaved in a more varied manner, ranging from some increase to no change to some decrease, for the various stages of construction, with the exception of site preparation where capital and labor switched roles. In the case of the best-practice packages, as given in Figures 3.2b and 3.3, the general trend observed is one of both labor and capital decreasing with changing technology, although a few exceptions in the case of capital show up between the 1950's and 1970's in Figure 3.3. It is also observed that the decrease between the 1920's and 1950's is generally more than that between the 1950's and 1970's, and that the decrease in labor is generally greater than that in capital.

In investigating the capital intensity of various stages of construction and its change over time, one comes to the same basic conclusions whether one looks at the share of unit costs attributed to capital and to labor in Figure 3.2b or one looks at the capital/labor ratios in Figure 3.3. The trend in capital/labor ratios is a steady increase with changing technology, the most marked increases generally occurring between the 1920's and 1950's; site preparation is an exception in that the ratios fall over time. The distinct differences between the stages show up in the magnitude of the ratio; for excavation/hauling it is some 70,000 to 90,000 investment dollars per man in the 1970's, while for surfacing it is only 14,000 to 16,000 dollars per man, with spreading/compaction falling in between at 24,000 and site preparation on the bottom at 5,500. The implications of this are that the earthworks activities, particularly excavation/hauling, have a strong tendency toward capital intensity, to the point of practically totally replacing labor with capital, while the surfacing activities, at least under current conditions, simply cannot be executed with such a high level of capital intensity, although what is used in the 1970's is certainly much greater than that in the 1920's. As for site preparation, it has a strong tendency toward capital intensity in the brush and tree removal activity, but the burning of the debris activity has remained a highly labor-intensive operation, requiring 30.0 out of the 34.3 unskilled men required to clear 1 hectare per hour in the 1970's. It might also be noted at this point that the technology change which has occurred in highway construction between the 1920's and 1970's obviously has components of both neutral and non-neutral change.

Returning to the list of best-practice packages presented in Table 3.6, it is observed that, with but a few minor exceptions, the best-practice package(s) for each stage of construction in each technology period is (are) the same for all three price periods. The exceptions consist of the deletion or addition of a technical package and/or modification of the order of the packages in the best-practice set. It is noteworthy that the few changes with price that do occur generally do so in the direction of increasing capital intensity over time; among the double bituminous surface treatment packages, for example, there is some tendency for those with higher capital/labor ratios to start at the end of the list, or not even on it, at 1930 prices and to move up, such that at 1974 prices they are at the top of the list. This meager suggestion of substitution of capital for labor over time is the only introduction of any substitution among alternative packages in each technology period for this price range.

This is not surprising for the 1950's and 1970's, as it was already observed in Section 4.11 that production functions do not really exist for these technology periods, or, in other words, that they have an elasticity of substitution of zero. As for the 1920's, where the technical packages form production functions for most of the stages of construction, these, too, are effectively right-angle production functions with zero elasticity of substitution over this price range. Finally, the 1970's best-practice packages are also the overall least-cost packages for all three price periods, yielding another effectively right-angle production function. It appears that substitution, brought about by changes in factor prices between 1930 and 1974, has not played a significant role in the technology change that is observed over that period.

Efficiency is the next aspect of technology change that is of interest, ignoring for the moment any potential economies of scale. It must be noted, however, that efficiency cannot be the whole story since, as observed above in conjunction with Figures 3.2b and 3.3, non-neutral as well as neutral technology change has occurred; with the possibility of substitution brought about by factor price changes eliminated, factor bias is left. A method, based on that of Salter (73) of separating the impact of efficiency and bias on proportionate changes in factor inputs is presented in Section 2.31, and the results of this analysis are given in Table 3.7. A few observations about the analysis need to be made before discussing the results.

In line with Salter's approach and Figure 3.3, the quantity of labor is measured in unskilled men and that of capital in 1974 investment dollars; the figures in the table thus represent the change (decrease [-] or increase [+]) in the number of men or amount of investment required by the best-practice packages from one technology period to the next as a percentage of the quantity required in the earlier period, and the distribution of this percentage change between efficiency and bias. Two measures of bias appear in the table, one derived using Salter's approach, and the other derived as the difference between the total percentage change in resource quantities that is actually observed between the 1920's and 1950's and the 1950's and 1970's as given in Figure 3.3 and the percentage change attributable to efficiency as given in Table 3.7. Salter's measure is but an indication of the direction and potential magnitude of bias' influence on the resource quantities, and is generally larger than that actually observed, particularly in the 1920's to 1950's transition where capital/labor ratios are widely different.

Since Salter's measure of bias serves only as an indicator, the slight variations that might arise, from the use of quantity measures other than unskilled men and 1974 investment dollars, price periods other than that of the earlier of the two technology periods being considered, and so forth, are of relatively little concern. As for the measures of bias derived from Figure 3.3, the use of men and investment as labor and capital measures is discussed above in conjunction with the figure. The measure of efficiency involves a comparison of the costs of using the best-practice packages of the two technology periods being considered, and thus the pricing of the inputs. Table 4.1 gives the results of various pricing methods; no real trend in terms of the pricing method used appears in the results, which are reasonably close together (with the exception of the 1950's to 1970's case of pricing skilled and unskilled labor hours separately and capital hours with hourly ownership and operating costs). For a variety of reasons, the first pricing alternative is used in the analysis. It is Salter's recommendation, as in much of the economic literature, that labor be priced with wages and capital with the capital recovery factor at the prices of one of the two technology periods. This brings out the fixed costs of capital, those costs which are incurred whether or not the equipment is in use. Moreover, since capital recovery factors specific to each particular item of capital are used in this study, the lifetime of the equipment is thus included, and as noted in conjunction with Figure 3.3, the equipment in the best-practice packages of the

Table 4.1: Testing the sensitivity of the percentage change due to efficiency to various means of pricing the labor and capital inputs in the case of excavation/hauling at 100 meters (source: Tables B.5 and B.6).

Pricing Alternative	Percentage Change Due to Efficiency: $100 \cdot \frac{\text{Resource}_{50} - \text{Resource}_{20}}{\text{Resource}_{20}}$	Percentage Change Due to Efficiency: $100 \cdot \frac{\text{Resource}_{70} - \text{Resource}_{50}}{\text{Resource}_{50}}$
Labor: priced by skilled and unskilled wages at 1930 or 1956 Capital: priced by capital recovery factor at 1930 or 1956	-69.9	-41.8
Labor: priced by skilled and unskilled wages at 1930 or 1956 Capital: priced by ownership and operating costs at 1930 or 1956	-70.0	-34.6
Labor: measured in unskilled men, priced by unskilled wages at 1930 or 1956 Capital: priced by capital recovery factor at 1930 or 1956	-73.3	-43.4
Labor: priced by skilled and unskilled wages at 1956 or 1974 Capital: priced by capital recovery factor at 1956 or 1974	-75.4	-41.3

<u>Note</u>: Equations for calculating these values are given and discussed in Section 2.31.

1920's is somewhat more in line with that of the 1950's and 1970's than is the full set of 1920's equipment. As for the pricing period, that of the earlier technology in the pair is used, as this is more compatible with the next step of determining the percentage change in resource quantities attributable to substitution brought about by factor price changes (if there were any to observe). Finally, the results obtained with this pricing alternative tend toward under rather than overstating the percentage change attributable to efficiency.

In order to begin to look at the relative roles of efficiency and bias in changing resource requirements over time, it is helpful to see it graphically as well as numerically. In Figure 3.3, using the results from Table 3.7, a dashed line is drawn indicating the level to which the quantities of labor and capital, of the 1950's and 1970's relative to those of the 1920's and 1950's, respectively, fell due to efficiency; the further drop, generally of labor, below this line and rise, generally of capital, above it represent the changes due to bias. It is evident from Figure 3.3 and Table 3.7 that twice in the 1920's to 1950's transition the measure of efficiency appears to be too small, and once in the 1950's to 1970's it appears to be too large. As indicated by the above discussion pertaining to alternative labor and capital measures and prices, this is undoubtedly a function of the particular measures and prices used; moreover, averaging over the best-practice technical packages, when there is more than one in a technology period, probably does not help the coordination of the various measures of change in Table 3.7 and Figure 3.3. The implication of this is simply that these measures of efficiency and bias should not be interpreted as absolute values, but rather as "ballpark" figures serving as a reliable indication of the relative roles of efficiency and bias in technology change.

The percentage decrease in resources required which is attributed to efficiency ranges from 36 percent for site preparation to 54 to 85 percent for earthworks to a peak of 79 to 90 percent for surfacing in the 1920's to 1950's transition (see Table 3.7 and Figure 3.3). These same figures for the 1950's to 1970's are significantly less, ranging from only 15 to 55 percent, and the positions of earthworks and surfacing are switched. Looking at the figures for total percentage change in resource quantities, as taken directly from Figure 3.3, the same basic trends are observed and were noted above in the discussion of Figure 3.3. Combining these two sets of data for labor (capital in the case of site preparation) yields the change in the quantity of labor (capital) attributed to efficiency as a share of the total change. In the 1920's to 1950's transition, this is some 66 percent for site preparation, 79 to 91 percent for earthworks, and 89 to 96 percent for surfacing; site preparation and excavation/hauling at 6 meters are notably less, being 46 to 54 percent, respectively, for the 1950's to 1970's transition, but the other stages exhibit about the same, or only a slightly smaller, percentage of total change in labor attributed to efficiency over this period. The role of bias toward labor-saving in the change in the quantity of labor required over the transition periods is thus relatively small, representing only 4 to 21 percent of the change and being about the same or slightly more in the 1950's to 1970's than in the 1920's to 1950's. As for site preparation, the technologically constant burning activity creates an appearance of bias toward capital-saving or labor-using; bias' share in the total change in capital required over time in this case is quite large, representing some 34 and 54 percent in the 1920's to 1950's and 1950's to 1970's transitions, respectively.

The analysis of the relative impacts of efficiency and bias on changes in the quantity of capital (labor in the case of site preparation) is less straightforward due to their having opposing influences. The percentage increase in capital attributable to bias toward labor-saving in the 1920's to 1950's is some 1 to 39 percent in earthworks and 9 to 17 percent in surfacing; it is noticeably larger in the 1950's to 1970's, being some 13 to 50 percent in earthworks and 10 to 41 percent in surfacing. It was noted above that the trend in efficiency shares is just the opposite. Combining these two sets of data for capital gives the share of the decrease in capital due to efficiency which is lost due to bias' influence. This ranges from 2 to 56 percent in earthworks and 10 to 19 percent in surfacing for the 1920's to 1950's; for the 1950's to 1970's, the figures are notably larger, being, respectively, 32 to 131 percent and 24 to 207 percent. Along similar lines, when one compares the ratio of the percentage change in capital due to bias to that in labor, the figures for the two periods are about the same, ranging from less than 1 to 3.5 or so; the introduction of the appropriate capital/labor ratios, however, in order to ascertain the cost, in terms of 1974 investment dollars, of bias' decreasing the number of men, shows significant differences. In the case of excavation/hauling at 100 meters, for example, it cost some 23,000 investment dollars in capital to decrease labor by one man in the 1920's to 1950's, while it cost some 100,000 investment dollars in the 1950's to 1970's. In summary, although the change in labor attributed to bias as a share of the total change in labor is about the same over the two periods, the cost, in terms of capital, of a unit of this bias, in terms of labor, in the 1950's to 1970's is significantly greater than that in the 1920's to 1950's, due to the higher capital/labor ratios; it is expected that the same trends might be observed in the case of site preparation, but with labor and capital switching roles, due to the lowering of capital/labor ratios over time.

Returning to the concern mentioned earlier, in conjunction with Figure 3.2, of overstating the magnitude of technology change and its effects, particularly with regard to the 1920's technology, it is useful to briefly consider the consequences of doubling the 1920's productivities and thus halving its quantities of men and investment. In Figure 3.3a, this is accomplished by simply a scale transformation, doubling it, and also bringing the 1920's packages down to the level of the new 100 percent; the effect on the percentage change in resource quantities due to efficiency is that it falls, while that due to bias doubles. The percentage change in labor attributed to efficiency as a share of the total change is still greater than that attributed to bias, with the same exceptions, site preparation and excavation/hauling at 6 meters, as noted in the previous discussion of doubling the 1920's productivities. Furthermore, the cost, in terms of capital, of a unit of labor-saving bias remains the same since the capital/labor ratios do not change, although the share of the decrease in capital due to efficiency which is lost due to bias' influence increases. Nevertheless, with but a few exceptions, bias' role in changing resource quantities is still overshadowed by that of efficiency.

In summary, the impact of technology change on highway construction in the U.S. from the 1920's to the 1970's appears indeed to have been significant. Between the 1920's and 1950's, it offset, or even more than offset, inflation with prices of the factors involved, while between the 1950's and 1970's it kept cost increases down to a factor of two. Efficiency seems to have played a major role in this technology change, resulting in sizeable decreases in the amount of labor and capital required for highway construction, although the magnitude of these decreases has lessened over time. Substitution brought about by changes in factor prices, on the other hand, seems to have played effectively no role in the technology change observed. Bias appears as the non-neutral component of technology change, bias toward labor-saving, except in the case of site preparation where it is bias toward labor-using. Efficiency apparently accounts for some 80 to 95 percent of the drop in labor both from the 1920's to 1950's and 1950's to 1970's, while bias is responsible for only 5 to 20 percent. The cost of this labor-saving bias in terms of capital seems to have increased over time, however, due to increasing capital/labor ratios; in the 1950's to

1970's transition the impact of bias on capital is such as to completely overshadow that of efficiency in a few cases, while this is far from occurring in the 1920's to 1950's transition. As for the various stages of construction, it is noteworthy that the earthworks activities, especially excavation/hauling, appear to have a greater propensity toward capital intensity than do the surfacing activities, as exhibited by their larger capital/labor ratios.

4.13 Summary and Implications of the Results

Highways can be constructed in the U.S. today using significantly less labor and capital than was possible in the second and third decades of this century. These technology advances appear to have played a major part in keeping construction costs down, such that between the 1920's and 1950's the cost of the labor and capital in construction remained steady or even declined slightly, while between the 1950's and 1970's it about doubled.

This was accomplished between the 1920's and 1950's by means of increased mechanization and introduction of new types of equipment; that is, the hand and animal-powered, small capacity equipment of the 1920's, operated largely by unskilled labor with skilled labor acting in a supervisory role, was replaced by powered, larger capacity equipment, operated generally by skilled labor with occasional unskilled assistants, in the 1950's. Between the 1950's and 1970's, the means of accomplishment consisted of improving the equipment and the effectiveness with which it was used; that is, the equipment of the 1970's is largely similar to that of the1950's except that it is generally a little more powerful, larger in capacity, and more productive, although a few new types of equipment have been introduced as well.

In economic terms, efficiency appears to have played a major role in the technology change observed between the 1920's and 1970's, although the percentage decrease in resource quantities attributable to efficiency between the 1950's and 1970's is only about half that between the 1920's and 1950's. Efficiency appears to account for some 80 to 95 percent of the drop in labor required for most stages of highway construction, while bias toward labor-saving accounts for the remainder. Over time, however, such labor-saving bias has become increasingly costly in terms of capital, with increasing capital/labor ratios, and between the 1950's and 1970's, efficiency's reducing effect on the quantity of capital required has been overshadowed by bias' opposite impact in a few stages of construction. It might, at the same time, be noted that part of what is interpreted as bias toward labor-saving or capital-using may actually be due to the fact that production functions are not really continuous functions, but rather are made up of discrete technical packages; a certain amount of shift in the capital/labor ratio may thus be necessary to meet a legitimate technical package. Interestingly enough, substitution brought about by factor price changes seems to have effectively played no part in the technology change observed. Returns to scale are assumed to have been constant, although the observed changes in equipment capacity and coincident changes in project scale over time suggest this may not truly be the case; it is thus suspected that some of the technology change attributed to efficiency may, in fact, actually be due to economies of scale, their separation posing an area for future investigation.

As for future expectations regarding technology change in U.S. highway construction, it is first useful to ascertain the motivations behind that of the past. The stability of demand in highway construction has likely been a primary factor, especially since the enactment of the highway trust fund in the fifties, although the market has always been rather steady as such construction is government-funded; this stability is a feature not shared by many sectors of the construction industry. Fairly stiff competition among equipment manufacturers and changes in highway design (e.g., standards and materials) and project scale have also undoubtedly motivated technology change. Although the increased cost of labor relative to capital cannot be cited as a direct motivation since no substitution was observed, it might be fair to say that expectations of such tended to induce technology change in the direction of increasing capital intensity. Moreover, it should be noted that it is primarily the equipment manufacturers who do the research, and it is to their obvious advantage to produce technical packages which utilize capital to the maximum extent possible.

As for the future, these same basic motivations are expected to continue, although some may be dampened a bit by an expected declining emphasis on highways, particularly on new construction, and increased emphasis on other modes of transport. Increased concern over energy and materials conservations is also expected to enter the picture. As for means of accomplishing technology change in the future, a continuation of past trends of improving the equipment is expected, but perhaps even more important is improving the effectiveness with which it is used through better management, organization, and supervision, both on and off the project. It is important to note, however, that efficiency's impact on resource quantities was considerably less between the 1950's and 1970's than between the 1920's and 1950's, particularly in the case of surfacing, suggesting that future gains may be expected to be still less; moreover, labor-saving bias may be expected to become increasingly costly in terms of capital and to increasingly overshadow the effects of efficiency on capital. Advances in project design, particularly in the standardization of specifications and road designs and in the modification and use of existing or development and use of new materials, may be seen as potentially opening the door to further advances in equipment as well as moving toward conservation of materials. Important, too, is modifying existing or developing new equipment in order to reduce fuel requirements or enable it to use more available fuels; this is likely not compatible with the use of bigger, more powerful equipment in the future, re-emphasizing the importance of the effectiveness with which equipment is used. Future analyses of technology and its change in U.S. highway construction can no longer be limited to labor and capital as the primary factors of production, but rather materials and energy must also be included.

The characterization of technology change primarily in terms of efficiency and perhaps some economies of scale, but only a rather small amount of bias and no substitution, appears to be a rather negative result in terms of developing countries' returning to the use of some of the older, more labor and animal-intensive technologies of the past. At the same time, however, it was observed that the 1920's technical packages formed a rather nice production function over a wide range of capital/labor ratios for most stages of highway construction, while those of the 1950's and 1970's largely fell along a single capital/labor ratio, resulting in right-angle production functions. Most importantly, an efficiency analysis over the production sets of all three periods also yielded a production function, although admittedly one with a large gap between the 1970's fully capital-intensive packages and the 1920's labor-intensive and animal-powered packages, with the latter likely arising as least cost only under rather extreme developing conditions such as those outlined in the research. It thus appears that the development of new technical packages since the 1920's has been focused on the capital-intensive end of the production function, where increased efficiency has indeed been achieved, and that the 1920's labor-intensive packages have essentially been forgotten, although they still appear as efficient.

In the case of some developing countries, it thus appears to be worthwhile for them to consider potentially using some of the more fully labor and animal-intensive packages of the 1920's, especially if they could improve the productivity; three frequently cited means include: (1) management, organization, and supervision; (2) tools and simple mechanical aids and the skills necessary to use them; and (3) general physical and social well-being of the workers. Moreover, the chances of the 1920's packages in the overall efficient set appearing as least cost may be strengthened by consideration of mobilization and various other fixed costs associated with the large 1950's and 1970's equipment, particularly in light of the small scale projects common in developing countries.

In conjunction with these comments, some limited sensitivity testing is appropriate, the results of which are presented in Table 4.2. In terms of productivity, doubling the productivity of the light equipment (in order to test the magnitude of the effect) and using one-tenth as many supervisory personnel (resulting in about one per hundred unskilled men, as is perhaps more realistic in developing situations) have been tried; in terms of heavy equipment use, halving the annual utilization and doubling the maintenance as a percentage of investment cost have been tried (as these are perhaps more realistic figures when heavy equipment is used in developing countries). In the cases of doubling the productivity and halving the equipment utilization, a fully labor and animal-intensive package, the horse-drawn elevating grader and wagon (tp 8-7), show up in the 1920's least cost set at the prices of 1930, while the usual bulldozer (tp 7-6) shows up at the prices of 1974; in all cases, however, the 1970's elevating scraper (tp 8-11) is least cost overall. Substitution brought about by factor price changes has thus entered the picture of technology change over the period 1930 to 1974, suggesting that such circumstances could indeed have a significant impact on the economic feasibility of using certain of the 1920's labor and animal-intensive packages in developing countries today.

Table 4.2: Least-cost technical packages and their unit costs (dollars per 100 BCM) for excavation/hauling at 100 meters, for two technology and price periods, under various modifications of the productivity data and heavy equipment characteristics.

	1920's Technology				1970's Technology			
	1930 Prices		1974 Prices		1930 Prices		1974 Prices	
1. Data as it stands	7-6 9-7	$10.3 $11.3	7-6	$63.1	8-11	$2.16	8-11	$14.8
2. Productivity modifications								
a. Double productivity of all light equipment, including associated men and horses	8-7	$6.75	7-6	$63.1	8-11	$2.16	8-11	$14.8
b. Use 1/10 as many supervisory personnel	7-6 9-7	$10.3 $11.2	7-6	$63.1	8-11	$2.16	8-11	$14.8
3. Heavy equipment modifications								
a. Halve hours used per year, leaving life in years the same, for all heavy equipment	9-7 8-7	$12.2 $13.5	7-6	$87.3	8-11	$3.48	8-11	$23.4
b. Double maintenance as a percentage of investment cost for all heavy equipment	7-6 9-7	$11.6 $11.7	7-6	$70.7	8-11	$2.68	8-11	$17.9

4.2 Interaction of Design and Technology in Highway Construction and Use

An investigation of the interaction of design and technology in highway construction and use involves the aggregation of the various stages, with their respective quantities, to the alternative projects and the evaluation of the quality of the final products. As noted in Section 2.32, the lack of production functions for the 1950's and 1970's and the existence of effectively right-angle production functions over the price range of 1930 to 1974 for each technology period alone and over all technology periods combined make the use of a production function-based aggregation procedure, as performed in the IBRD-I (42) and ILO-Iran (44) studies discussed in Section 2.21, unnecessary, as there is no choice of technical packages over this price range. As indicated in Table 3.10, then, the best-practice technical packages of the 1920's, the 1950's, and 1970's, as identified in the stage-level analysis, are used in the project-level analysis at the prices of 1930 and 1974. As there is, however, some choice of technical packages, at least among those of the 1920's and overall sets, if one is willing to go to more extreme pricing conditions, the project-level analysis is also carried out at the prices of a developing country today. As indicated in Table 3.10, the least-cost technical packages of the 1950's and 1970's at developing conditions are, not surprisingly, basically the same as those at 1930 and 1974 prices, while those of the 1920's and overall are vastly different. For the 1920's technology, the labor-intensive, animal-assisted technical packages are least-cost at developing conditions, while the overall least-cost set is a mix of the 1920's and 1970's packages, the 1970's only taking over in the waterbound macadam and double bituminous surface treatment stages where fully labor and animal-intensive techniques were not even used in the 1920's.

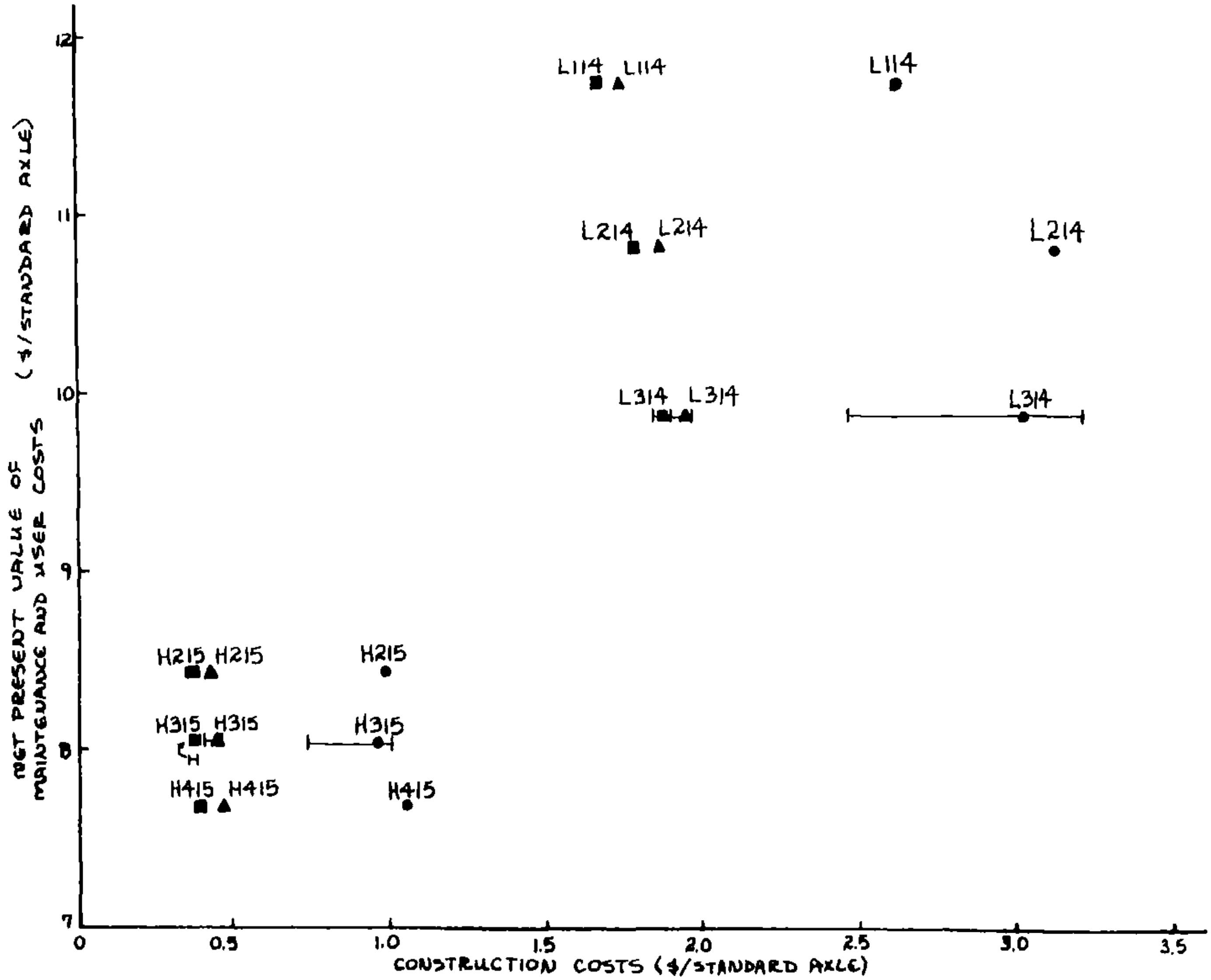
4.21 Comparison of Alternative Projects

Given the project quantities (Table 3.9) and the least-cost technical packages with their unit costs (Tables 3.10 and B.5), the construction costs of the various projects (Table 3.8 and C.5) can be derived under various technology and price conditions. With construction costs as a measure of fixed inputs, or inputs now, to the project, maintenance and user costs, derived via the HCM and expressed in terms of equivalent annual costs, serve as a measure of largely variable inputs, or inputs over time, to the project. As the purpose of the road is to get someone from point A to point B and its life is taken as 15 years with its maintenance being such as to leave all projects in roughly the same condition at the end of that time, the only measure of output required is the volume of traffic the road is to carry over its life, most easily expressed in terms of cumulative standard axles; there are thus two levels of output, one tied to each set of design standards. Using this data then, production isoquants are developed as given in Figure 3.4, where each of the three groups of projects at each of the two design standards/traffic volumes must be analyzed separately.

Looking at the production isoquants for the two traffic volumes, certain economies of scale are evident in all cases; while the cumulative number of standard axles goes up by a factor of over 7.5, construction costs rise by a factor of about 2 and equivalent annual maintenance and user costs by a factor on the order of 5 or 6. Moreover, a comparison of construction costs and maintenance and user costs on a cost per standard axle over project life basis, as given in Table C.5, for the two traffic volumes shows the unit costs to be significantly less for the high volume road in all cases. Similarly, plotting these unit costs, as in Figure 4.4, instead of the total costs, as in Figure 3.4, gives a single production isoquant for each project group in which the low volume projects appear to be inefficient. The implications of this are just what has been observed in the U.S., a trend toward building higher standard roads, although the traffic volume must be at least sufficient to offset the increased construction and likely maintenance costs.

As for the various project groups, the results are the same across all technology and price periods with the exception of the materials alternatives in the high standard/traffic volume case. Differences between the 1920's and the 1950's and 1970's technologies at 1974 prices can be explained by the overall low productivity of the 1920's technology in constructing a waterbound macadam surface (p H215). As for differences in the 1950's and 1970's technologies at 1930 and 1974 prices, these arise as a result of relative changes in materials prices over the period; that of bitumen rose by a factor of 5.0, while that of aggregate went up by one of 1.7. Under developing countries conditions, the double bituminous surface treatment over gravel road (p H315) falls out of the efficient set while the waterbound macadam road (p H215) enters it, again

Figure 4.4: Construction costs and maintenance and user costs, expressed in net present value terms, per standard axle over project life of each project/technology combination at each design standard/traffic volume, for all project groups and all technology periods, at the prices of 1974 (source: Table C.5).



(Figure 4.4 continued)

Note: Technology periods: ● 1920, ▲ 1950, ■ 1970.

⊢—⊣ Indicates the range of construction costs of the alternative excavation/hauling scenarios, for a particular design standard and technology period.

largely as a result of relative changes in bitumen and aggregate prices. Waterbound macadam appears to fair rather poorly in terms of being an efficient alternative surface. It is felt that its construction costs may be overstated because of the compaction requirements placed upon it on the basis of 1920's descriptions of such road construction; at the same time, however, it is felt that its maintenance and user costs may be understated due to the use of a modified, surface treated road deterioration model. In the subgrade strength/surface design alternatives, the properly designed alternative on the weak subgrade (p L324, H325) is inefficient by definition, while the other two alternatives appear as efficient. As for the excavation/hauling scenarios, that with the shortest possible hauls (p L311, H312) comes out with the least construction costs and is thus most efficient.

The trends exhibited by the individual technical packages in terms of unit costs (see Tables 3.10 and B.5) are duplicated in the trends exhibited by the technologies in Figure 3.4 in terms of total construction costs. At the prices of 1930 and 1974, the 1970's technology has the lowest construction costs and is thus most efficient; also notable is the closeness of the 1950's costs to those of the 1970's relative to that of the 1920's and 1950's. Under developing conditions, the mix of 1920's and 1970's technologies is least in construction costs and thus most efficient, followed closely by the 1920's alone and more distantly by the 1970's and eventually 1950's. Underlying all of this, of course, is the assumption that each product is equal in quality regardless of how it is constructed; if this is not the case, the tendency is generally to argue in support of greater capital intensity yielding better quality, at least in highway construction, thus strengthening the case for the 1970's technology.

Before trying to draw any further implications from this efficiency analysis, it is useful to look at the set of best-practice projects in each project group/design standard under various price and technology conditions, as presented in Table 3.11, in order to develop a feeling for the nature and magnitudes of the differences being observed. In line with the efficiency analysis, the best-practice projects are those which are least-cost, or within 10 percent of it, in terms of total project costs expressed as equivalent annual or net present values. Looking over the results in Table 3.11 reveals that, with the exception of the low standard materials and subgrade strength/surface design alternatives where at least two out of three projects end up in the least-cost set, all project alternatives in any project group fall into the best-practice set within any particular technology and price period. Moreover, looking across technologies in these groups leads to the observation that at 1930 and 1974 prices the 1950's technology always, and the 1920's better than half of the time, fall into the least-cost set along with the 1970's technology; at developing conditions, the 1920's technology always, and 1970's and 1950's technologies, often fall into the least-cost set along with the 1920-70 mix technology. A disaggregation of these costs into the partial construction, total construction, maintenance, and user cost components, as given in Table 3.11, is necessary in order to see the dominance of various cost factors and to determine where differences among the projects and technologies lie.

Differences among projects are most evident at the level of maintenance costs and least at the level of user costs, while partial and total construction costs fall in between. On a total cost basis, the low standard/traffic volume design is significantly less than is the high standard/traffic volume design for all cost components except maybe maintenance, while on a cost per standard axle basis, the reverse is true for all cost items with some exceptions in partial construction costs; this is basically in accord with previous observations.

In the project group involving different surfacing materials, generally one or two projects are identified as least-cost at the level of partial construction costs; these are most frequently gravel (p L114) for the low standard, and double bituminous surface treatment over gravel (p H315) and waterbound macadam (p H215) for the high standard. The addition of surfacing materials in arriving at total construction costs generally has some impact, most commonly through the addition of projects to the least-cost set, thus expanding it, and less commonly through the replacement or deletion of projects in the least-cost set, thus changing it. As for maintenance and user costs, projects at the opposite end of the spectrum fall into the least-cost set; in the case of maintenance, for example, double bituminous surface treatment over gravel (p L314) and the same over waterbound macadam (p H415) are least-cost for the low and high standard designs, respectively. It is the user costs which dominate total project costs, however. Only in the case of the 1920's technology at 1930 prices and in all cases at developing prices for the low standard design does the influence of low construction costs appear in the least-cost set under total project costs (i.e., p L114).

The situation is somewhat different in the group of subgrade strength/surface design alternatives. No distinction among projects is possible at the partial construction cost level, while the addition of surfacing materials to obtain total construction costs results in the deletion of the properly designed surface on the weak subgrade (p L324, H325). As for maintenance costs, the two sets of properly designed surfaces (p L314, L324; p H315, H325) exhibit the same costs and are least-cost, but at the level of user costs any distinction among projects is again impossible. As previously, user costs tend to dominate the total project costs, although in the case of the low standard project there is evidence of the influence of high construction costs in one case (at 1930 prices, L324 is not included in the final least-cost set) and of high maintenance costs in another (at developing prices, L334 is not included in the final least-cost set).

Finally, in the case of the various excavation/hauling scenarios, the situation is more like that in the first group of projects, although maintenance and user costs are constant across all projects at a single design standard. At the level of partial construction costs, generally only one project, that with the shortest set of haul distances (p L311, H312), shows up as least-cost. The addition of surfacing materials, which are the same across all projects at one design standard, generally obscures any differences among projects, however. Maintenance and user costs complete the process for the few remaining cases where distinction is still possible.

Looking across the technologies in these three project groups for the various cost components shows basically that which is expected. At the prices of 1930 and 1974, the least-cost projects in terms of partial construction costs are those using the 1970's technology; in the case of total construction costs, the 1950's technology frequently enters the least-cost set along with the 1970's. Similarly, at the prices of a developing country, in the partial construction cost case the 1920-70 technology mix generally stands alone as least-cost, while in the total construction cost case the 1920's technology generally joins it. This progression continues until, as noted above, in the total project cost case it is not uncommon for all technologies to end up in the least-cost set.

In order to gain some feeling for the relative magnitudes of these various cost components as well as their change over time in the U.S. and for the rather overshadowing influence of materials and user costs, various cost data are plotted for a road at each design standard in Figure 3.5. Much as observed in the stage-level analysis, technology change in highway construction between the 1920's and 1970's seems to have nearly offset the coincident inflation in labor and capital prices, as indicated by the graph of partial construction costs. At the total construction cost level, assuming no change in materials usage, technology change appears to have been instrumental in keeping cost increases between 1930 and 1974 down to a factor of about 1.7; this is somewhat less than the cost increase observed for materials over that period, and about half of what construction cost increases would have been had technology not changed. The cost-reducing influence of technology change in highway construction appears to be rather diminished at the total project cost level due to the magnitude of user costs, the technology of which along with that of maintenance is assumed constant at today's. Project cost increases on the order of 3.5 are exhibited between the 1920's and 1970's, notably less than those in maintenance and user costs but only slightly less than those expected had technology not changed. Had the 1950's and 1970's technologies similarly been compared at 1956 and 1974, it is expected that the diminishing role of technology change would be more evident at the total construction cost level, due to the relative magnitudes of materials and partial construction costs.

At this point it is appropriate to look at some of the components comprising these various cost items. As expected, labor's share of partial construction costs decreases while capital's increases with the progression in technology; moreover, labor's share in the high standard project is somewhat less than in the low standard one, primarily as a result of the large amount of earthwork required in the high standard design, activities which are highly capital-intensive. Nevertheless, labor's share looks somewhat low relative to capital's, with the exception of the 1920's technology at 1974 prices. A possible explanation is that expenses for labor beyond the basic wage and fringe benefits (e.g., social security [FICA], workmen's compensation insurance, and unemployment, amounting to about 15 percent in 1974 [54]) are included in overhead and profit, although mobilization costs for equipment are also included there, rather than directly with the labor and capital costs, respectively.

Proceeding to examine total construction costs, the cost of labor and capital relative to that of materials appears to be too small, with the exception of the 1920's technology at 1974 prices. A number of factors account for labor and capital's share being too low; these include: (1) the figures represent the best-practice technical packages for each period, selected under the assumption that the project at hand is part of a larger project, and there is thus no constraint as to minimum period of use of any package on the project or need for coordination of packages among activities (using an average-practice technical package in the case of excavation/hauling in the 1970's, for example, might increase the unit cost of the package by a factor of less than 2 to over 3 depending upon the haul distance); (2) as indicated above, additional expenses associated with labor, as well as mobilization and any other fixed costs associated with capital, are included in overhead and profit, which is expressed as a percentage of all direct costs, although it might be more appropriate, at least for overhead associated directly with labor and capital, to express it as a percentage of the labor and capital costs and to include it with them (especially in light of the fact that a charge for transport costs to the site is included in the cost of materials); and (3) in the case of the low standard road at least, there is very little earthwork, which is where the sizable labor and capital requirements appear, and thus the project is largely surfacing, which is oriented more toward materials than toward labor and capital.

The share of materials in total construction costs may appear to be high for a few additional reasons, as follows: (1) the quantity of surfacing materials required is rather sizable, especially that of gravel due to the rather low subgrade strength (e.g., p L114 requires 29.2 centimeters [11.5 inches] of gravel and p H315 requires 33.0 centimeters [13.0 inches]); and (2) the surfacing materials, particularly the aggregate, may be higher quality than is necessary for road construction and may thus be overpriced, as data on materials is largely for building, not heavy, construction (e.g., aggregate is often given in conjunction with concrete, suggesting it is probably cleaner and more accurately sized than is necessary for many highway projects). Finally, minor structures are not included in the construction costs, and these could be expected to augment both labor and capital costs and materials costs.

Looking at the bar graphs of total project costs, the magnitude of user costs relative to other project costs is evident, and as expected, is somewhat greater in the high standard design with the higher traffic volume. Maintenance costs are, as expected, significantly less than construction costs, and both represent a smaller share of the costs in the high standard/traffic volume project. Finally, several of the comments made above would serve to augment construction's part in overall project costs.

4.22 Summary and Implications of the Results

The efficiency analysis yields the following results: (1) the apparent existence of economies of scale among projects for various traffic volumes; (2) an indication of the efficient surfacing materials alternatives (generally all except waterbound macadam [p L214, H215] which appears in the high standard case when bitumen is expensive), efficient subgrade strength/surface design alternatives (all but the one which is properly designed on a weak subgrade [p L324, H325]), and efficient excavation/hauling scenarios (that with the shortest set of hauls [p L311, H312]); and (3) an indication of the overall efficient technologies under various price conditions (1970's at 1930 and 1974 and 1920-70 mix at developing). The significance of these results becomes questionable, however, when the results of the least-cost analysis show all projects, or at least two out of three, to be within 10 percent of each other in total project costs. Similarly, for a particular project group/design standard, all technologies or at least two of them are found in the overall least-cost set.

Upon disaggregating the total project costs to their various components, distinctions among projects again become evident, most clearly at the level of maintenance costs and least so at the level of user costs;

this latter cost item generally dominates the outcome at the total project cost level with only an occasional influence from the construction or maintenance cost level. Moreover, the technologies also regain their distinction, with one technology (1970's at 1930 and 1974; 1920-70 mix at developing) showing up in the overall least-cost set at partial construction costs, and two (1970's and 1950's at 1930 and 1974; 1920-70 mix and 1920's at developing) at total construction costs. Such disaggregation, however, does little to help in the analysis of project alternatives where materials, maintenance, and user costs vary, as in the case of two of the project groups under study. An incremental analysis, such as that given as an example in Table 4.3, where the overall least-cost project/technology combination at 1974 prices (i.e., L314 at 1970 and H415 at 1970) is used as a base to be subtracted from the other projects in the group, sheds little further insight into the problem. Although sizable cost differences and greater distinctions seem to appear among the various projects and technologies, their significance is questionable; that is, many of the incremental costs, at the more aggregate and user cost levels in particular, represent only a small share of their respective total costs, an observation in accord with that of insensitivity in the full cost analysis in Table 3.11.

It is apparent, nevertheless, that the cost-reducing influence of technology change in highway construction on project costs is indeed significant. At the disaggregate level of partial construction costs, for example, technology change between the 1920's and 1970's appears to

Table 4.3: Incremental costs (in $1000), over the base case at each design standard, of each project/technology combination, for all surface materials alternatives and all technology periods, at the prices of 1974, for the various cost components (source: Table C.5).

Design Standard/ Technology Period/ Project	Construction Costs		Operation Costs[b]		Total Project Costs[b]
	Partial[a]	Total	Maintenance	User	
Low Standard Design					
Base Case					
1970-L314	32.9	501	199	2416	3115
Incremental Values					
1920-L114	+206	+195	+58	+443	+696
-L214	+305	+327	+114	+139	+580
-L314	+251	+302	0	0	+302
1950-L114	+8.2	-43	+58	+443	+458
-L214	+27.2	-7	+114	+139	+246
-L314	+12.7	+16	0	0	+16
1970-L114	-2.7	-56	+58	+443	+445
-L214	+10.8	-26	+114	+139	+227
High Standard Design					
Base Case					
1970-H415	138	789	187	15171	16147
Incremental Values					
1920-H215	+1024	+1179	+250	+1260	+2689
-H315	+950	+1133	+125	+604	+1862
-H415	+1083	+1300	0	0	+1300
1950-H215	+94	+63	+250	+1260	+1573
-H315	+75	+82	+125	+604	+811
-H415	+100	+121	0	0	+121
1970-H215	-4	-55	+250	+1260	+1455
-H315	-18	-29	+125	+604	+700

Note: The base case is the overall least-cost project/technology combination at 1974 prices and is subtracted from the other combinations to give the incremental values.

[a] Include cost of labor and capital used in construction, although site preparation materials (≤4% of this cost item) are also included in the few cases where they are used.

[b] Expressed in net present value terms, the discount rate being 8%.

essentially offset inflation in factor prices. Upon aggregation in the direction of total project costs, however, other factors come into view, materials and user costs in particular. In order to study the overall impact of technology change on highway construction and use in the U.S., be the technology change via the technical packages of construction, materials usage, maintenance policies and procedures, or transport technology, studies similar to the one at hand are first needed in these other areas as well; the results of the construction-based study are reasonably encouraging, at least in terms of past trends. Knowledge of the trends of the past as well as the expectations for the future in all of these areas in the U.S. is of importance. As noted in the stage-level analysis, the modification and use of existing or development and use of new materials, for example, is seen as necessary for future advances in the area of equipment as well as in that of materials conservation. The role of user costs in total project costs is such as to warrant major studies in the area of transport technology and its development; important, too, is the development of more sensitive models for measuring user costs. Finally, future studies should involve a broader set of projects and eliminate some of the shortcomings and limitations of the current study such as explicit consideration of mobilization costs and project size.

On a somewhat different note, a few comments remain to be made about the implications of this analysis for developing countries. The results, in terms of alternative construction methods, certainly do look promising.

That is, under developing conditions, admittedly rather extreme ones, the 1920's fully labor-intensive, animal-powered packages do appear as least-cost for all stages except waterbound macadam surfacing and double bituminous surface treatment. Further testing is certainly needed, however, with regard to the range of economic conditions under which this occurs. As noted in the stage-level analysis, the case is potentially strengthened by consideration of possible productivity improvements and inclusion of mobilization and other fixed costs associated with heavy equipment. It should further be noted, however, that as in the U.S. situation, research is also needed in the areas of materials usage, maintenance policies and technology, and, probably most importantly, transport technology, if project costs are to be minimized.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

5.1 Conclusions

The role of technology in the productivity of highway construction over the years in the U.S. appears indeed to have been a significant one. Highways can be constructed today using considerably less labor and even less capital than was possible in the second and third decades of this century. These advances in highway construction technology appear to have played a major part in keeping project costs down, essentially offsetting, or more than offsetting, inflation in the prices of labor and capital between the 1920's and 1950's, and keeping labor and capital cost increases down to a factor of two between the 1950's and 1970's; it should, at the same time, however, be noted that at the level of total project costs, the cost-reducing influence of such technology change tends to be overshadowed by other cost components, user costs being most dominant.

Efficiency seems to have played a major role in the observed technology change, although the magnitude and rate of the decrease in resource requirements attributable to efficiency has lessened over time. For most stages of highway construction, efficiency appears to be responsible for some 80 to 95 percent of the drop in labor required, with bias toward labor-saving accounting for the remainder. This labor-saving bias, however, has become increasingly costly in terms of capital, to the point of overshadowing efficiency's reducing effect on the capital requirements in a few stages of construction. Part of what is interpreted as bias may, in fact, be due to the discrete, as opposed to continuous, nature of production functions. As for substitution brought about by factor price changes, it seems to have had effectively no part in the technology change observed. Constant returns to scale are assumed, but it is suspected that some of the technology change attributed to efficiency may, in fact, be due to economies of scale, in light of the coincident changes in equipment capacity and project scale over time.

Increased mechanization and introduction of new types of equipment appear to constitute the primary means of accomplishment of such technology change between the 1920's and 1950's in the U.S., while between the 1950's and 1970's it is largely just improving the equipment and the effectiveness with which it is used. A primary motivation in all of this has likely been the stability of the market in highway construction, a government-funded operation. Reasonably stiff competition among equipment manufacturers, along with changes in highway design and project scale and some standardization of design features, in part a result of the interstate program, has also undoubtedly motivated technology change. As for its being in the direction of increasing capital intensity, it should be remembered that it is primarily the equipment manufacturers who do the research; it also seems likely that expectations of labor's cost rising relative to that of capital have tended to induce technology change in the direction of saving labor although no substitution was observed.

As for the future, these same basic motivations are expected to continue, although some switching of emphasis toward the repair and upgrading of highways, as opposed to new construction, and toward other modes of transportation may dampen some of them a bit. Energy and materials conservation is also expected to be of increasing interest. As for means of accomplishing technology change in the future, a continuation of past trends of improving the equipment and, more importantly, improving the effectiveness with which it is used is expected. Research in materials and standardization of specifications and road designs among other advances in project design may assist in the advancement of equipment as well as in the conservation of materials. Research in the area of fuel conservation and use of alternative fuels in relation to equipment use is also of importance; the likely incompatibility of using bigger, more powerful equipment and conserving fuel in the future reemphasizes the importance of the effectiveness with which equipment is used.

It has thus been observed in the course of this research that gains in both labor and capital productivity and efficiency in highway construction over the years in the U.S. have been substantial, resulting in certain offsetting of factor price increases. Nevertheless, if trends of the past are indicative of the future and a continuation of past means of accomplishing technology change is to continue as the primary means in the future, then gains in efficiency can be expected to be less than those previously, and labor-saving bias to become increasingly costly and to increasingly overshadow efficiency's effects on capital. This means that labor productivity will increase at a slowed rate, while the productivity of capital will increasingly tend to decline. In line with this, productivity's effectiveness in offsetting factor price increases may be expected to continue to . .ll. At the same time, the somewhat inexplicable substitution of labor by capital may be expected to continue. This suggests that new means of accomplishing technology change in highway construction need to be investigated; moreover, the motivation and meaning of labor-saving bias in the industry ought to be looked into, in order to ascertain its desirability from the viewpoint of all involved.

As for the developing countries, the results of the study, at first glance, appear to be rather negative in terms of the wisdom of their returning to the use of some of the more labor-intensive, animal-powered technologies of the past, in that technology change in highway construction in the U.S. appears to be primarily characterized by efficiency and perhaps some economies of scale, but only a relatively small amount of bias and no substitution. At the same time, however, it was observed that an efficiency analysis over the technical packages of all three periods results in production functions for most stages of construction, ones largely made up of the 1970's fully capital-intensive packages and the 1920's fully labor and animal-intensive packages, with just a couple from the 1950's. Moreover, under the developing conditions outlined in the study, admittedly rather extreme ones, the 1920's packages arise as least cost for all stages except the two higher standard surfaces. The development of technical packages since the 1920's thus seems to have been focused on the capital-intensive end of the production function, where increased efficiency has indeed been achieved; the 1920's labor-intensive packages seem to have been essentially forgotten, although they still appear to be efficient and, under some conditions, economic. It does, therefore, appear to be worthwhile for at least some developing countries to consider potentially using some of the more fully labor and animal-intensive packages of the 1920's, particularly in light of, for example, possible productivity improvements, inclusion of mobilization and other fixed costs associated with heavy equipment, and application of more realistic utilization rates for developing conditions.

5.2 Recommendations for Further Research

The first recommendation for further research is a more in-depth analysis of the means and motivations behind technology change in highway construction in the U.S., past, present, and future. The current research provides greater understanding of the nature and magnitude of technology change over the past fifty years or so; a component, which is still lacking, however, and which is so necessary in guiding the future direction of technology change, is greater insight into why this change occurred — what were the underlying motivations. Moreover, as observed above, the means of accomplishing technology change in the past do not look very promising for the future, and therefore, new approaches to improving resource utilization need to be investigated. Finally too, certain characteristics of the technology change that has been observed, such as the labor-saving bias, are puzzling and need further analysis in terms, for example, of what has motivated them, who benefits, and should such trends be encouraged or discouraged in the future.

A second recommendation is testing and, as appropriate, reducing some of the restrictions in the current research in future studies. Restrictions limiting the general applicability of the results lie, for example, in the assumption of "typical" institutional and environmental conditions and in the limited number of alternative surfaces, designs, and projects investigated. Omission of certain activities, such as minor and major structures and materials production and transport, constitutes another area. A third area of restrictions, and perhaps the most important, is that of simplifying assumptions, such as full utilization of equipment, balancing of additional labor and capital costs above the basic hourly rate and their inclusion in general overhead and profit, constant returns to scale, generally uniform product quality and time to produce a given output across technical packages (excepting, of course, specification of 93 versus 98 percent earthwork compaction and various surfacing materials), and each project's being a part of a larger project thereby being able to use only best-practice technical packages and having no need for coordination of packages. Several of these assumptions relate in one way or another to project scale, an aspect of highway construction definitely warranting further consideration; economies of scale, for example, are felt to be in part, at least, responsible for some of the technology change attributed to efficiency. The feasibility of further analysis of many of these restrictions rests on the availability of data, which is a problem in that historical data often fails to be sufficiently detailed.

A third recommendation is that studies of materials usage, maintenance policies and procedures, and transport technology and their change over time in highway construction and operation in the U.S. be made; the impact of this overall technology change might then be better understood, with the results of this study of the technical packages of construction being reasonably encouraging, at least in terms of past trends. Knowledge of past trends and future expectations is of importance in all of these areas. The modification and use of existing or development and use of new surfacing materials, for example, is perceived to be necessary for further advances in equipment as well as in materials conservation. User costs constitute such a major share of total project costs that studies in the area of transport technology and its development are clearly warranted; also important is the expansion of the data base pertaining to the estimation of road surface deterioration and the impact of design standards and surface conditions on road user costs, making more feasible the development of more sensitive models for measuring user costs.

Investigation of the role of technology in other sectors of the construction industry in the U.S. and elsewhere and its influence on productivity and efficiency and product quality and cost constitutes the fourth recommendation for further research. This is of importance in terms of indicating the direction of technology advance in the past and its potential in the future in these sectors in the U.S. and other developed countries; in the case of developing countries, it is of use in terms of assessing the potential appropriateness of various technical packages. Other areas of heavy construction provide some interesting possibilities for research; in the case of tunneling, for example, the main thrust of technology change has occurred more recently, with research in the area potentially guiding its future path. Building construction is also of interest, particularly in light of the criticism it receives for being slow to adopt advances in technology. The study of technology and productivity in this sector of construction, even narrowing the scope to a single type of building like federal office buildings, is more complex, however, due to the large number of steps in the construction process and difficulties in the measurement of output in quantity, quality, and use terms.

The fifth and final recommendation pertains to developing countries and the additional testing and evaluation of the implications of the research at hand for the developing situation. First and foremost is further testing with regard to the range of economic conditions under which the more labor-intensive technical packages of the 1920's appear to be economic. At the same time it is appropriate to try to alleviate some of the more relevant and restrictive limitations, omissions, and simplifying assumptions discussed under the second recommendation. In view of the small scale projects common in developing countries, for example, explicit inclusion of mobilization and other fixed costs associated with heavy equipment as well as more realistic utilization rates for such equipment seems appropriate; such adjustments would, of course, tend to strengthen the case supporting the use of the 1920's technical packages. Also of importance is investigation of alternative means of improving productivity, perhaps via management, organization, and supervision, tools and simple mechanical aids and the skills necessary to use them, and general physical and social well-being of the workers; in a couple of the case studies reviewed in Section 2.21 (e.g., IBRD-III [38,39,40] and ILO-Philippines [43]), field studies and demonstration projects are successfully used in the development, testing, and implementation of such measures to improve labor productivity. In line with recommendation three above, further study is also needed in the areas of materials usage, maintenance policies and technology, and, probably most importantly, transport technology in the developing countries, if project costs are to be minimized. Of interest, too, as noted at various points throughout the study, is the potential for labor-capital substitution in maintenance, materials production, and major and minor structures construction.

APPENDIX A

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APPENDIX B

CONSTRUCTION TECHNOLOGIES AND COSTS

B.1 Resource Productivities

The productivities of the labor, equipment, and materials included in each technical package are usually derived from a variety of sources, generally at the activities level, under typical institutional and environmental conditions, for each stage of construction for the 1920's, 1950's, and 1970's. In order to remain consistent and logical throughout the course of deriving the various resource productivities, certain assumptions were made at the outset and as necessary throughout this phase of the work.

The more generally applicable assumptions are discussed in Section B.11, while discussion of the stage-specific assumptions is left to Section B.12, where sample calculations of the productivity figures for the various stages of construction are given. These sample calculations serve to demonstrate the estimation procedure and also to give an indication of the range in quality and detail found in the original data; a sample is given for each stage of construction, except in the case of excavation/hauling, where three are given, one for each technology period, since the range of technical packages reviewed is so broad, and in the case of surfacing, where a sample is given for each of the three materials. Table B.1 in Section B.13, then, lists the full set of estimated resource requirements of each technical package for all stages and all three technology periods, as well as identifying the sources for each package. A complete list of sources for this appendix is given in Section B.3. All assumptions and productivity estimations are made with the project-level analysis in mind.

B.11 General Assumptions

As the study is limited to the U.S., it seems appropriate, within reason, to assume that the health and nutritional conditions, work attitudes, and basic quality of the workforce are relatively uniform, the equipment is reasonably fully utilized, the necessary amenities for labor and maintenance and repair facilities for equipment are available, and the work is generally performed on a contract basis and payment of labor is by the hour. The climate is taken as temperate.

Throughout the analysis, normal productivity figures are used as opposed to peak or actual; management is thus assumed to be average to good, and an allowance for the human factor, in the form of minor delays which are generally unavoidable on any job, is included, while major delays, which tend to be highly variable among jobs and are often weather or management-related, are excluded. A default working efficiency factor of 80 percent (i.e., a 48-minute hour) is used when one is not specified for a particular operation; in cases where data is in the form of actual productivities, a default factor of 125 percent is applied to bring the figures up to the level of normal productivities (21, 37, 44, 45). Where the workforce is predominantly unskilled laborers, mostly arising in the 1920's technical packages, one supervisory person (treated as a skilled laborer) per a crew of ten or so men is assumed (26). Finally, parameters of time to complete the job and project scale are not considered, as they are beyond the scope of this analysis, and the necessary data appears to be largely unavailable.

B.12 Sample Calculations of Resource Productivities

Site Preparation: Site preparation consists of brush, tree, and stump removal and burning of the debris; it is measured in hectares or acres, generally including the road and borrow areas. Vegetation is assumed to be medium, with 100 trees/acre averaging 10 in. in diameter (22, 86). For certain site preparation technical packages (e.g., 1950 tp 31), as in the spreading/compaction and surfacing stages, the width of the road may be a factor in resource productivity; in such cases the productivity data for the two road widths designed in Section 3.2 are calculated and averaged to get a figure relatively independent of road width. In the case of site preparation, average cleared widths of 60 ft and 75 ft are assumed for the two design standards, averages being based on the widths obtained under various excavation/hauling scenarios.

Example-1970 Site Preparation Technical Package 21: Dodge (22) cites the following productivities for a 90 fwhp crawler bulldozer, 4 chain saws, 1 pickup truck, handtools, 1 skilled laborer, and 6 unskilled laborers:

Clearing trees less than 6 in. in diameter	- 3 acres/8 hr day
Grubbing and disposing of (burning) stumps less than 6 in. in diameter	- 6 acres/8 hr day
Clearing, grubbing, and disposing of trees greater than or equal to 6 in. in diameter	- 1.5 acres/8 hr day

Peurifoy (57) gives productivity for a 93 fwhp crawler bulldozer with unspecified crew as follows:

Felling trees	2.18 hrs/acre	(49%)
Stacking trees	0.53 hrs/acre	(12%)
Burning	1.75 hrs/acre	(39%)
Total	4.46 hrs/acre	

33.3 gal of fuel per acre used in burning

Assuming the site has 100 trees per acre and their diameters are normally distributed with mean 10 in. and standard deviation 5, there are 33 trees less than 6 in. in diameter and 67 trees with diameters greater than or equal to 6 in. From Dodge:

Clearing trees less than 6 in. -2.67 hrs/acre x 33%	= 0.88 hrs/acre
Grubbing and burning above trees -1.33 hrs/acre x 33%	= 0.44 hrs/acre
Clear, grub, and dispose of trees greater than or equal to 6 in. -5.33 hrs/acre x 67%	= 3.57 hrs/acre
Total time to clear and grub 100 trees	4.89 hrs/acre

The average of this figure with that from Peurifoy is 4.67 hrs/acre.

In order to get individual productivities for equipment and labor, the process is divided into activities using the percentages given in Peurifoy and the crew given in Dodge. It should first be noted that in site preparation, as in excavation/hauling and in the spreading activity of the spreading/compaction and surfacing stages, handtool packages appropriate to the task at hand are assembled and an average initial cost and life for each set estimated; handtool hours, then, are allocated on the basis of man-hours of using the handtools, with each unskilled laborer using no other equipment in a particular task being given such a package.

Brushing and tree removal:

49% of 4.67 hrs/acre	= 2.29 hrs/acre
Equipment: 1 70 dbhp crawler tractor (644)	2.29 hrs/acre
1 8 ft dozer blade (614)	2.29 hrs/acre

Equipment:	4 chain saws (236)	9.16 hrs/acre
Crew:	1 skilled laborer	2.29 hrs/acre
	4 unskilled laborers	9.16 hrs/acre

Stacking: 12% of 4.67 hrs/acre =		0.56 hrs/acre
Equipment:	1 70 dbhp crawler tractor (644)	0.56 hrs/acre
	1 8 ft dozer blade (614)	0.56 hrs/acre
	1 pickup truck (336)	0.56 hrs/acre
	6 handtools (209)	3.36 hrs/acre
Crew:	1 skilled laborer	0.56 hrs/acre
	7 unskilled laborers	3.92 hrs/acre

For burning, Peurifoy cites a different productivity with each of three examples. The average of these three figures is used, rather than the result of applying a percentage (39%) to 4.67 hrs/acre as is done for the other activities; this is to keep the burning productivity the same across all three 1970's technical packages since it is always done the same way.

Burning:		1.75 hrs/acre
Equipment:	6 handtools (209)	10.5 hrs/acre
Crew:	6 unskilled laborers	10.5 hrs/acre
	3/4 foreman	1.31 hrs/acre
Material:	kerosene (823)	33.3 gal/acre

Excavation/Hauling: Loosen and load constitute the first part of excavation/hauling, while load, haul, unload, and return constitute the second ; the units of measure are bank cubic meters or bank cubic yards, where the materials may be from cuts for the road itself or from borrow areas and may be going to the embankment or to spoil. Ordinary/common soil and no rock is assumed, with the soil requiring only a limited amount of loosening; an expansion factor of 25 percent is assumed for this material, which means that output in bank measure is 80 percent of that in loose measure (21, 26, 68). The soil is later made more specifically silty clay as this is one of only a few materials for which a relationship could be found in the literature between the amount of compaction and subgrade strength.

The condition of the haul route is assumed to be average to good, while the distance is allowed to vary. A total of 7 haul distances* ranging from 6M (20ft) to 800 M (2625 ft) are derived for the two basic road designs under various borrow situations in Section 3.2; these fall into three groups of haul distances represented by 6, 100, and 800 M (20, 330, and 2625 ft) in the stage-level analysis. The original plan had been to use a simple equation for the hauling activity, with both a constant and distance-dependent component, but this proved infeasible for much of the 1950's and 1970's equipment where data is sufficiently detailed as to show variations in haul speed with the distance traveled; productivities are thus calculated for each individual haul distance. The productivity of elevating graders (1920 tp 8-7, 9-7; 1950 tp 4-2, 4-4), in particular, is dependent upon the length of the cut in which they are working, 450 ft being assumed as it appears to be a common size; such equipment is generally used in borrow pits, as its turning radius is also quite large (31, 33, 56, 77). It thus follows naturally that a minimum haul distance associated with such excavating equipment would be 200 ft or so.

Example 1-1920 Excavation/Hauling Technical Package 1-1: The most labor-intensive excavation/hauling method employs men with handtools (picks and shovels) for loosening and loading and men with wheelbarrows for trans-

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*The project-level analysis requires an additional, essentially no haul (2 M or 7 ft) situation in the form of ditch excavation; for the 1950's and 1970's a special technical package (1950 tp 11-0; 1970 tp 14-0) is defined for this, while for the 1920's any package up to and including 6-5 can be used.

porting the earth. Data for loosening is as follows:

Material	Productivity	Source
common loam	4 bcy/hr	Arthur (12)
light sand	6 bcy/hr	Arthur (12)
medium soil	2-4 bcy/hr	Pulver (58)
average	35-40 bcy/10 hr day	Gillette and Black (26)

Converting these numbers to units of hr/bcy and averaging gives 0.255 hr/bcy for men loosening soil with handtools.

The data for loading is given in both bank and loose measure:

Material	Productivity	Source
common earth	1-1.25 bcy/hr	Arthur (12)
loose earth	2 lcy/hr	Arthur (12)
sand	0.40-0.80 hr/lcy*	Pulver (58)
loam	0.40-1.00 hr/lcy*	Pulver (58)
medium soil	0.50-1.00 hr/lcy*	Pulver (58)

Converting loose to bank measure by multiplying by 0.80 and inverting where necessary, the data becomes:

0.889 hr/bcy
0.625
0.750
0.875
0.938

average - 0.813 hr/bcy

This is the productivity for men, handtools, and wheelbarrows during loading.

Finally, for the hauling, Pulver (58) gives the capacity of a wheelbarrow as 0.07-0.12 bcy and the speed as 75-125 fpm loaded and 100-175 fpm empty. Averaging, the wheelbarrow will hold 0.095 bcy and has a speed of

*These figures are for a lift height of 4 ft or less, which is appropriate for both the wheelbarrow and handcart modes of transport.

119 fpm. In addition, the same source gives the dump time as 0.20-0.30 min, for an average of 0.25 min. The productivity of the wheelbarrow for the haul, dump, and return cycle is thus $\frac{0.25 \text{ min/load}}{60 \text{ min/hr} \times 0.095 \text{ bcy/load}}$ or 0.0439 hr/bcy plus $\frac{1.40 \times 10^{-4} \text{hr/load-ft traveled}}{0.095 \text{ bcy/load}}$ or 2.96×10^{-3} hr/bcy per ft of haul distance.

Final productivities are as follows:

Handtools (202)	0.255 hr/bcy	- loosening
	0.813 hr/bcy	- loading
	1.068 hr/bcy	- total

Wheelbarrow (301) $0.813 + 0.0439 + 2.96 \times 10^{-3} \times$ (Haul distance)

6 M/20 ft	0.916 hr/bcy
100 M/330 ft	1.83 hr/bcy
800 M/2625 ft	8.62 hr/bcy

Unskilled labor - productivity of handtools plus that of wheelbarrow less the time for loading (0.813 hr/bcy)*

6 M/20 ft	1.17 hr/bcy
100 M/330 ft	3.09 hr/bcy
800 M/2625 ft	8.87 hr/bcy

Skilled labor - 1 supervisory person per 10 unskilled men except during actual transport or 0.111 hr/bcy

Example 2 - 1950 Excavation/Hauling Technical Package 2-2: The cycle for the power shovel is load bucket, swing to haul vehicle, dump load into vehicle, and return to excavation site. The U. S. Bureau of Public Roads

*In labor-intensive operations where the transport equipment is separate from the excavating equipment (as in 1920 tp 1-1, 1-2, 2-1, 2-2, 3-1, 3-2), it is reasonable to assume that during loading the man operating the transport vehicle either assists in the loading operation or leaves the vehicle to be loaded by others while he moves an already loaded vehicle.

production studies (77) include the following data for five 2 cy power shovels loading earth:

Average dipper load	1.4 bcy
Average productivity (production/net available working time - i.e., normal productivity)	121.3 bcy/hr

One may then calculate dipper loads per hour and productivity in hours per cubic yard:

$$\frac{121.3 \text{ bcy/hr}}{1.4 \text{ bcy/dipper load}} = 86.6 \text{ dipper loads/hr}$$

$$1/121.3 \text{ bcy/hr} = 0.00824 \text{ hr/bcy}$$

Peurifoy (56) states that a 2cy power shovel, with 90° swing, under excellent management and job conditions, at its optimum face height (10.2 ft), operating in good common earth, has a productivity of 300 bcy/hr. This should be reduced by 20% for operation at 40% of optimum height*, and by 25% for average to good management and job conditions:

$$0.80 \times 0.75 \times 300 = 180 \text{ bcy/hr} \quad \text{or } 0.00556 \text{ hr/bcy}$$

At an average dipper load of 0.80 x 2.0 cy = 1.6 bcy, this is equivalent to:

$$\frac{180 \text{ bcy/hr}}{1.6 \text{ bcy/dipper load}} = 112.5 \text{ dipper loads/hr}$$

To arrive at a final productivity for the power shovel (232) and its skilled operator, the two figures derived above are averaged: 0.00691 hr/bcy.

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*A power shovel can only be effectively used in deep cuts along the road or in borrow pits; cuts along the road could vary in depth, but those in borrow pits are assumed to be some 9 feet, restricted to such depth since it assumed that just common/ordinary soil is being borrowed from pits reasonably near the road and that this is about as deep as such soil might be expected to go.

Also involved in the excavation and loading process is the haul vehicle, which in this case is a 20 ton, 15cy rear dump truck. Its productivity during loading is the same as that of the power shovel, since its loading time is constrained by the speed of the excavator. The rest of the cycle for the truck is haul, dump, turn, and return. Depending on the operating conditions, Kellogg (46) cites 1.50 and 2.00 min for dumping and turning, while Stubbs (63) gives 1.00 and 1.30 min for the same activities. The average of these four figures is 1.45 min and adding 25 percent for delays results in a time constant of 1.81 min. This is equivalent to:

$$\frac{1.81 \text{ min/load}}{60 \text{ min/hr} \times 15 \text{ bcy/load}} = 0.00201 \text{ hr/bcy}$$

Kellogg, Peurifoy, and Stubbs each give several figures for truck maximum travel speed. For this study, round numbers in the center of the range were chosen. Hence, 30 mph and 18 mph were used for maximum travel speeds empty and loaded, respectively. Reduction factors from Stubbs were applied to account for the extent to which acceleration and deceleration times affect the average speed for each haul distance. The final speeds used are:

Haul Distance	Average Speed (mph) Loaded	Average Speed (mph) Empty
6 M/20 ft	3.6	6.0
100 M/330 ft	3.6	6.0
800 M/2625 ft	10.7	17.9

Final productivities consist of the loading time (0.00691 hr/bcy) and the time constant (0.00201 hr/bcy) plus a distance dependent component. For the 20 ft and 330 ft hauls, the average speed is 4.8 mph or 422 fpm. This becomes 2.63×10^{-6} hr/bcy per ft traveled or 5.26×10^{-6} hr/bcy per ft of haul distance. Similarly, for the 2625 ft haul, the speed is 14.3 mph which is equivalent to 1.77×10^{-6} hr/bcy per ft of haul distance.

The final productivities for the various distances for both trucks (333) and their skilled drivers are:

Haul Distance	Productivity (hr/bcy)
6 M/20 ft	$.00691 + .00201 + 20\ (5.26 \times 10^{-6}) = 0.00903$
100 M/330 ft	$.00691 + .00201 + 330\ (5.26 \times 10^{-6}) = 0.0107$
800 M/2625 ft	$.00691 + .00201 + 2625\ (1.77 \times 10^{-6}) = 0.0136$

Example 3 - 1970 Excavation/Hauling Technical Package 9-12: This excavation method employs a wheel scraper, which has a capacity of 14 lcy struck or 20 lcy heaped and a 300 fwhp, two wheel tractor as its prime mover. In addition, a 270 fwhp bulldozer is used as a pusher during loading. Havers and Stubbs (34) cite the following data for this size scraper:

Average payload	16.0 bcy
Average time to load	0.68 min
Fixed time at dump (turn and dump)	0.70
Turn time at excavation	0.25
Total	1.63 min

Adding 25% for delays to the total, the time constant becomes 2.04 min, which is equivalent to a productivity of:

$$\frac{2.04 \text{ min/load}}{60 \text{ min/hr} \times 16.0 \text{ bcy/load}} = 0.00213 \text{ hr/bcy}$$

To this must be added the distance dependent portion of the cycle time.

Day (18) uses 0.4 min and 0.7 min as acceleration, deceleration, and braking times for shifting between first and second and between first and third gears, respectively. For a 14/20 cy scraper operating on a 4 percent effective grade (equivalent to flat terrain and 80 lb/ton rolling resistance), Caterpillar (21) gives maximum speeds of 21.0 mph (1848 fpm) loaded and 29.5 mph (2596 fpm) empty, and an average of 4.3 mph (378 fpm) in low gear.

For the 20 ft haul, done in low gear, and therefore necessitating no gear changes, the effective speed is 4.3 mph or 378 fpm. Thus:

$$\frac{2.64 \times 10^{-3} \text{ min/load-ft traveled}}{60 \text{ min/hr} \times 16.0 \text{ bcy/load}} = \begin{array}{l} 2.75 \times 10^{-6} \text{ hr/bcy per ft} \\ \text{of distance traveled or,} \end{array}$$

$$2.75 \times 10^{-6} \times 2 = 5.51 \times 10^{-6} \text{ hr/bcy per ft of haul distance}$$

For a distance of 330 ft, hauling is done in second gear. The effective speed is obtained by dividing the distance traveled by the total time, which includes travel time and acceleration, deceleration, and braking time:

$$\frac{330 \text{ ft}}{\frac{330 \text{ ft}}{1848 \text{ fpm}} + 0.4 \text{ min}} = 570 \text{ fpm} = 6.5 \text{ mph}$$

The return trip may or may not be made in third gear. If it were, the effective speed would be:

$$\frac{330 \text{ ft}}{\frac{330 \text{ ft}}{2596 \text{ fpm}} + 0.7 \text{ min}} = 399 \text{ fpm} = 4.5 \text{ mph}$$

Since this is slower than the haul speed, the return trip is also made in second gear, at 6.5 mph. A calculation similar to the one shown above for the 20 ft haul results in a productivity of 3.65×10^{-6} hr/bcy per ft of haul distance.

Finally, for the 2625 ft haul, there are different speeds for haul and return. For haul, the speed is:

$$\frac{2625 \text{ ft}}{\frac{2625 \text{ ft}}{1848 \text{ fmp}} + 0.4 \text{ min}} = 1442 \text{ fpm}$$

and for the return the speed is:

$$\frac{2625\ \text{ft}}{\frac{2625\ \text{ft}}{2596\ \text{fpm}} + 0.7\ \text{min}} = 1534\ \text{fpm}$$

The average of these two numbers is 1488 fpm or 16.9 mph, which is 1.40×10^{-6} hr/bcy per ft of haul distance.

The final productivities for the scraper/two wheel tractor combination (651) and a skilled operator for each haul distance are:

Haul Distance	Productivity (hrs/bcy)
6 M/20 ft	$0.00213 + 20(5.51 \times 10^{-6}) = 0.00224$
100 M/330 ft	$0.00213 + 330(3.65 \times 10^{-6}) = 0.00334$
800 M/2625 ft	$0.00213 + 2625(1.40 \times 10^{-6}) = 0.00581$

The amount of time the pusher is used depends on the total cycle time which, in turn, depends on the haul distance. The cycle time for the pusher is load time plus exchange time, which is the time for it to go from one scraper to the next. For example, it takes

$$\frac{2625\ \text{ft} \times 2}{1488\ \text{fpm}} + 2.04\ \text{min or } 5.57\ \text{min}$$

for a 14/20 cy scraper to load, haul, dump, and return 2625 ft. At this distance, the pusher cycle is 0.68 min to load plus 1.00 min to exchange. One pusher bulldozer can thus service $\frac{5.57}{1.68} = 3.3$ scrapers. Rounding this ratio to one pusher for three scrapers, the productivity of the pusher and its operator in hrs/bcy is one-third that of the scraper. For the other haul distances, one pusher can service only two scrapers, making its productivity half that of the scraper. Final productivities for the pusher bulldozer (616,653) and its skilled operator are:

Haul Distance	Productivity (hrs/bcy)
6 M/20 ft	(1/2) x .00224 = .00112
100 M/330 ft	(1/2) x .00334 = .00167
800 M/2625 ft	(1/3) x .00581 = .00194

Spreading/Compaction: Spreading/compaction is made up of the activities spread, compact, and finish; it is measured in bank cubic meters or bank cubic yards and pertains to subgrade materials coming from cuts for the road or from borrow areas and going to fills for the embankment. Some 95 to 100 percent of standard AASHO compaction, achieved at some $\pm$ 2 percent of the optimum moisture content, appears to be an acceptable level of compaction for embankments in recent years (35, 87, 91, 93); that is, the ratio of the actual dry density of the compacted soil to the maximum dry density obtainable in standard lab tests, achieved at $\pm$ 2 percent of the optimum moisture content, is .95 - 1.00 with .98 being used in the current study. Taking the mass and cross-sectional area as constants, density becomes proportional to the inverse of the thickness of the layer, or

$$\frac{\text{actual dry density}}{\text{optimal dry density}} = \frac{1/(\text{actual thickness})}{1/(\text{optimal thickness})} = .98$$

A shrinkage factor of 20 percent appears to be the best obtainable for common/ordinary soil, resulting in a compacted to bank ratio of 0.80 and a compacted to loose ratio of 0.64 (21). The optimal thickness is thus 64 percent of the loose thickness while the actual thickness is the compacted thickness; thus:

$$\frac{1/(\text{compacted thickness})}{1/(.64\ \text{loose thickness})} = .98, \text{ or}$$

$$\text{compacted thickness} = .65\ (\text{loose thickness})$$

Loose layers of 9 in. appear to be commonly used and are thus assumed, resulting in 5.9 in. compacted layers (35, 87, 91, 93).

Such compaction is standardly achieved by the rollers of the 1950's and 1970's, and data is generally available on the number of passes required to do so at or near the optimum moisture content. Data on compaction for the 1920's is particularly sparse, however; by means of a British publication (61), among others (15, 35), which relates material dry density to number of passes for a few materials at or near optimum moisture content and a couple of rollers, it is determined that the powered roller of the 1920's might reasonably achieve 98 percent compaction, while the horse-drawn roller requires an inordinate number of passes (29) to do so. Resource requirements for the horse-drawn roller are thus determined for two levels of compaction, 98 and 93 percent, the second being achieved with 6 passes, the same number as is required by the 1920's powered roller to achieve 98 percent compaction; 93 percent compaction represents a compacted to loose ratio of 69 percent, or a 9 in. loose layer compacted to 6.2 in. At the project-level, then, the trade-offs among subgrade strength, surface design, and product quality (as measured by maintenance and user costs) can be investigated to some extent.

Example - 1950 Spreading/Compaction Technical Package 31: This package makes use of a 10 ft blade grader for spreading and leveling and a sheepsfoot roller drawn by a 70 dbhp crawler tractor for compacting. Stubbs (63) gives the following basic equation for time (in hrs) required to grade a given length of road:

$$T = \frac{N \times D}{S \times E}$$

where		
	N = Number	S = Effective speed (mph)
	D = Distance (mi)	E = Efficiency factor

The number of passes required depends on the effective width of the grader, the width of the road, and the number of passes over any given spot necessary to satisfactorily spread and level the earth. The roads considered here are 28 ft and 40 ft wide at the bottom of the fill layer and 24 ft and 36 ft wide at the top. Peurifoy (56) suggests using 75 percent of the blade length as the effective width of the grader to account for the tilt of the blade. Allis-Chalmers (8) cites 3 passes per layer as sufficient for a blade grader spreading earth. Therefore, the total number of passes required is either:

Passes to Cover		Passes/Layer	
$\frac{28\text{ ft}}{0.75 \times 10\text{ ft}}$	x	3	= 4 x 3 = 12 passes, or
$\frac{40\text{ ft}}{0.75 \times 10\text{ ft}}$	x	3	= 6 x 3 = 18 passes

In order to make the results somewhat road independent, the average of 12 and 18 or 15 passes is used. Kellogg (46) suggests spreading is done in first or second gear at speeds of 1.83 mph or 3.80 mph. Averaging these numbers results in a speed of 2.81 mph. Stubbs gives an efficiency factor of 0.60, and Kellogg uses 0.75. The average of these, 0.68, is used and is assumed to account for turns as well as delays. Therefore, no further reduction of travel speed is necessary. The time required to spread and level earth for one mile of road is:

$$T = \frac{15\text{ passes} \times 1\text{ mi/pass}}{2.81\text{ mph} \times 0.68} = 7.85\text{ hrs}$$

The thickness of the spread layer is 7.2 in. bank measure, making the volume of the earth spread in 7.85 hrs:

$$\frac{7.2\text{ in.}}{36\text{ in./yd}} \times \frac{26\text{ ft} + 38\text{ ft}}{2 \times 3\text{ ft/yd}} \times 1760\text{ yd} = 3755\text{ bcy}$$

This is equivalent to a final productivity of 0.00209 hr/bcy for the grader (420) and its skilled operator.

The sheepsfoot roller is commonly used as two 4 ft drums mounted side-by-side and pulled by a tractor. The basic equation for roller productivity, given by the U.S. Department of the Army (94), is:

$$\text{Productivity (hrs/bcy)} = \frac{N}{L \times W \times S \times E}$$

where
N = Number of passes per layer
L = Lift thickness (yd, bank measure)
W = Effective width of roller (yd)
S = Effective speed (yd/hr)
E = Efficiency factor

Data from Allis-Chalmers (8), Peurifoy (56), and Walker (88) suggest that the number of passes should be 10. As in spreading, the lift thickness is 7.2 in. or 0.20 yd (bank measure). The effective width of the two rolls is 8 ft minus 1.5 ft for overlap of passes, which is 6.5 ft or 2.17 yd. Allis-Chalmers and Walker cite travel speed as 2.5 mph. For a 1500 ft pass length, with a 0.5 min turn time as given by Kellogg (46), the effective speed is:

$$\frac{1500 \text{ ft}}{\dfrac{1500 \text{ ft}}{2.5 \text{ mph} \times 88 \text{ fpm/mph}} + 0.5 \text{ min}} = 206 \text{ fpm} = 4118 \text{ yd/hr}$$

The efficiency factor is 0.80, or 25 percent delays. The final productivity of the roller (502), tractor (641), and skilled operator is:

$$\frac{10 \text{ passes}}{0.20 \text{ yd} \times 2.17 \text{ yd} \times 4118 \text{ yd/hr} \times 0.80} = 0.00700 \text{ hr/bcy}$$

Surfacing: The activities involved in surfacing vary with the material, as does the quality of the final product; the activities involved in materials production and transport to the site are included in the cost of the material rather than as a surfacing activity. The resource productiv ities associated with the various materials are assumed to be the same regard less of whether the material is used as a subbase, or surface; an exception to th is double bituminous surface treatment, where the quantity of primer used on a waterbound macadam base is estimated to be half that used on a gravel one. In deriving materials productivities, an extra 5 percent is included to account for losses in haulage and construction (41). Labor and equipment productivities are based on materials in place, and thus on materials productivity before inclusion of the loss factor. An effort is made to base the derivation of materials productivity on designs generally spanning all three technology periods.

Gravel Surfacing: Spreading, compacting, and finishing the gravel constitute gravel surfacing, given the assumption that the gravel is purchased and arrives on the site properly mixed and with a moisture content such that it can be spread and rolled without any sprinkling. Compacted cubic meters or compacted cubic yards are the units of measure. Some 100 to 105 percent of standard AASHO compaction, achieved at some $\pm$ 2 percent of the optimum moisture content, appears to be an acceptable level of compaction for well-graded gravel subbases, bases, and surfaces in recent years (35, 70, 87); as in the spreading/compaction stage above then,

$$\frac{1/(\text{actual thickness})}{1/(\text{optimal thickness})} = 1.02$$

An expansion factor, from bank to loose measure, of some 14 percent appears to be common, while a shrinkage factor, from bank to compacted measure, of some 14 percent appears to be the best obtainable for well-graded gravel (21); the result is a compacted to bank ratio of 0.86 and a bank to loose of 0.88, or an optimal compacted to loose ratio of 0.76.

Thus: $$\frac{1/(\text{compacted thickness})}{1/(.76\ \text{loose thickness})} = 1.02, \text{ or}$$

$$\text{Compacted thickness} = .75\ (\text{loose thickness})$$

Loose lifts of 6 to 8 in. appear to be common (50, 54, 87, 93) except that the British publication (61), used in estimating the number of passes for the 1920's compaction equipment, uses 9 in. lifts. Since the productivities based on 9 in. loose lifts seem rather high, the number of passes indicated by the British publication are used for the 1920's, but 7.5 in. loose lifts are assumed as a compromise. Compacted lifts are thus 5.6 in., which is reasonably compatible with the gravel thicknesses designed in the project-level analysis.

Although the degree of compaction might again be allowed to vary, as in the spreading/compaction stage, compaction in the range of 100 to 105 percent standard AASHO can reasonably be achieved by all rollers in the study (e.g., the horse-drawn roller of the 1920's takes 16 passes while the powered one of that period takes 9 [15, 35, 61]). This variable is thus assumed constant for surfacing.

As for materials productivity, this follows directly from the compacted to loose ratio of 0.75, which inverted becomes 1.33. Adding 5 percent for loss results in a materials productivity of 1.40 loose cubic yards of gravel (830) per compacted cubic yard of gravel.

Example - 1970 Gravel Surfacing Technical Package 22: The methods used for gravel surfacing are similar to those used for spreading and compacting earth. This particular method employs a 385 fwhp crawler tracto with a 14 ft bulldozer blade for spreading and a 25 ton self-propelled, pneumatic roller for compacting. The equations for determining the productivity of the bulldozer are the same as those used for the blade grade in the previous example. Thus the time to spread (in hours) is:

$$T = \frac{N \times D}{S \times E}$$

where N = Total number of passes
D = Distance (mi)
S = Effective speed (mph)
E = Efficiency factor

The blade grader takes 3 passes per layer to achieve satisfactory spreading (8). Assuming the bulldozer is less suited to the task of spreading than is the grader, it must make more passes per layer; 4 passes per laye are thus used. The two roads with gravel surfaces are 24 ft and 36 ft wide at the bottom of the gravel layer. The 14 ft bulldozer blade must make two passes on the narrow road and three passes on the wide one for complete coverage, resulting in total numbers of passes of 8 and 12. As with earthworks, the average number of passes, in this case 10, is used to make the results somewhat road independent. In determining the trave speed, it is assumed that gravel is easier to spread than is soil; therefore, second gear, rather than first, is used. Caterpillar (18) gives this speed as 4.0 mph. Havers and Stubbs (34) state that the time for one gear shift (forward to reverse) is 0.05 min for a power shift vehicle Using a pass length of 100 ft, based on the way in which a bulldozer spreads materials, the effective spreading speed is:

$$\frac{100 \text{ ft}}{\frac{100 \text{ ft}}{4 \text{ mph} \times 88 \text{ fpm/mph}} + 0.05 \text{ min}} = 299 \text{ fpm} = 3.4 \text{ mph}$$

Efficiency is taken as 80 percent, and the total time to spread gravel over 100 ft is thus:

$$T = \frac{10 \text{ passes} \times \frac{100 \text{ ft/pass}}{5280 \text{ ft/mi}}}{3.4 \text{ mph} \times 0.80} = 0.070 \text{ hrs}$$

The lift thickness is 7.5 in. loose or 5.6 in. compacted. The volum gravel spread in 0.070 hrs is:

$$\frac{5.6 \text{ in.}}{36 \text{ in/yd}} \times \frac{24 \text{ ft} + 36 \text{ ft}}{2 \times 3 \text{ ft/yd}} \times \frac{100 \text{ ft}}{3 \text{ ft/yd}} = 51.9 \text{ ccy}$$

The final productivity for the tractor (654), blade (617), and skilled operator is thus 0.00134 hr/ccy.

The productivity of the pneumatic roller is computed in the same way as that of the sheepsfoot roller discussed above:

$$\text{Productivity (hr/ccy)} = \frac{N}{L \times W \times S \times E}$$

where N = Number of passes per layer
L = Lift thickness (yd, compacted measu
W = Effective width of roller (yd)
S = Effective speed (yd/hr)
E = Efficiency factor

Due to the spacing of tires on the roller, two passes over the same area are required to make one complete coverage. Moavenzadeh (50) indicates that 3 complete coverages or 6 passes are necessary to achieve a satisfactory level of compaction. Havers and Stubbs list specifications for seve pneumatic rollers. The average width is 86 in. from which 18 in. is subtracted to account for overlap, resulting in an effective width of 68 in. The same source also cites and average travel speed for this size pneumatic roller as 5.0 mph. Assuming a 1500 ft pass length and using Day's (2 figure of a 20 ft turning distance, the effective speed is:

$$\frac{1500 \text{ ft}}{\frac{1500 \text{ ft} + 20 \text{ ft}}{5 \text{ mph} \times 88 \text{ fpm/mph}}} = 434 \text{ fpm} = 8680 \text{ yd/hr} = 4.93 \text{ mph}$$

The efficiency factor is 80 percent. The final productivity for the roller (537) and its skilled operator is thus calculated as follows:

$$\frac{6 \text{ passes}}{\frac{5.6 \text{ in.}}{36 \text{ in./yd}} \times \frac{68 \text{ in.}}{36 \text{ in./yd}} \times 8680 \text{ yd/hr} \times 0.80} = 0.00294 \text{ hr/ccy}$$

Waterbound Macadam Surfacing: The construction of waterbound macadam consists of spreading very coarse crushed rock (1/2-2 1/2 in.), compacting, spreading screenings (No. 100-3/8 in.), and sprinkling, compacting, and finishing; it is measured in compacted cubic meters or compacted cubic yards. According to the sources discussing waterbound macadam in the 1920's (15, 26), which is when it was most commonly used, nearly a hundred passes are necessary in the final compaction activity in order to properly float the mixture of screenings and water between the crushed rock as a binder; unfortunately, there is no indication of the surface behavior if less compaction is used, so this parameter could not be varie For the 1950's and 1970's, there is a paucity of data on the compaction of waterbound macadam. On the basis of 1920's data (15), it is thus assumed that 8.5 times as many passes are required on the screenings laye as on the coarse crushed rock layer, where the number of passes on the latter is taken as equal to that required for compacting gravel (thicknesses are about the same - gravel: 7.5 in. loose, coarse crushed rock: 7.8 in loose).

As for the specific materials productivities, these come from Gillet and Black (26) but they correspond closely to those discussed by more recent highway engineering sources (54, 60, 91). A compacted thickness of 6 in. is typical for waterbound macadam. For the coarse crushed rock, in. of loose material is placed, yielding a loose to compacted ratio of 1.30, which grows to 1.37 with the inclusion of the 5 percent loss factor 1.8 in. of screenings are placed, yeilding a loose to compacted ratio of 0.30, or 0.32 with the loss factor included. Final materials productivit are thus:

Material	Productivity (qty/ccy of wbm) w/o loss factor	w/ loss factor
coarse crushed rock (831)	1.30 lcy	1.37 lcy
screenings (832)	0.30 lcy	0.32 lcy
water (833)	60 gal	63 gal

Example - 1920 Waterbound Macadam Surfacing Technical Package 111:

This method involved spreading stone and screenings with shovels and rakes, rolling with a 10 ton, 3-wheel roller, and sprinkling with a horse-drawn water wagon. Gillette and Black (26) give the following data for spreading loose stone by hand:

25 lcy in 10 hrs
28 lcy in 10 hrs
25 lcy in 10 yrs
22 lcy in 10 hrs

The average of these numbers is 25 lcy in 10 hrs or 0.40 hr/lcy. Given that there are 1.30 lcy of coarse crushed rock in every cubic yard of finished macadam, this becomes 1.30 x 0.40 = 0.52 hr/ccy of wbm. This is the final productivity for unskilled labor using handtools (401) spreading the stone.

For spreading screenings by hand, Gillette and Black indicate that 10 lcy may be spread in 10 hrs by one man. This is equivalent to 1.0 hr/lcy. There are 0.30 lcy of screenings in every cubic yard of finished macadam, so the final productivity for unskilled labor with handtools (401) spreading screenings is 0.30 x 1.0 = 0.30 hr/ccy of wbm.

The compaction is accomplished with a 10 ton, 3-wheel roller and skilled operator. Gillette and Black give 7 and 8 ccy/hr as productivities. Using the average, 7.5 ccy/hr, and inverting results in 0.133 hr/ccy. After this figure had been calculated and used in the analysis, more information on waterbound macadam surfacing was discovered. Blanchard and Drowne (15) give the following data for compaction of waterbound macadam on a stone base:

2.5 in. of 2.5 in. stone	8 - 10 passes
1.5 in. of 1.5 in. stone	10 - 12 passes
0.5 -1.0 in of screenings	80 - 90 passes

The above were compacted to a final thickness of 4 in. Using the averages of 10 passes on the coarse material and 85 passes on the screenings, one may compute roller productivity. The formula used in the two previous examples requires, in addition to the number of passes, the width and speed of the roller and the lift thickness. Using an 8 ton, 3-wheel roller with 70 in. rolls, as described in Soil Mechanics for Road Engineers (61), and subtracting 18 in. for overlap of passes, results in an effective width of 52 in. or 1.44 yd. Baker (14) suggests 2-2.5 mph as a speed and Blanchard and Drowne suggest 2-3 mph. Using the average, 2.4 mph, as a travel speed and adjusting for turns, assuming 1500 ft pass length and 0.1 min/turn, the effective speed is:

$$\frac{1500 \text{ ft}}{\frac{1500 \text{ ft}}{2.4 \text{ mph} \times 88 \text{ fpm/mph}} + 0.1 \text{ min}} = 208 \text{ fpm or } 4160 \text{ yd/hr}$$

The lift thickness is 6 in. compacted measure or 1/6 yd. The productivity for the roller and operator is, therefore:

$$\frac{95 \text{ passes}}{1/6 \text{ yd} \times 1.44 \text{ yd} \times 4160 \text{ yd/hr} \times 0.80} = 0.119 \text{ hr/ccy}$$

This is some 90% of 0.133 hr/ccy which was calculated initially. Because of the closeness of the two numbers and because that calculated first came from the same source as the rest of the 1920's wbm data and should therefore be compatible, the original calculation was left unchanged. The final productivity for the roller (531) and its skilled operator is thus 0.133 hr/ccy of wbm.

Sprinkling is done with a 450 gal steel tank mounted on a wagon which is pulled by 2 horses. Assuming a haul distance of less than one mile, the roller constrains the productivity of the water wagon according to Gillette and Black, making its production rate the same as that of the roller, 0.133 hr/ccy of wbm.* The final productivities for the wagon (405) and unskilled driver are thus 0.133 hr/ccy of wbm and for the horse 0.267 hr/ccy.

The workforce involved in these activities is largely unskilled, and thus supervisory personnel are needed. Looking at the various productivity figures, it appears that for each roller, a crew of 7 unskilled men is needed (4 spreading coarse stone, 2 spreading screenings, and 1 sprinkling). One supervisory person is thus assigned for every two rollers or every 14 unskilled men. The final productivity of the skilled supervisory personnel is thus:

$$\frac{0.520 + 0.300 + 0.133}{14} = 0.0680 \text{ hrs/ccy of wbm}$$

Double Bituminous Surface Treatment: Double bituminous surface treatment involves sweeping the base, spreading the primer bitumen (light grade), binder bitumen (heavy grade), and quite finely crushed stone (3/8 to 3/4 in.), compacting very lightly, spreading binder bitumen (heavy grade) and even finer crushed stone (No. 8 to 3/8 in.),

*In the 1950's and 1970's, it is similarly assumed that the rolling activity constrains the sprinking activity, but then it is assumed that one water truck can handle five rollers.

and compacting very lightly and finishing. Since this is, as its name suggests, simply a surface treatment, it is measured in square meters or square yards, having a finished thickness of only some 2.2 cm (7/8 in.).

A ratio of 1 to 100 for gallons of binder to pounds of aggregate for each layer appears to be a standard mix for dbst roads; medium curing, cutback liquid asphalt appears to be a commonly used bitumen. It is decided to basically follow the Transport and Road Research Laboratory's design for dbst roads given in Road Note 31 (65), since their surface deterioration models (66) are used in the project-level analysis, and their overall design is reasonably similar to those given by both old and new, U.S.-based, highway engineering sources (16,52, 53,91,93). Primer on a gravel base is applied at the rate of 0.40 gal/sy (including the 5% loss factor, 0.42 gal/sy); on a wbm base it is applied at the rateof 0.20 gal/sy (0.21 gal/sy).* The first course consists of 0.27 gal/sy (6.28 gal/sy) of binder and 27 lbs/sy (28.4 lbs/sy) of aggregate (around 5/8 in.); the second course is somewhat lighter, consisting of 0.22 gal/sy (0.23 gal/sy) of binder and 22 lbs/sy (23.1 lbs/sy) of aggregate (around 3/8 in.). When pricing these materials, it was found that both grades of bitumen and both sizes of aggregate are

*Only in the 1970's is the productivity data such that different labor and equipment requirements can be determined for these two different rates of application of primer; in the productivity data for the 1920's and 1950's technical packages for dbst on gravel and dbst on wbm, therefore, the labor and equipment figures are constant, only the materials figures change.

about the same price, so they are lumped together, with the aggregate being converted to loose cubic yards by applying a factor of 1.35 tons/lcy (22). Final materials productivities are thus:

Material	Productivity (qty/sy of dbst) w/o loss factor	Productivity (qty/sy of dbst) w/ loss factor
dbst on gravel:		
bitumen (835)	0.89 gal	0.93 gal
crushed stone (834)	0.0181 lcy	0.0191 lcy
dbst on wbm:		
bitumen (835)	0.69 gal	0.72 gal
crushed stone (834)	0.0181 lcy	0.0191 lcy

Example - 1950 Double Bituminous Surface Treatment Technical Package 1121: This particular method of constructing a dbst road employs a drag broom pulled by a 1/2 ton pickup truck, a 1,000 gal bitumen distributor with its own truck, a 12 ft spreader box attached to a 10 ton dump truck, and a 5-8 ton tandem roller. Data on the drag broom comes from the U.S. Bureau of Public Roads production studies (77); its production is 6,300 sy/hr, including turns but no delays, based on 7 passes to cover a 21 ft road. The dbst roads considered here are 16 ft and 22 ft wide, which should require 6 to 7 passes for complete coverage. Using the same productivity and applying an efficiency factor of 0.80 results in a production rate of 5040 sy/hr or 0.00020 hr/sy for the drag broom (440) pickup truck (335) and unskilled truck driver.

The same source gives the following productivities for a 1000 gal bitumen distributor:

2.66 mi x 16 ft	3.5 hrs	7146 sy/hr
8.79 mi x 16 ft	12.75 hrs	6473 sy/hr
2.28 mi x 18 ft	188 min	7648 sy/hr
6.00 mi x 18 ft	438 min	8679 sy/hr
0.96 mi x 18 ft	120 min	5069 sy/hr
2.15 mi x 18 ft	172 min	7920 sy/hr
1.90 mi x 18 ft	315 min	3822 sy/hr
3.85 mi x 18 ft	480 min	5082 sy/hr
5.64 mi x 18 ft	585 min	6109 sy/hr

The weighted average of these numbersis 6379 sy/hr, or an effective speed of 1087 yd/hr or 0.618 mph. This includes all delays, turns, etc. The distributor is standardly 16 ft wide with extensions available to make it 18 ft. For the 22 ft road, 2 passes will be necessary to make one coverage. The time required to do one mile of road will be:

$$\text{Time} = \frac{\text{2 passes x 1 mi/pass}}{\text{0.618 mph}} = \text{3.24 hrs}$$

In one mile there are 1760 yd x $\frac{\text{22 ft}}{\text{3 ft/yd}}$ = 12,97 sy, for a productivity of 3988 sy/hr or 0.00025 hr/sy. For the 16 ft road, one pass will be sufficient. Productivity may be calculated as above:

$$\text{Time} = \frac{\text{1 pass x 1 mi/pass}}{\text{0.618 mph}} = \text{1.62 hrs}$$

and

$$\text{Area} = 1760 \text{ yd} \times \frac{16 \text{ ft}}{3 \text{ ft/yd}} = 9387 \text{ sy},$$

for a productivity of 5801 sy/hr or 0.00017 hr/sy. The average of these two is taken, 0.00021 hr/sy, and is then multiplied by 3, since this activity is done three times in the course of construction. Final productivity for the distributor (452), unskilled driver, and skilled operator is thus 0.00061 hr/sy.

Spreading is done with a 12 ft spreader box pulled by a 10 ton, 7 cy truck.* There is one skilled laborer driving the truck, and one unskilled laborer with handtools riding on the back. The U.S. Bureau of Public Roads production studies gives the spread speed as 136 fpm, and the cycle fixed times as:

3.64 min/load - hook up spreader
2.67 min/load - unhook spreader
1.77 min/load - move and maneuver trucks
1.24 min/load - exchange trucks
9.32 min/load - total

For a dbst surface, 0.0181 lcy of aggregate are distributed per square yard in two applications, for an average of 0.00905 lcy/sy per application.

*In the 1950's and 1970's (the situation does not arise in the 1920's), in the excavation/hauling stage where the truck is used in hauling soil, its given volumetric capacity is taken as being bank measure; in the surfacing stages where it is used in hauling aggregate which is denser than soil, its given capacity is taken as being loose measure due to weight limitations.

The 7 lcy truck, therefore, can do $\frac{7 \text{ lcy}}{0.00905 \text{ lcy/sy}}$ or 773 sy/load.

For the 16 ft road, done in 2 passes, 773 sy is equivalent to 290 linear yards. This can be done in $\frac{290 \text{ yd} \times 3 \text{ ft/yd}}{136 \text{ fpm}}$ = 6.40 min. The total time is therefore:

6.40 min/load	- spread time
9.32 min/load	- fixed time
15.72 min/load	- subtotal
3.93 min/load	- 25 percent for delays
19.65 min/load	- total

This is the same as $\frac{60 \text{ min/hr}}{19.65 \text{ min/load}}$ = 3.05 loads/hr. Productivity for this road is, therefore, 3.05 loads/hr x 773 sy/load = 2358 sy/hr or 0.00042 hr/sy. The 22 ft road is also done in two passes, and 773 sy/load is equivalent to 211 linear yd/load. At 136 fpm, it will take 4.65 min to spread one truck load of aggregate. Total cycle time is 4.65 + 9.32 + 25 percent = 17.46 min/load, which is 3.44 loads/hr. Productivity for the 22 ft road is 3.44 loads/hr x 773 sy/load = 2659 sy/hr or 0.00038 hr/sy. The average of the productivity for the 16 ft and 22 ft roads is 0.00040 hr/sy, which must then be multiplied by two to give 0.00080 hr/sy, since this activity is done twice; this then is the productivity of the spreader box (409), truck (332), and skilled driver and of the unskilled helper with his hand tools (408).

Rolling is done with a 5-8 ton tandem roller as suggested by Woods (91). For the size and speed of roller, the average of 6 rollers from a Highway Research Board bulletin (35) is used. The average width is 50 in., for an effective width of 50 - 18 = 32 in. Average intermediate rolling speed is 3.33 mph. Using a pass length of 500 ft and a turning time of 0.10 min (15ft/[1.75 mph x 88 fpm/mph] = 0.10 min), the effective speed is:

$$\frac{500 \text{ ft}}{\frac{500 \text{ ft}}{3.33 \text{ mph} \times 88 \text{ fmp/mph}} + 0.10 \text{ min}} = 276 \text{ fpm or } 5520 \text{ yd/hr or } 3.14 \text{ mph}$$

Stubbs (63) suggests one pass is sufficient for surface rolling dbst. Using the same basic equation as used above for compacting earth and gravel, but omitting the lift height factor, gives:

$$\frac{1 \text{ pass}}{\frac{32 \text{ in.}}{36 \text{ in./yd}} \times 5520 \text{ yd/hr} \times 0.80} = 0.00025 \text{ hr/sy}$$

This activity is done twice, resulting in a productivity of 0.00050 hr/sy for the roller (535) and skilled operator.

B.13 Tables of All Resource Productivities

Table B.1 presents the full set of resource requirements of the technical packages for all stages of construction in each technology period; Table B.1A covers the 1920's, B.1B the 1950's, and B.1C the 1970's. Materials productivities for the surfacing stage are given in the note at the end of each of the three parts, as they are constant over all technical packages. Data pertaining to the equipment and materials referred to by number in the table are given in Sections B.21 and B.22 and Section B.24, respectively. All sources are listed in Section B.3.

TABLE B.1A: LABOR, EQUIPMENT, AND MATERIALS REQUIREMENTS OF THE TECHNICAL PACKAGES FOR ALL STAGES IN THE 1920'S.

STAGE/TECHNICAL PACKAGE NUMBER	LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO., HRS/UNIT)	MATERIALS (NO., QTY/UNIT)	SOURCES
SITE PREP (ACRE)					
11	0.447E 02	0.349E 03	201 0.338E 03	820 0.578E 02	26
			601 0.207E 02	821 0.199E 01	
				822 0.103E 01	
21	0.884E 01	0.878E 01	201 0.878E 01		26
			602 0.774E 01		
			630 0.774E 01		

(TABLE B.1A CONTINUED)

TASK/TECHNICAL PACKAGE NUMBER		LABOR (HRS/UNIT)		EQUIPMENT				SOURCES
		SKILLED	UNSKILLED	(NO.,	HRS/UNIT)	(NO.,	HRS/UNIT)	
EXC/HAUL (BCY)								
2M	1-1	0.111E 00	0.113E 01	202	0.107E 01	301	0.878E 00	12,26,58
	1-2	0.112E 00	0.114E 01	202	0.107E 01	302	0.880E 00	12,26,58
	2-1	0.907E-01	0.928E 00	202	0.813E 00	203	0.250E-01	12,58
				601	0.500E-01	301	0.878E 00	
	2-2	0.912E-01	0.930E 00	202	0.813E 00	203	0.250E-01	12,58
				601	0.500E-01	302	0.880E 00	
	3-1	0.897E-01	0.918E 00	202	0.813E 00	203	0.200E-01	12,58
				631	0.200E-01	301	0.878E 00	
	3-2	0.902E-01	0.920E 00	202	0.813E 00	203	0.200E-01	12,58
				631	0.200E-01	302	0.880E 00	
	4-3	0.131E-01	0.138E 00	203	0.250E-01	601	0.226E 00	12,58
				604	0.880E-01			
	5-4	0.122E-01	0.114E 00	203	0.250E-01	601	0.241E 00	11,12,28,30,58
				603	0.635E-01			
	6-5	0.288E-01	0.377E 00	203	0.250E-01	601	0.454E 00	11,12,29,30,58
				605	0.127E 00			
6M	1-1	0.111E 00	0.117E 01	202	0.107E 01	301	0.916E 00	12,26,58
	1-2	0.112E 00	0.117E 01	202	0.107E 01	302	0.914E 00	12,26,58
	2-1	0.907E-01	0.966E 00	202	0.813E 00	203	0.250E-01	12,58
				601	0.500E-01	301	0.916E 00	
	2-2	0.912E-01	0.964E 00	202	0.813E 00	203	0.250E-01	12,58
				601	0.500E-01	302	0.914E 00	
	3-1	0.897E-01	0.956E 00	202	0.813E 00	203	0.200E-01	12,58
				631	0.200E-01	301	0.916E 00	
	3-2	0.902E-01	0.954E 00	202	0.813E 00	203	0.200E-01	12,58
				631	0.200E-01	302	0.914E 00	
	4-3	0.131E-01	0.151E 00	203	0.250E-01	601	0.252E 00	12,58
				604	0.101E 00			
	5-4	0.122E-01	0.120E 00	203	0.250E-01	601	0.260E 00	11,12,28,30,58
				603	0.701E-01			
	6-5	0.288E-01	0.381E 00	203	0.250E-01	601	0.462E 00	11,12,29,30,58
				605	0.131E 00			

(TABLE B.1A CONTINUED)

TASK/TECHNICAL PACKAGE NUMBER		LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO.,	HRS/UNIT)	(NO.,	HRS/UNIT)	SOURCES
	7-6	0.378E-02	0.000E 00	606	0.378E-02	633	0.378E-02	9
	10-7	0.205E-01	0.577E-01	202	0.330E-01	204	0.165E-01	5,6,7,48
				230	0.165E-01	303	0.247E-01	
				601	0.493E-01			
	10-8	0.204E-01	0.582E-01	230	0.165E-01	204	0.165E-01	5,7,48
				202	0.330E-01	304	0.252E-01	
				631	0.252E-01			
	10-9	0.544E-01	0.330E-01	202	0.330E-01	204	0.165E-01	5,7,48
				230	0.165E-01	330	0.379E-01	
9M	1-1	0.111E 00	0.120E 01	202	0.107E 01	301	0.946E 00	12,26,58
	1-2	0.112E 00	0.119E 01	202	0.107E 01	302	0.940E 00	12,26,58
	2-1	0.907E-01	0.996E 00	202	0.813E 00	203	0.250E-01	12,58
				601	0.500E-01	301	0.946E 00	
	2-2	0.912E-01	0.990E 00	202	0.813E 00	203	0.250E-01	12,58
				601	0.500E-01	302	0.940E 00	
	3-1	0.897E-01	0.986E 00	202	0.813E 00	203	0.200E-01	12,58
				631	0.200E-01	301	0.946E 00	
	3-2	0.902E-01	0.980E 00	202	0.813E 00	203	0.200E-01	12,58
				631	0.200E-01	302	0.940E 00	
	4-3	0.131E-01	0.161E 00	203	0.250E-01	601	0.273E 00	12,58
				604	0.111E 00			
	5-4	0.122E-01	0.125E 00	203	0.250E-01	601	0.275E 00	11,12,28,30,58
				603	0.752E-01			
	6-5	0.288E-01	0.384E 00	203	0.250E-01	601	0.468E 00	11,12,29,30,58
				605	0.134E 00			
	7-6	0.442E-02	0.000E 00	606	0.442E-02	633	0.442E-02	9
	10-7	0.205E-01	0.589E-01	202	0.330E-01	204	0.165E-01	5,6,7,48
				230	0.165E-01	303	0.259E-01	
				601	0.518E-01			
	10-8	0.204E-01	0.586E-01	230	0.165E-01	204	0.165E-01	5,7,48
				202	0.330E-01	304	0.256E-01	
				631	0.256E-01			
	10-9	0.547E-01	0.330E-01	202	0.330E-01	204	0.165E-01	5,7,48

(TABLE B.1A CONTINUED)

TASK/TECHNICAL PACKAGE NUMBER		LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO.,	HRS/UNIT)	(NO.,	HRS/UNIT)	SOURCES
				230	0.165E-01	330	0.382E-01	
60M	1-1	0.111E 00	0.170E 01	202	0.107E 01	301	0.145E 01	12,26,58
	1-2	0.112E 00	0.164E 01	202	0.107E 01	302	0.138E 01	12,26,58
	2-1	0.907E-01	0.150E 01	202	0.813E 00	203	0.250E-01	12,58
				601	0.500E-01	301	0.145E 01	
	2-2	0.912E-01	0.143E 01	202	0.813E 00	203	0.250E-01	12,58
				601	0.500E-01	302	0.138E 01	
	3-1	0.897E-01	0.149E 01	202	0.813E 00	203	0.200E-01	12,58
				631	0.200E-01	301	0.145E 01	
	3-2	0.902E-01	0.142E 01	202	0.813E 00	203	0.200E-01	12,58
				631	0.200E-01	302	0.138E 01	
	4-3	0.131E-01	0.334E 00	203	0.250E-01	601	0.618E 00	12,58
				604	0.284E 00			
	5-4	0.122E-01	0.211E 00	203	0.250E-01	601	0.533E 00	11,12,28,30,58
				603	0.161E 00			
	6-5	0.288E-01	0.434E 00	203	0.250E-01	601	0.568E 00	11,12,29,30,58
				605	0.184E 00			
	7-6	0.153E-01	0.000E 00	606	0.153E-01	633	0.153E-01	9
	8-7	0.820E-02	0.888E-01	202	0.117E-01	205	0.117E-01	6,31,33
				303	0.420E-01	601	0.271E 00	
	9-7	0.156E-01	0.545E-01	202	0.121E-01	303	0.424E-01	6,31,33
				205	0.121E-01	601	0.848E-01	
				634	0.121E-01			
	10-7	0.205E-01	0.798E-01	202	0.330E-01	204	0.165E-01	5,6,7,48
				230	0.165E-01	303	0.468E-01	
				601	0.936E-01			
	10-8	0.204E-01	0.654E-01	230	0.165E-01	204	0.165E-01	5,7,48
				202	0.330E-01	304	0.324E-01	
				631	0.324E-01			
	10-9	0.598E-01	0.330E-01	202	0.330E-01	204	0.165E-01	5,7,48
				230	0.165E-01	330	0.433E-01	
100M	1-1	0.111E 00	0.209E 01	202	0.107E 01	301	0.183E 01	12,26,58
	1-2	0.112E 00	0.197E 01	202	0.107E 01	302	0.172E 01	12,26,58

(TABLE B.1A CONTINUED)

TASK/TECHNICAL PACKAGE NUMBER		LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO.,	HRS/UNIT)	(NO.,	HRS/UNIT)	SOURCES
	2-1	0.907E-01	0.188E 01	202	0.813E 00	203	0.250E-01	12,58
				601	0.500E-01	301	0.183E 01	
	2-2	0.912E-01	0.177E 01	202	0.813E 00	203	0.250E-01	12,58
				601	0.500E-01	302	0.172E 01	
	3-1	0.897E-01	0.187E 01	202	0.813E 00	203	0.200E-01	12,58
				631	0.200E-01	301	0.183E 01	
	3-2	0.902E-01	0.176E 01	202	0.813E 00	203	0.200E-01	12,58
				631	0.200E-01	302	0.172E 01	
	4-3	0.131E-01	0.466E 00	203	0.250E-01	601	0.882E 00	12,58
				604	0.416E 00			
	5-4	0.122E-01	0.277E 00	203	0.250E-01	601	0.730E 00	11,12,28,30,58
				603	0.227E 00			
	6-5	0.288E-01	0.473E 00	203	0.250E-01	601	0.645E 00	11,12,29,30,58
				605	0.223E 00			
	7-6	0.236E-01	0.000E 00	606	0.236E-01	633	0.236E-01	9
	8-7	0.820E-02	0.105E 00	202	0.117E-01	205	0.117E-01	6,31,33
				303	0.580E-01	601	0.303E 00	
	9-7	0.156E-01	0.705E-01	202	0.121E-01	303	0.584E-01	6,31,33
				205	0.121E-01	601	0.117E 00	
				634	0.121E-01			
	10-7	0.205E-01	0.958E-01	202	0.330E-01	204	0.165E-01	5,6,7,48
				230	0.165E-01	303	0.628E-01	
				601	0.126E 00			
	10-8	0.204E-01	0.706E-01	230	0.165E-01	204	0.165E-01	5,7,48
				202	0.330E-01	304	0.376E-01	
				631	0.376E-01			
	10-9	0.637E-01	0.330E-01	202	0.330E-01	204	0.165E-01	5,7,48
				230	0.165E-01	330	0.472E-01	
165M	1-1	0.111E 00	0.271E 01	202	0.107E 01	301	0.245E 01	12,26,58
	1-2	0.112E 00	0.252E 01	202	0.107E 01	302	0.226E 01	12,26,58
	2-1	0.907E-01	0.250E 01	202	0.813E 00	203	0.250E-01	12,58
				601	0.500E-01	301	0.245E 01	
	2-2	0.912E-01	0.231E 01	202	0.813E 00	203	0.250E-01	12,58

(TABLE B.1A CONTINUED)

TASK/TECHNICAL PACKAGE NUMBER		LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO.,	HRS/UNIT)	(NO.,	HRS/UNIT)	SOURCES
				601	0.500E-01	302	0.226E 01	
	3-1	0.897E-01	0.249E 01	202	0.813E 00	203	0.200E-01	12,58
				631	0.200E-01	301	0.245E 01	
	3-2	0.902E-01	0.230E 01	202	0.813E 00	203	0.200E-01	12,58
				631	0.200E-01	302	0.226E 01	
	4-3	0.131E-01	0.679E 00	203	0.250E-01	601	0.131E 01	12,58
				604	0.629E 00			
	5-4	0.122E-01	0.383E 00	203	0.250E-01	601	0.105E 01	11,12,28,30,58
				603	0.333E 00			
	6-5	0.288E-01	0.535E 00	203	0.250E-01	601	0.770E 00	11,12,29,30,58
				605	0.285E 00			
	7-6	0.371E-01	0.000E 00	606	0.371E-01	633	0.371E-01	9
	8-7	0.820E-02	0.131E 00	202	0.117E-01	205	0.117E-01	6,31,33
				303	0.838E-01	601	0.355E 00	
	9-7	0.156E-01	0.963E-01	202	0.121E-01	303	0.842E-01	6,31,33
				205	0.121E-01	601	0.168E 00	
				634	0.121E-01			
	10-7	0.205E-01	0.122E 00	202	0.330E-01	204	0.165E-01	5,6,7,48
				230	0.165E-01	303	0.886E-01	
				601	0.177E 00			
	10-8	0.204E-01	0.790E-01	230	0.165E-01	204	0.165E-01	5,7,48
				202	0.330E-01	304	0.460E-01	
				631	0.460E-01			
	10-9	0.700E-01	0.330E-01	202	0.330E-01	204	0.165E-01	5,7,48
				230	0.165E-01	330	0.535E-01	
500M	1-1	0.111E 00	0.596E 01	202	0.107E 01	301	0.571E 01	12,26,58
	1-2	0.112E 00	0.537E 01	202	0.107E 01	302	0.511E 01	12,26,58
	2-1	0.907E-01	0.576E 01	202	0.813E 00	203	0.250E-01	12,58
				601	0.500E-01	301	0.571E 01	
	2-2	0.912E-01	0.516E 01	202	0.813E 00	203	0.250E-01	12,58
				601	0.500E-01	302	0.511E 01	
	3-1	0.897E-01	0.575E 01	202	0.813E 00	203	0.200E-01	12,58
				631	0.200E-01	301	0.571E 01	

(TABLE B.1A CONTINUED)

TASK/TECHNICAL PACKAGE NUMBER		LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO.,	HRS/UNIT)	(NO.,	HRS/UNIT)	SOURCES
	3-2	0.902E-01	0.515E 01	202	0.813E 00	203	0.200E-01	12,58
				631	0.200E-01	302	0.511E 01	
	4-3	0.131E-01	0.180E 01	203	0.250E-01	601	0.354E 01	12,58
				604	0.175E 01			
	5-4	0.122E-01	0.938E 00	203	0.250E-01	601	0.271E 01	11,12,28,30,58
				603	0.888E 00			
	6-5	0.288E-01	0.860E 00	203	0.250E-01	601	0.142E 01	11,12,29,30,58
				605	0.610E 00			
	7-6	0.107E 00	0.000E 00	606	0.107E 00	633	0.107E 00	9
	8-7	0.820E-02	0.266E 00	202	0.117E-01	205	0.117E-01	6,31,33
				303	0.219E 00	601	0.625E 00	
	9-7	0.156E-01	0.232E 00	202	0.121E-01	303	0.220E 00	6,31,33
				205	0.121E-01	601	0.439E 00	
				634	0.121E-01			
	10-7	0.205E-01	0.257E 00	202	0.330E-01	204	0.165E-01	5,6,7,48
				230	0.165E-01	303	0.224E 00	
				601	0.448E 00			
	10-8	0.204E-01	0.123E 00	230	0.165E-01	204	0.165E-01	5,7,48
				202	0.330E-01	304	0.900E-01	
				631	0.900E-01			
	10-9	0.103E 00	0.330E-01	202	0.330E-01	204	0.165E-01	5,7,48
				230	0.165E-01	330	0.865E-01	
800M	1-1	0.111E 00	0.887E 01	202	0.107E 01	301	0.862E 01	12,26,58
	1-2	0.112E 00	0.792E 01	202	0.107E 01	302	0.766E 01	12,26,58
	2-1	0.907E-01	0.867E 01	202	0.813E 00	203	0.250E-01	12,58
				601	0.500E-01	301	0.862E 01	
	2-2	0.912E-01	0.771E 01	202	0.813E 00	203	0.250E-01	12,58
				601	0.500E-01	302	0.766E 01	
	3-1	0.897E-01	0.866E 01	202	0.813E 00	203	0.200E-01	12,58
				631	0.200E-01	301	0.862E 01	
	3-2	0.902E-01	0.770E 01	202	0.813E 00	203	0.200E-01	12,58
				631	0.200E-01	302	0.766E 01	
	4-3	0.131E-01	0.280E 01	203	0.250E-01	601	0.555E 01	12,58

(TABLE B.1A CONTINUED)

TASK/TECHNICAL PACKAGE NUMBER		LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO.,HRS/UNIT)	(NO.,HRS/UNIT)	SOURCES
				604 0.275E 01		
	5-4	0.122E-01	0.144E 01	203 0.250E-01	601 0.421E 01	11,12,28,30,58
				603 0.139E 01		
	6-5	0.288E-01	0.115E 01	203 0.250E-01	601 0.200E 01	11,12,29,30,58
				605 0.901E 00		
	7-6	0.170E 00	0.000E 00	606 0.170E 00	633 0.170E 00	9
	8-7	0.820E-02	0.387E 00	202 0.117E-01	205 0.117E-01	6,31,33
				303 0.340E 00	601 0.868E 00	
	9-7	0.156E-01	0.353E 00	202 0.121E-01	303 0.341E 00	6,31,33
				205 0.121E-01	601 0.681E 00	
				634 0.121E-01		
	10-7	0.205E-01	0.378E 00	202 0.330E-01	204 0.165E-01	5,6,7,48
				230 0.165E-01	303 0.345E 00	
				601 0.690E 00		
	10-8	0.204E-01	0.162E 00	230 0.165E-01	204 0.165E-01	5,7,48
				202 0.330E-01	304 0.129E 00	
				631 0.129E 00		
	10-9	0.132E 00	0.330E-01	202 0.330E-01	204 0.165E-01	5,7,48
				230 0.165E-01	330 0.116E 00	
SPR/COMP (BCY)						
93%	11	0.371E-01	0.371E 00	401 0.361E 00	501 0.950E-02	12,15,26,29,58,61
				601 0.380E-01		
	21	0.232E-01	0.327E-01	402 0.232E-01	501 0.950E-02	12,14,15,26,29,61
				601 0.131E 00		
98%	11	0.452E-01	0.407E 00	401 0.361E 00	501 0.453E-01	12,15,26,29,58,61
				601 0.181E 00		
	21	0.232E-01	0.685E-01	402 0.232E-01	501 0.453E-01	12,14,15,26,29,61
				601 0.274E 00		
	12	0.392E-01	0.361E 00	401 0.361E 00	530 0.630E-02	12,26,35,58,61
	22	0.295E-01	0.232E-01	402 0.232E-01	530 0.630E-02	14,26,35,61
				601 0.928E-01		
	32	0.193E-01	0.000E 00	403 0.650E-02	530 0.630E-02	26,35,61
				632 0.650E-02		

(TABLE B.1A CONTINUED)

TASK/TECHNICAL	PACKAGE NUMBER	LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO.,	HRS/UNIT)	(NO.,	HRS/UNIT)	SOURCES
SURFACING								
GRVL (CCY)	11	0.329E-01	0.361E 00	401	0.329E 00	501	0.324E-01	12,15,26,29,61
				601	0.130E 00			
	21	0.106E-01	0.127E 00	401	0.546E-01	404	0.200E-01	12,15,26,29,61
				501	0.324E-01	601	0.170E 00	
	12	0.489E-01	0.329E 00	401	0.329E 00	530	0.124E-01	15,26,35,61
	22	0.229E-01	0.946E-01	401	0.546E-01	404	0.200E-01	15,26,35,61
				530	0.124E-01	601	0.400E-01	
WBM (CCY)	111	0.201E 00	0.953E 00	401	0.820E 00	405	0.133E 00	26
				531	0.133E 00	601	0.267E 00	
	211	0.169E 00	0.572E 00	401	0.387E 00	404	0.260E-01	26
				405	0.133E 00	531	0.133E 00	
				601	0.319E 00			
DBST/G (SY)	1111	0.102E-01	0.849E-01	401	0.849E-01	450	0.208E-02	15,26,35
				530	0.547E-03			
	1121	0.766E-02	0.383E-01	331	0.361E-02	401	0.383E-01	15,26,35
				406	0.361E-02	450	0.208E-02	
				530	0.547E-03			
DBST/W (SY)	1111	0.102E-01	0.849E-01	401	0.849E-01	450	0.208E-02	15,26,35
				530	0.547E-03			
	1121	0.766E-02	0.383E-01	331	0.361E-02	401	0.383E-01	15,26,35
				406	0.361E-02	450	0.208E-02	
				530	0.547E-03			

(TABLE B.1A CONTINUED)

NOTE: ALL TECHNICAL PACKAGES FOR SURFACING ALSO INCLUDE MATERIALS:

GRAVEL:	830-1.40 LCY/CCY
WATERBOUND MACADAM:	831-1.37 LCY/CCY
	832-0.32 LCY/CCY
	833-63 GAL/CCY
DOUBLE BITUMINOUS SURFACE TREATMENT ON GRAVEL:	835-0.93 GAL/SY
	834-0.0191 LCY /SY
DOUBLE BITUMINOUS SURFACE TREATMENT ON WATERBCUND MACADAM:	835-0.72 GAL/SY
	834-0.0191 LCY/SY

TABLE B.1B: LABOR,EQUIPMENT, AND MATERIALS REQUIREMENTS OF THE TECHNICAL PACKAGES FOR ALL STAGES IN THE 1950'S.

STAGE/TECHNICAL PACKAGE NUMBER	LABOR (HRS/UNIT) SKILLED	LABOR (HRS/UNIT) UNSKILLED	EQUIPMENT (NO.,HRS/UNIT)	MATERIALS (NO.,QTY/UNIT)	SOURCES
SITE PREP (ACRE)					
11	C.621E 02	0.497E 03	206 0.372E 02	820 0.136E 03	26,36,46,63,88
			207 0.142E 03	821 0.200E 01	
			208 0.310E 03	822 0.100E 01	
			235 C.749E 01		
21	0.788E 01	0.878E 01	206 0.878E 01		26,46,63
			608 C.678E 01		
			642 0.678E 01		
31	C.538E 01	0.878E 01	608 0.178E 01		26,46
			610 C.292E 01		
			642 0.428E 01		
			206 0.878E 01		

(TABLE B.1B CONTINUED)

TASK/TECHNICAL PACKAGE NUMBER		LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO.,	HRS/UNIT)	(NO.,	HRS/UNIT)	SOURCES
EXC/HAUL (BCY)								
2M	11-0	C.324E-02	0.000E 00	423	C.324E-02			46
6M	1-1	C.178E-01	0.000E 00	231	0.664E-02	332	0.112E-01	46,56,63,77
	1-2	C.154E-01	0.000E 00	231	0.664E-02	333	0.876E-02	46,56,63,77
	1-3	C.151E-01	0.000E 00	231	0.664E-02	305	0.842E-02	46,56,63,77
				638	0.842E-02			
	1-4	C.143E-01	0.000E 00	306	0.765E-02	639	0.765E-02	46,56,63,77
				231	C.664E-02			
	2-1	0.184E-01	0.000E 00	232	0.691E-02	332	0.115E-01	46,56,63,77
	2-2	C.159E-01	0.000E 00	232	0.691E-02	333	0.903E-02	46,56,63,77
	2-3	C.156E-01	0.000E 00	232	0.691E-02	305	0.869E-02	46,56,63,77
				638	0.869E-02			
	2-4	0.148E-01	0.000E 00	232	0.691E-02	306	0.792E-02	46,56,63,77
				639	0.792E-02			
	3-1	0.149E-01	0.000E 00	233	0.516E-02	332	0.970E-02	46,56,63,77
	3-2	0.124E-01	0.000E 00	233	0.516E-02	333	0.728E-02	46,56,63,77
	3-3	0.121E-01	0.000E 00	233	0.516E-02	305	0.694E-02	46,56,63,77
				638	0.694E-02			
	3-4	0.113E-01	0.000E 00	233	0.516E-02	306	0.617E-02	46,56,63,77
				639	0.617E-02			
	5-5	C.123E-01	0.000E 00	611	0.819E-02	638	0.819E-02	77
				641	0.409E-02	607	0.409E-02	
	6-6	0.115E-01	0.000E 00	639	C.765E-02	612	0.765E-02	77
				642	0.383E-02	608	0.383E-02	
	7-7	C.537E-02	0.000E 00	613	0.358E-02	640	0.358E-02	77
				643	0.186E-02	609	0.186E-02	
	8-8	0.358E-02	0.000E 00	607	0.358E-02	641	0.358E-02	56,63
	9-9	C.195E-02	0.000E 00	608	0.195E-02	642	0.195E-02	56,63
	10-10	C.159E-02	0.000E 00	609	0.159E-02	643	0.159E-02	56,63
9M	1-1	0.179E-01	0.000E 00	231	0.664E-02	332	0.113E-01	46,56,63,77
	1-2	C.154E-01	0.000E 00	231	0.664E-02	333	0.881E-02	46,56,63,77
	1-3	C.151E-01	0.000E 00	231	0.664E-02	305	0.851E-02	46,56,63,77
				638	0.851E-02			

(TABLE B.1B CCNTINUEC)

TASK/TECHNICAL PACKAGE NUMBER		LABCR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO.,	HRS/UNIT)	(NC.,	HRS/UNIT)	SOURCES
	1-4	C.143E-01	C.000E 00	306	0.770E-02	639	C.770E-02	46,56,63,77
				231	0.664E-02			
	2-1	C.185E-01	0.000E 00	232	0.691E-02	332	0.116E-01	46,56,63,77
	2-2	C.160E-01	0.000E 00	232	0.691E-02	333	0.908E-02	46,56,63,77
	2-3	C.157E-01	0.000E 00	232	0.691E-02	305	0.878E-02	46,56,63,77
				638	0.878E-02			
	2-4	C.149E-01	0.000E 00	232	0.691E-02	306	0.797E-02	46,56,63,77
				639	0.797E-02			
	3-1	C.150E-01	0.000E 00	233	C.516E-02	332	0.981E-02	46,56,63,77
	3-2	0.125E-01	0.000E 00	233	0.516E-02	333	0.733E-02	46,56,63,77
	3-3	C.122E-01	0.000E 00	233	0.516E-02	305	0.703E-02	46,56,63,77
				638	0.703E-02			
	3-4	C.114E-01	0.000E 00	233	0.516E-02	306	0.622E-02	46,56,63,77
				639	C.622E-02			
	5-5	0.124E-01	0.000E 00	611	0.828E-02	638	0.828E-02	77
				641	0.414E-02	607	0.414E-02	
	6-6	0.116E-01	0.000E 00	639	0.772E-02	612	0.772E-02	77
				642	0.386E-02	608	0.386E-02	
	7-7	0.542E-02	0.000E 00	613	0.361E-02	640	0.361E-02	77
				643	0.181E-02	609	0.181E-02	
	8-8	0.471E-02	0.000E 00	607	0.471E-02	641	0.471E-02	56,63
	9-9	C.256E-02	0.000E 00	608	0.256E-02	642	0.256E-02	56.63
	10-10	C.205E-02	0.000E 00	609	0.205E-02	643	0.205E-02	56,63
60M	1-1	0.198E-01	0.000E 00	231	0.664E-02	332	0.132E-01	46,56,63,77
	1-2	0.163E-01	0.000E 00	231	0.664E-02	333	0.970E-02	46,56,63,77
	1-3	C.167E-01	0.000E 00	231	0.664E-02	305	0.101E-01	46,56,63,77
				638	0.101E-01			
	1-4	C.152E-01	0.000E 00	306	0.859E-02	639	0.859E-02	46,56,63,77
				231	0.664E-02			
	2-1	C.204E-01	0.000E 00	232	0.691E-02	332	0.135E-01	46,56,63,77
	2-2	0.169E-01	0.000E 00	232	0.691E-02	333	0.997E-02	46,56,63,77
	2-3	C.173E-01	0.000E 00	232	C.691E-02	305	0.104E-01	46,56,63,77
				638	0.104E-01			

(TABLE B.1B CONTINUED)

TASK/TECHNICAL PACKAGE NUMBER		LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO.,	HRS/UNIT)	(NO.,	HRS/UNIT)	SOURCES
	2-4	0.158E-01	0.000E 00	232	0.691E-02	306	0.886E-02	46,56,63,77
				639	0.886E-02			
	3-1	0.169E-01	0.000E 00	233	0.516E-02	332	0.117E-01	46,56,63,77
	3-2	0.134E-01	0.000E 00	233	0.516E-02	333	0.822E-02	46,56,63,77
	3-3	0.138E-01	0.000E 00	233	0.516E-02	305	0.861E-02	46,56,63,77
				638	0.861E-02			
	3-4	0.123E-01	0.000E 00	233	0.516E-02	306	0.711E-02	46,56,63,77
				639	0.711E-02			
	4-2	0.688E-02	0.000E 00	234	0.191E-02	642	0.191E-02	46,56,63,77
				333	0.497E-02			
	4-4	0.577E-02	0.000E 00	234	0.191E-02	642	0.191E-02	46,56,63,77
				306	0.386E-02	639	0.386E-02	
	5-5	0.148E-01	0.000E 00	611	0.985E-02	638	0.985E-02	77
				641	0.493E-02	607	0.493E-02	
	6-6	0.133E-01	0.000E 00	639	0.883E-02	612	0.883E-02	77
				642	0.442E-02	608	0.442E-02	
	7-7	0.630E-02	0.000E 00	613	0.420E-02	640	0.420E-02	77
				643	0.210E-02	609	0.210E-02	
	8-8	0.239E-01	0.000E 00	607	0.239E-01	641	0.239E-01	56,63
	9-9	0.130E-01	0.000E 00	608	0.130E-01	642	0.130E-01	56,63
	10-10	0.996E-02	0.000E 00	609	0.996E-02	643	0.996E-02	56,63
100M	1-1	0.213E-01	0.000E 00	231	0.664E-02	332	0.147E-01	46,56,63,77
	1-2	0.170E-01	0.000E 00	231	0.664E-02	333	0.104E-01	46,56,63,77
	1-3	0.179E-01	0.000E 00	231	0.664E-02	305	0.113E-01	46,56,63,77
				638	0.113E-01			
	1-4	0.159E-01	0.000E 00	306	0.928E-02	639	0.928E-02	46,56,63,77
				231	0.664E-02			
	2-1	0.219E-01	0.000E 00	232	0.691E-02	332	0.149E-01	46,56,63,77
	2-2	0.176E-01	0.000E 00	232	0.691E-02	333	0.107E-01	46,56,63,77
	2-3	0.185E-01	0.000E 00	232	0.691E-02	305	0.116E-01	46,56,63,77
				638	0.116E-01			
	2-4	0.165E-01	0.000E 00	232	0.691E-02	306	0.955E-02	46,56,63,77
				639	0.955E-02			

(TABLE B.1B CONTINUED)

TASK/TECHNICAL PACKAGE NUMBER		LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO.,	HRS/UNIT)	(NO.,	HRS/UNIT)	SOURCES
	3-1	0.184E-01	0.000E 00	233	0.516E-02	332	0.132E-01	46,56,63,77
	3-2	0.141E-01	0.000E 00	233	0.516E-02	333	0.891E-02	46,56,63,77
	3-3	0.150E-01	0.000E 00	233	0.516E-02	305	0.981E-02	46,56,63,77
				638	0.981E-02			
	3-4	0.130E-01	0.000E 00	233	0.516E-02	306	0.780E-02	46,56,63,77
				639	0.780E-02			
	4-2	0.757E-02	0.000E 00	234	0.191E-02	642	0.191E-02	46,56,63,77
				333	0.566E-02			
	4-4	0.646E-02	0.000E 00	234	0.191E-02	642	0.191E-02	46,56,63,77
				306	0.455E-02	639	0.455E-02	
	5-5	0.166E-01	0.000E 00	611	0.111E-01	638	0.111E-01	77
				641	0.553E-02	607	0.553E-02	
	6-6	0.145E-01	0.000E 00	639	0.969E-02	612	0.969E-02	77
				642	0.485E-02	608	0.485E-02	
	7-7	0.620E-02	0.000E 00	613	0.465E-02	640	0.465E-02	77
				643	0.155E-02	609	0.155E-02	
	8-8	0.386E-01	0.000E 00	607	0.386E-01	641	0.386E-01	56,63
	9-9	0.210E-01	0.000E 00	608	0.210E-01	642	0.210E-01	56,63
	10-10	0.160E-01	0.000E 00	609	0.160E-01	643	0.160E-01	56,63
165M	1-1	0.237E-01	0.000E 00	231	0.664E-02	332	0.170E-01	46,56,63,77
	1-2	0.181E-01	0.000E 00	231	0.664E-02	333	0.115E-01	46,56,63,77
	1-3	0.199E-01	0.000E 00	231	0.664E-02	305	0.132E-01	46,56,63,77
				638	0.132E-01			
	1-4	0.170E-01	0.000E 00	306	0.104E-01	639	0.104E-01	46,56,63,77
				231	0.664E-02			
	2-1	0.242E-01	0.000E 00	232	0.691E-02	332	0.173E-01	46,56,63,77
	2-2	0.187E-01	0.000E 00	232	0.691E-02	333	0.118E-01	46,56,63,77
	2-3	0.204E-01	0.000E 00	232	0.691E-02	305	0.135E-01	46,56,63,77
				638	0.135E-01			
	2-4	0.176E-01	0.000E 00	232	0.691E-02	306	0.107E-01	46,56,63,77
				639	0.107E-01			
	3-1	0.207E-01	0.000E 00	233	0.516E-02	332	0.156E-01	46,56,63,77
	3-2	0.152E-01	0.000E 00	233	0.516E-02	333	0.100E-01	46,56,63,77

(TABLE B.1B CONTINUED)

TASK/TECHNICAL PACKAGE NUMBER		LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO.,HRS/UNIT)		(NO.,HRS/UNIT)		SOURCES
	3-3	0.169E-01	0.000E 00	233	0.516E-02	305	0.118E-01	46,56,63,77
				638	0.118E-01			
	3-4	0.141E-01	0.000E 00	233	0.516E-02	306	0.890E-02	46,56,63,77
				639	0.890E-02			
	4-2	0.867E-02	0.000E 00	234	0.191E-02	642	0.191E-02	46,56,63,77
				333	0.676E-02			
	4-4	0.756E-02	0.000E 00	234	0.191E-02	642	0.191E-02	46,56,63,77
				306	0.565E-02	639	0.565E-02	
	5-5	0.195E-01	0.000E 00	611	0.130E-01	638	0.130E-01	77
				641	0.651E-02	607	0.651E-02	
	6-6	0.148E-01	0.000E 00	639	0.111E-01	612	0.111E-01	77
				642	0.369E-02	608	0.369E-02	
	7-7	0.716E-02	0.000E 00	613	0.537E-02	640	0.537E-02	77
				643	0.179E-02	609	0.179E-02	
	8-8	0.623E-01	0.000E 00	607	0.623E-01	641	0.623E-01	56,63
	9-9	0.340E-01	0.000E 00	608	0.340E-01	642	0.340E-01	56,63
	10-10	0.257E-01	0.000E 00	609	0.257E-01	643	0.257E-01	56,63
500M	1-1	0.244E-01	0.000E 00	231	0.664E-02	332	0.177E-01	46,56,63,77
	1-2	0.184E-01	0.000E 00	231	0.664E-02	333	0.118E-01	46,56,63,77
	1-3	0.204E-01	0.000E 00	231	0.664E-02	305	0.138E-01	46,56,63,77
				638	0.138E-01			
	1-4	0.173E-01	0.000E 00	306	0.107E-01	639	0.107E-01	46,56,63,77
				231	0.664E-02			
	2-1	0.249E-01	0.000E 00	232	0.691E-02	332	0.180E-01	46,56,63,77
	2-2	0.190E-01	0.000E 00	232	0.691E-02	333	0.121E-01	46,56,63,77
	2-3	0.210E-01	0.000E 00	232	0.691E-02	305	0.141E-01	46,56,63,77
				638	0.141E-01			
	2-4	0.179E-01	0.000E 00	232	0.691E-02	306	0.110E-01	46,56,63,77
				639	0.110E-01			
	3-1	0.214E-01	0.000E 00	233	0.516E-02	332	0.162E-01	46,56,63,77
	3-2	0.155E-01	0.000E 00	233	0.516E-02	333	0.103E-01	46,56,63,77
	3-3	0.175E-01	0.000E 00	233	0.516E-02	305	0.123E-01	46,56,63,77
				638	0.123E-01			

(TABLE B.1B CONTINUED)

TASK/TECHNICAL PACKAGE NUMBER		LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO., HRS/UNIT)		(NO., HRS/UNIT)		SOURCES
	3-4	0.144E-01	0.000E 00	233	0.516E-02	306	0.922E-02	46,56,63,77
				639	0.922E-02			
	4-2	0.899E-02	0.000E 00	234	0.191E-02	642	0.191E-02	46,56,63,77
				333	0.708E-02			
	4-4	0.788E-02	0.000E 00	234	0.191E-02	642	0.191E-02	46,56,63,77
				306	0.597E-02	639	0.597E-02	
	5-5	0.290E-01	0.000E 00	611	0.232E-01	638	0.232E-01	77
				641	0.580E-02	607	0.580E-02	
	6-6	0.244E-01	0.000E 00	639	0.183E-01	612	0.183E-01	77
				642	0.610E-02	608	0.610E-02	
	7-7	0.122E-01	0.000E 00	613	0.916E-02	640	0.916E-02	77
				643	0.305E-02	609	0.305E-02	
	8-8	0.186E 00	0.000E 00	607	0.186E 00	641	0.186E 00	56,63
	9-9	0.102E 00	0.000E 00	608	0.102E 00	642	0.102E 00	56,63
	10-10	0.766E-01	0.000E 00	609	0.766E-01	643	0.766E-01	56,63
800M	1-1	0.275E-01	0.000E 00	231	0.664E-02	332	0.209E-01	46,56,63,77
	1-2	0.199E-01	0.000E 00	231	0.664E-02	333	0.133E-01	46,56,63,77
	1-3	0.230E-01	0.000E 00	231	0.664E-02	305	0.164E-01	46,56,63,77
				638	0.164E-01			
	1-4	0.188E-01	0.000E 00	306	0.122E-01	639	0.122E-01	46,56,63,77
				231	0.664E-02			
	2-1	0.281E-01	0.000E 00	232	0.691E-02	332	0.212E-01	46,56,63,77
	2-2	0.205E-01	0.000E 00	232	0.691E-02	333	0.136E-01	46,56,63,77
	2-3	0.236E-01	0.000E 00	232	0.691E-02	305	0.167E-01	46,56,63,77
				638	0.167E-01			
	2-4	0.194E-01	0.000E 00	232	0.691E-02	306	0.124E-01	46,56,63,77
				639	0.124E-01			
	3-1	0.246E-01	0.000E 00	233	0.516E-02	332	0.194E-01	46,56,63,77
	3-2	0.170E-01	0.000E 00	233	0.516E-02	333	0.118E-01	46,56,63,77
	3-3	0.201E-01	0.000E 00	233	0.516E-02	305	0.149E-01	46,56,63,77
				638	0.149E-01			
	3-4	0.159E-01	0.000E 00	233	0.516E-02	306	0.107E-01	46,56,63,77
				639	0.107E-01			

(TABLE 6.1B CONTINUED)

TASK/TECHNICAL PACKAGE NUMBER		LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO.,	HRS/UNIT)	(NO.,	HRS/UNIT)	SOURCES
	4-2	0.105E-01	0.000E 00	234	0.191E-02	642	0.191E-02	46,56,63,77
				333	0.857E-02			
	4-4	0.936E-02	0.000E 00	234	0.191E-02	642	0.191E-02	46,56,63,77
				306	0.745E-02	639	0.745E-02	
	5-5	0.388E-01	0.000E 00	611	0.323E-01	638	0.323E-01	77
				641	0.647E-02	607	0.647E-02	
	6-6	0.310E-01	0.000E 00	639	0.248E-01	612	0.248E-01	77
				642	0.619E-02	608	0.619E-02	
	7-7	0.157E-01	0.000E 00	613	0.125E-01	640	0.125E-01	77
				643	0.314E-02	609	0.314E-02	
	8-8	0.297E 00	0.000E 00	607	0.297E 00	641	0.297E 00	56,63
	9-9	0.162E 00	0.000E 00	608	0.162E 00	642	0.162E 00	56,63
	10-10	0.122E 00	0.000E 00	609	0.122E 00	643	0.122E 00	56,63
SPR/COMP (BCY)								
98%	11	0.121E-01	0.000E 00	502	0.700E-02	607	0.508E-02	8,46,56,63,88
				641	0.121E-01			
	12	0.858E-02	0.000E 00	502	0.700E-02	607	0.508E-02	8,46,56,63,88
				641	0.508E-02	642	0.350E-02	
	13	0.887E-02	0.000E 00	532	0.379E-02	607	0.508E-02	20,35,56,63
				641	0.508E-02			
	14	0.779E-02	0.000E 00	607	0.508E-02	641	0.508E-02	20,38,56,63
				533	0.271E-02			
	21	0.104E-01	0.000E 00	643	0.335E-02	609	0.335E-02	8,46,56,63,88
				641	0.700E-02	502	0.700E-02	
	22	0.685E-02	0.000E 00	502	0.700E-02	609	0.335E-02	8,46,56,63,88
				642	0.350E-02	643	0.335E-02	
	23	0.714E-02	0.000E 00	532	0.379E-02	643	0.335E-02	20,35,56,63
				609	0.335E-02			
	24	0.606E-02	0.000E 00	609	0.335E-02	643	0.335E-02	20,38,56,63
				533	0.271E-02			
	31	0.909E-02	0.000E 00	420	0.209E-02	502	0.700E-02	8,46,56,63,88
				641	0.700E-02			
	32	0.559E-02	0.000E 00	420	0.209E-02	502	0.700E-02	8,46,56,63,88

(TABLE B.1B CONTINUED)

TASK/TECHNICAL	PACKAGE NUMBER	LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO.,	HRS/UNIT)	(NO.,	HRS/UNIT)	SOURCES
				642	0.350E-02			
	33	0.588E-02	0.000E 00	420	0.209E-02	532	0.379E-02	20,35,46,56,63
	34	0.480E-02	0.000E 00	420	0.209E-02	533	0.271E-02	20,38,46,56,63
	41	0.853E-02	0.000E 00	421	0.153E-02	641	0.700E-02	8,46,56,63,88
				502	0.700E-02			
	42	0.503E-02	0.000E 00	421	0.153E-02	502	0.700E-02	8,46,56,63,88
				642	0.350E-02			
	43	0.532E-02	0.000E 00	421	0.153E-02	532	0.379E-02	20,35,46,56,63
	44	0.424E-02	0.000E 00	421	0.153E-02	533	0.271E-02	20,38,46,56,63
SURFACING								
GRVL (CCY)	11	0.105E-01	0.000E 00	607	0.424E-02	534	0.625E-02	35,56,61,63
				641	0.424E-02			
	12	0.772E-02	0.000E 00	607	0.424E-02	641	0.424E-02	20,38,39,56,63
				533	0.348E-02			
	21	0.972E-02	0.000E 00	609	0.347E-02	643	0.347E-02	35,56,61,63
				534	0.625E-02			
	22	0.695E-02	0.000E 00	609	0.347E-02	643	0.347E-02	20,38,39,56,63
				533	0.348E-02			
	31	0.821E-02	0.000E 00	420	0.196E-02	534	0.625E-02	8,35,46,56,61,63
	32	0.544E-02	0.000E 00	420	0.196E-02	533	0.348E-02	8,20,38,39,46,63
	41	0.779E-02	0.000E 00	421	0.154E-02	534	0.625E-02	8,35,46,56,61,63
	42	0.502E-02	0.000E 00	421	0.154E-02	533	0.348E-02	8,20,38,39,46,63
	51	0.117E-01	0.291E-02	422	0.291E-02	333	0.253E-02	35,56,61,63,77
				408	0.291E-02	534	0.625E-02	
	52	0.892E-02	0.291E-02	422	0.291E-02	333	0.253E-02	20,38,39,63,77
				408	0.291E-02	533	0.348E-02	
WBM (CCY)	111	0.831E-01	0.222E-01	607	0.498E-02	641	0.498E-02	15,35,40,56,63,77
				332	0.820E-02	408	0.820E-02	
				409	0.820E-02	534	0.699E-01	
				334	0.140E-01	407	0.140E-01	

(TABLE B.1B CONTINUED)

TASK/TECHNICAL PACKAGE NUMBER	LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO.,	HRS/UNIT)	(NO.,	HRS/UNIT)	SOURCES
112	0.643E-01	0.184E-01	607	0.498E-02	641	0.498E-02	15,35,40,56,63,77
			332	0.820E-02	408	0.820E-02	
			409	0.820E-02	533	0.511E-01	
			334	0.102E-01	407	0.102E-01	
211	0.814E-01	0.222E-01	643	0.334E-02	609	0.334E-02	15,35,40,56,63,77
			332	0.820E-02	408	0.820E-02	
			409	0.820E-02	534	0.699E-01	
			334	0.140E-01	407	0.140E-01	
212	0.627E-01	0.184E-01	643	0.334E-02	609	0.334E-02	15,35,40,56,63,77
			332	0.820E-02	408	0.820E-02	
			409	0.820E-02	533	0.511E-01	
			334	0.102E-01	407	0.102E-01	
311	0.802E-01	0.222E-01	420	0.206E-02	332	0.820E-02	8,15,35,40,46,56,63,77
			408	0.820E-02	409	0.820E-02	
			534	0.699E-01	334	0.140E-01	
			407	0.140E-01			
312	0.614E-01	0.184E-01	420	0.206E-02	332	0.820E-02	8,15,35,40,46,56,63,77
			408	0.820E-02	409	0.820E-02	
			533	0.511E-01	334	0.102E-01	
			407	0.102E-01			
411	0.796E-01	0.222E-01	421	0.150E-02	332	0.820E-02	8,15,35,40,46,56,63,77
			408	0.820E-02	409	0.820E-02	
			534	0.699E-01	334	0.140E-01	
			407	0.140E-01			
412	0.608E-01	0.184E-01	421	0.150E-02	332	0.820E-02	8,15,35,40,46,56,63,77
			408	0.820E-02	409	0.820E-02	
			533	0.511E-01	334	0.102E-01	
			407	0.102E-01			

(TABLE B.1B CONTINUED)

TASK/TECHNICAL PACKAGE NUMBER		LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO.,	HRS/UNIT)	(NO.,	HRS/UNIT)	SOURCES
	511	0.837E-01	0.251E-01	333	0.266E-02	408	0.111E-01	15,35,40,56,63,77
				422	0.291E-02	332	0.820E-02	
				409	0.820E-02	534	0.699E-01	
				334	0.140E-01	407	0.140E-01	
	512	0.649E-01	0.213E-01	333	0.266E-02	408	0.111E-01	15,35,40,56,63,77
				422	0.291E-02	332	0.820E-02	
				409	0.820E-02	533	0.511E-01	
				334	0.102E-01	407	0.102E-01	
DBST/G (SY)	1111	0.188E-02	0.120E-02	335	0.197E-03	440	0.197E-03	35,63,77,91
				452	0.612E-03	422	0.405E-03	
				333	0.405E-03	408	0.405E-03	
				535	0.503E-03			
	1112	0.166E-02	0.120E-02	335	0.197E-03	440	0.197E-03	20,38,63,77
				452	0.612E-03	422	0.405E-03	
				333	0.405E-03	408	0.405E-03	
				533	0.284E-03			
	1121	0.191E-02	0.161E-02	335	0.197E-03	440	0.197E-03	35,63,77,91
				452	0.612E-03	332	0.798E-03	
				409	0.798E-03	408	0.798E-03	
				535	0.503E-03			
	1122	0.170E-02	0.161E-02	335	0.197E-03	440	0.197E-03	20,38,63,77
				452	0.612E-03	332	0.798E-03	
				409	0.798E-03	408	0.798E-03	
				533	0.284E-03			
	2111	0.188E-02	0.112E-02	451	0.120E-03	452	0.612E-03	35,63,77,91
				422	0.405E-03	333	0.405E-03	
				408	0.405E-03	535	0.503E-03	
	2112	0.166E-02	0.112E-02	451	0.120E-03	452	0.612E-03	20,38,63,77
				422	0.405E-03	333	0.405E-03	
				408	0.405E-03	533	0.284E-03	

(TABLE B.1B CONTINUED)

TASK/TECHNICAL PACKAGE	NUMBER	LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO.,	HRS/UNIT)	(NO.,	HRS/UNIT)	SOURCES
	2121	0.191E-02	0.153E-02	451	0.120E-03	452	0.612E-03	35,63,77,91
				332	0.798E-03	409	0.798E-03	
				408	0.798E-03	535	0.503E-03	
	2122	0.170E-02	0.153E-02	451	0.120E-03	452	0.612E-03	20,38,63,77
				332	0.798E-03	409	0.798E-03	
				408	0.798E-03	533	0.284E-03	
DBST/W (SY)	1111	0.188E-02	0.120E-02	335	0.197E-03	440	0.197E-03	35,63,77,91
				452	0.612E-03	422	0.405E-03	
				333	0.405E-03	408	0.405E-03	
				535	0.503E-03			
	1112	0.166E-02	0.120E-02	335	0.197E-03	440	0.197E-03	20,38,63,77
				452	0.612E-03	422	0.405E-03	
				333	0.405E-03	408	0.405E-03	
				533	0.284E-03			
	1121	0.191E-02	0.161E-02	335	0.197E-03	440	0.197E-03	35,63,77,91
				452	0.612E-03	332	0.798E-03	
				409	0.798E-03	408	0.798E-03	
				535	0.503E-03			
	1122	0.170E-02	0.161E-02	335	0.197E-03	440	0.197E-03	20,38,63,77
				452	0.612E-03	332	0.798E-03	
				409	0.798E-03	408	0.798E-03	
				533	0.284E-03			
	2111	0.188E-02	0.112E-02	451	0.120E-03	452	0.612E-03	35,63,77,91
				422	0.405E-03	333	0.405E-03	
				408	0.405E-03	535	0.503E-03	
	2112	0.166E-02	0.112E-02	451	0.120E-03	452	0.612E-03	20,38,63,77
				422	0.405E-03	333	0.405E-03	
				408	0.405E-03	533	0.284E-03	
	2121	0.191E-02	0.153E-02	451	0.120E-03	452	0.612E-03	35,63,77,91
				332	0.798E-03	409	0.798E-03	
				408	0.798E-03	535	0.503E-03	
	2122	0.170E-02	0.153E-02	451	0.120E-03	452	0.612E-03	20,38,63,77
				332	0.798E-03	409	0.798E-03	
				408	0.798E-03	533	0.284E-03	

(TABLE B.1B CONTINUED)

NOTE: ALL TECHNICAL PACKAGES FOR SURFACING ALSO INCLUDE MATERIALS:

GRAVEL:	830-1.40 LCY/CCY
WATERBOUND MACADAM:	831-1.37 LCY/CCY
	832-0.32 LCY/CCY
	833-63 GAL/CCY
DOUBLE BITUMINOUS SURFACE TREATMENT ON GRAVEL:	835-0.93 GAL/SY
	834-0.0191 LCY /SY
DOUBLE BITUMINOUS SURFACE TREATMENT ON WATERBOUND MACADAM:	835-0.72 GAL/SY
	834-0.0191 LCY/SY

TABLE B.1C: LABOR,EQUIPMENT, AND MATERIALS REQUIREMENTS OF THE TECHNICAL PACKAGES FOR ALL STAGES IN THE 1970'S.

STAGE/TECHNICAL PACKAGE NUMBER	LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO.,HRS/UNIT)		MATERIALS (NO.,QTY/UNIT)		SOURCES
SITE PREP (ACRE)							
11	0.245E 02	0.142E 03	209	0.445E 02	823	0.333E 02	49,57
			236	0.640E 02			
			237	0.667E 01			
			241	0.340E 02			
21	0.416E 01	0.236E 02	209	0.139E 02	823	0.333E 02	22,57
			236	0.916E 01			
			336	0.560E 00			
			614	0.285E 01			
			644	0.285E 01			
31	0.271E 01	0.105E 02	209	0.105E 02	823	0.333E 02	57
			615	0.140E 01			
			645	0.140E 01			

(TABLE B.1C CONTINUED)

TASK/TECHNICAL PACKAGE NUMBER		LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO.,	HRS/UNIT)	(NO.,	HRS/UNIT)	SOURCES
EXC/HAUL (BCY)								
2M	14-0	0.145E-02	0.000E 00	424	0.145E-02			18,57
6M	1-1	0.137E-01	0.000E 00	238	0.610E-02	337	0.761E-02	21,22,34,57
	1-2	0.133E-01	0.000E 00	238	0.610E-02	338	0.716E-02	21,22,34,57
	2-3	0.107E-01	0.000E 00	239	0.444E-02	339	0.627E-02	21,22,34,57
	2-5	0.992E-02	0.000E 00	239	0.444E-02	341	0.548E-02	21,22,34,57
	3-4	0.751E-02	0.000E 00	240	0.307E-02	340	0.444E-02	22,34,47,57
	3-6	0.672E-02	0.000E 00	240	0.307E-02	342	0.365E-02	22,34,47,57
	4-1	0.135E-01	0.000E 00	337	0.749E-02	646	0.598E-02	18,21,22,34,56,83
	4-2	0.130E-01	0.000E 00	338	0.704E-02	646	0.598E-02	18,21,22,34,56,83
	4-7	0.872E-02	0.000E 00	646	0.872E-02			18,22,34,83
	5-3	0.989E-02	0.000E 00	339	0.586E-02	647	0.403E-02	18,22,34,49,57,83
	5-5	0.910E-02	0.000E 00	341	0.507E-02	647	0.403E-02	18,22,34,49,57,83
	5-8	0.464E-02	0.000E 00	647	0.464E-02			18,22,34,49,83
	6-4	0.683E-02	0.000E 00	340	0.410E-02	648	0.273E-02	18,22,34,49,57,83
	6-6	0.604E-02	0.000E 00	342	0.331E-02	648	0.273E-02	18,22,34,49,57,83
	6-9	0.307E-02	0.000E 00	648	0.307E-02			18,22,34,49,83
	7-10	0.476E-02	0.000E 00	649	0.476E-02			18,21,34
	8-11	0.246E-02	0.000E 00	650	0.246E-02			18,21,34
	9-12	0.336E-02	0.000E 00	651	0.224E-02	653	0.112E-02	18,21,34
				616	0.112E-02			
	10-13	0.246E-02	0.000E 00	652	0.164E-02	654	0.819E-03	18,21,34
				617	0.819E-03			
	11-14	0.283E-02	0.000E 00	614	0.283E-02	644	0.283E-02	18,21,34
	12-15	0.109E-02	0.000E 00	616	0.109E-02	645	0.109E-02	18,21,34
	13-16	0.563E-03	0.000E 00	617	0.563E-03	654	0.563E-03	18,21,34
9M	1-1	0.137E-01	0.000E 00	238	0.610E-02	337	0.765E-02	21,22,34,57
	1-2	0.133E-01	0.000E 00	238	0.610E-02	338	0.718E-02	21,22,34,57
	2-3	0.107E-01	0.000E 00	239	0.444E-02	339	0.629E-02	21,22,34,57
	2-5	0.996E-02	0.000E 00	239	0.444E-02	341	0.552E-02	21,22,34,57
	3-4	0.752E-02	0.000E 00	240	0.307E-02	340	0.445E-02	22,34,47,57
	3-6	0.674E-02	0.000E 00	240	0.307E-02	342	0.367E-02	22,34,47,57
	4-1	0.135E-01	0.000E 00	337	0.753E-02	646	0.598E-02	18,21,22,34,56,83

(TABLE B.1C CONTINUED)

TASK/TECHNICAL PACKAGE NUMBER		LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO.,	HRS/UNIT)	(NO.,	HRS/UNIT)	SOURCES
	4-2	0.130E-01	0.000E 00	339	0.706E-02	646	0.598E-02	18,21,22,34,56,83
	4-7	0.101E-01	0.000E 00	646	0.101E-01			18,22,34,83
	5-3	0.991E-02	0.000E 00	339	0.588E-02	647	0.403E-02	18,22,34,49,57,83
	5-5	0.914E-02	0.000E 00	341	0.511E-02	647	0.403E-02	18,22,34,49,57,83
	5-8	0.494E-02	0.000E 00	647	0.494E-02			18,22,34,49,83
	6-4	0.684E-02	0.000E 00	340	0.411E-02	648	0.273E-02	18,22,34,49,57,83
	6-6	0.606E-02	0.000E 00	342	0.333E-02	648	0.273E-02	18,22,34,49,57,83
	6-9	0.324E-02	0.000E 00	648	0.324E-02			18,22,34,49,83
	7-10	0.497E-02	0.000E 00	649	0.497E-02			18,21,34
	8-11	0.253E-02	0.000E 00	650	0.253E-02			18,21,34
	9-12	0.344E-02	0.000E 00	651	0.229E-02	653	0.115E-02	18,21,34
				616	0.115E-02			
	10-13	0.250E-02	0.000E 00	652	0.167E-02	654	0.833E-03	18,21,34
				617	0.833E-03			
	11-14	0.371E-02	0.000E 00	614	0.371E-02	644	0.371E-02	18,21,34
	12-15	0.143E-02	0.000E 00	616	0.143E-02	645	0.143E-02	18,21,34
	13-16	0.782E-03	0.000E 00	617	0.782E-03	654	0.782E-03	18,21,34
60M	1-1	0.144E-01	0.000E 00	238	0.610E-02	337	0.832E-02	21,22,34,57
	1-2	0.137E-01	0.000E 00	238	0.610E-02	338	0.765E-02	21,22,34,57
	2-3	0.111E-01	0.000E 00	239	0.444E-02	339	0.669E-02	21,22,34,57
	2-5	0.106E-01	0.000E 00	239	0.444E-02	341	0.612E-02	21,22,34,57
	3-4	0.782E-02	0.000E 00	240	0.307E-02	340	0.475E-02	22,34,47,57
	3-6	0.707E-02	0.000E 00	240	0.307E-02	342	0.400E-02	22,34,47,57
	4-1	0.142E-01	0.000E 00	337	0.820E-02	646	0.598E-02	18,21,22,34,56,83
	4-2	0.135E-01	0.000E 00	338	0.753E-02	646	0.598E-02	18,21,22,34,56,83
	4-7	0.334E-01	0.000E 00	646	0.334E-01			18,22,34,83
	5-3	0.103E-01	0.000E 00	339	0.628E-02	647	0.403E-02	18,22,34,49,57,83
	5-5	0.974E-02	0.000E 00	341	0.571E-02	647	0.403E-02	18,22,34,49,57,83
	5-8	0.101E-01	0.000E 00	647	0.101E-01			18,22,34,49,83
	6-4	0.714E-02	0.000E 00	340	0.441E-02	648	0.273E-02	18,22,34,49,57,83
	6-6	0.639E-02	0.000E 00	342	0.366E-02	648	0.273E-02	18,22,34,49,57,83
	6-9	0.613E-02	0.000E 00	648	0.613E-02			18,22,34,49,83
	7-10	0.639E-02	0.000E 00	649	0.639E-02			18,21,34

(TABLE B.1C CONTINUED)

TASK/TECHNICAL PACKAGE NUMBER		LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO.	,HRS/UNIT)	(NO.	,HRS/UNIT)	SOURCES
	8-11	0.334E-02	0.000E 00	650	0.334E-02			18,21,34
	9-12	0.478E-02	0.000E 00	651	0.319E-02	653	0.159E-02	18,21,34
				616	0.159E-02			
	10-13	0.323E-02	0.000E 00	652	0.215E-02	654	0.108E-02	18,21,34
				617	0.108E-02			
	11-14	0.168E-01	0.000E 00	614	0.168E-01	644	0.168E-01	18,21,34
	12-15	0.644E-02	0.000E 00	616	0.644E-02	645	0.644E-02	18,21,34
	13-16	0.403E-02	0.000E 00	617	0.403E-02	654	0.403E-02	18,21,34
100M	1-1	0.149E-01	0.000E 00	238	0.610E-02	337	0.884E-02	21,22,34,57
	1-2	0.141E-01	0.000E 00	238	0.610E-02	338	0.801E-02	21,22,34,57
	2-3	0.114E-01	0.000E 00	239	0.444E-02	339	0.699E-02	21,22,34,57
	2-5	0.110E-01	0.000E 00	239	0.444E-02	341	0.658E-02	21,22,34,57
	3-4	0.805E-02	0.000E 00	240	0.307E-02	340	0.498E-02	22,34,47,57
	3-6	0.733E-02	0.000E 00	240	0.307E-02	342	0.426E-02	22,34,47,57
	4-1	0.147E-01	0.000E 00	337	0.872E-02	646	0.598E-02	18,21,22,34,56,83
	4-2	0.139E-01	0.000E 00	338	0.789E-02	646	0.598E-02	18,21,22,34,56,83
	4-7	0.512E-01	0.000E 00	646	0.512E-01			18,22,34,83
	5-3	0.106E-01	0.000E 00	339	0.658E-02	647	0.403E-02	18,22,34,49,57,83
	5-5	0.102E-01	0.000E 00	341	0.617E-02	647	0.403E-02	18,22,34,49,57,83
	5-8	0.140E-01	0.000E 00	647	0.140E-01			18,22,34,49,83
	6-4	0.737E-02	0.000E 00	340	0.464E-02	648	0.273E-02	18,22,34,49,57,83
	6-6	0.665E-02	0.000E 00	342	0.392E-02	648	0.273E-02	18,22,34,49,57,83
	6-9	0.867E-02	0.000E 00	648	0.867E-02			18,22,34,49,83
	7-10	0.677E-02	0.000E 00	649	0.677E-02			18,21,34
	8-11	0.349E-02	0.000E 00	650	0.349E-02			18,21,34
	9-12	0.501E-02	0.000E 00	651	0.334E-02	653	0.167E-02	18,21,34
				616	0.167E-02			
	10-13	0.360E-02	0.000E 00	652	0.239E-02	654	0.120E-02	18,21,34
				617	0.120E-02			
	11-14	0.241E-01	0.000E 00	614	0.241E-01	644	0.241E-01	18,21,34
	12-15	0.927E-02	0.000E 00	616	0.927E-02	645	0.927E-02	18,21,34
	13-16	0.587E-02	0.000E 00	617	0.587E-02	654	0.587E-02	18,21,34
165M	1-1	0.155E-01	0.000E 00	238	0.610E-02	337	0.937E-02	21,22,34,57

(TABLE B.1C CONTINUED)

TASK/TECHNICAL PACKAGE NUMBER		LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO.,	HRS/UNIT)	(NO.,	HRS/UNIT)	SOURCES
	1-2	0.145E-01	0.000E 00	238	0.610E-02	338	0.839E-02	21,22,34,57
	2-3	0.117E-01	0.000E 00	239	0.444E-02	339	0.730E-02	21,22,34,57
	2-5	0.115E-01	0.000E 00	239	0.444E-02	341	0.703E-02	21,22,34,57
	3-4	0.828E-02	0.000E 00	240	0.307E-02	340	0.521E-02	22,34,47,57
	3-6	0.758E-02	0.000E 00	240	0.307E-02	342	0.451E-02	22,34,47,57
	4-1	0.152E-01	0.000E 00	337	0.925E-02	646	0.598E-02	18,21,22,34,56,83
	4-2	0.142E-01	0.000E 00	338	0.827E-02	646	0.598E-02	18,21,22,34,56,83
	4-7	0.699E-01	0.000E 00	646	0.699E-01			18,22,34,83
	5-3	0.109E-01	0.000E 00	339	0.689E-02	647	0.403E-02	18,22,34,49,57,83
	5-5	0.106E-01	0.000E 00	341	0.662E-02	647	0.403E-02	18,22,34,49,57,83
	5-8	0.183E-01	0.000E 00	647	0.183E-01			18,22,34,49,83
	6-4	0.760E-02	0.000E 00	340	0.487E-02	648	0.273E-02	18,22,34,49,57,83
	6-6	0.690E-02	0.000E 00	342	0.417E-02	648	0.273E-02	18,22,34,49,57,83
	6-9	0.109E-01	0.000E 00	648	0.109E-01			18,22,34,49,83
	7-10	0.738E-02	0.000E 00	649	0.738E-02			18,21,34
	8-11	0.373E-02	0.000E 00	650	0.373E-02			18,21,34
	9-12	0.542E-02	0.000E 00	651	0.363E-02	653	0.179E-02	18,21,34
				616	0.179E-02			
	10-13	0.384E-02	0.000E 00	652	0.256E-02	654	0.128E-02	18,21,34
				617	0.128E-02			
	11-14	0.364E-01	0.000E 00	614	0.364E-01	644	0.364E-01	18,21,34
	12-15	0.140E-01	0.000E 00	616	0.140E-01	645	0.140E-01	18,21,34
	13-16	0.892E-02	0.000E 00	617	0.892E-02	654	0.892E-02	18,21,34
500M	1-1	0.180E-01	0.000E 00	238	0.610E-02	337	0.119E-01	21,22,34,57
	1-2	0.163E-01	0.000E 00	238	0.610E-02	338	0.102E-01	21,22,34,57
	2-3	0.132E-01	0.000E 00	239	0.444E-02	339	0.878E-02	21,22,34,57
	2-5	0.136E-01	0.000E 00	239	0.444E-02	341	0.920E-02	21,22,34,57
	3-4	0.939E-02	0.000E 00	240	0.307E-02	340	0.632E-02	22,34,47,57
	3-6	0.878E-02	0.000E 00	240	0.307E-02	342	0.571E-02	22,34,47,57
	4-1	0.178E-01	0.000E 00	337	0.118E-01	646	0.598E-02	18,21,22,34,56,83
	4-2	0.160E-01	0.000E 00	338	0.101E-01	646	0.598E-02	18,21,22,34,56,83
	4-7	0.172E 00	0.000E 00	646	0.172E 00			18,22,34,83
	5-3	0.124E-01	0.000E 00	339	0.837E-02	647	0.403E-02	18,22,34,49,57,83

(TABLE B.1C CONTINUED)

TASK/TECHNICAL PACKAGE NUMBER		LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO.,HRS/UNIT)		(NO.,HRS/UNIT)		SOURCES
	5-5	0.128E-01	0.000E 00	341	0.879E-02	647	0.403E-02	18,22,34,49,57,83
	5-8	0.374E-01	0.000E 00	647	0.374E-01			18,22,34,49,83
	6-4	0.871E-02	0.000E 00	340	0.598E-02	648	0.273E-02	18,22,34,49,57,83
	6-6	0.810E-02	0.000E 00	342	0.537E-02	648	0.273E-02	18,22,34,49,57,83
	6-9	0.219E-01	0.000E 00	648	0.219E-01			18,22,34,49,83
	7-10	0.103E-01	0.000E 00	649	0.103E-01			18,21,34
	8-11	0.499E-02	0.000E 00	650	0.499E-02			18,21,34
	9-12	0.723E-02	0.000E 00	651	0.482E-02	653	0.241E-02	18,21,34
				616	0.241E-02			
	10-13	0.510E-02	0.000E 00	652	0.340E-02	654	0.170E-02	18,21,34
				617	0.170E-02			
	11-14	0.102E 00	0.000E 00	614	0.102E 00	644	0.102E 00	18,21,34
	12-15	0.391E-01	0.000E 00	616	0.391E-01	645	0.391E-01	18,21,34
	13-16	0.252E-01	0.000E 00	617	0.252E-01	654	0.252E-01	18,21,34
800M	1-1	0.194E-01	0.000E 00	238	0.610E-02	337	0.133E-01	21,22,34,57
	1-2	0.173E-01	0.000E 00	238	0.610E-02	338	0.112E-01	21,22,34,57
	2-3	0.140E-01	0.000E 00	239	0.444E-02	339	0.958E-02	21,22,34,57
	2-5	0.149E-01	0.000E 00	239	0.444E-02	341	0.104E-01	21,22,34,57
	3-4	0.998E-02	0.000E 00	240	0.307E-02	340	0.691E-02	22,34,47,57
	3-6	0.941E-02	0.000E 00	240	0.307E-02	342	0.634E-02	22,34,47,57
	4-1	0.192E-01	0.000E 00	337	0.132E-01	646	0.598E-02	18,21,22,34,56,83
	4-2	0.170E-01	0.000E 00	338	0.111E-01	646	0.598E-02	18,21,22,34,56,83
	4-7	0.225E 00	0.000E 00	646	0.225E 00			18,22,34,83
	5-3	0.132E-01	0.000E 00	339	0.917E-02	647	0.403E-02	18,22,34,49,57,83
	5-5	0.140E-01	0.000E 00	341	0.100E-01	647	0.403E-02	18,22,34,49,57,83
	5-8	0.481E-01	0.000E 00	647	0.481E-01			18,22,34,49,83
	6-4	0.930E-02	0.000E 00	340	0.657E-02	648	0.273E-02	18,22,34,49,57,83
	6-6	0.873E-02	0.000E 00	342	0.600E-02	648	0.273E-02	18,22,34,49,57,83
	6-9	0.279E-01	0.000E 00	648	0.279E-01			18,22,34,49,83
	7-10	0.126E-01	0.000E 00	649	0.126E-01			18,21,34
	8-11	0.593E-02	0.000E 00	650	0.593E-02			18,21,34
	9-12	0.775E-02	0.000E 00	651	0.581E-02	653	0.194E-02	18,21,34
				616	0.194E-02			

(TABLE B.1C CONTINUED)

TASK/TECHNICAL PACKAGE	NUMBER	LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO.	HRS/UNIT)	(NO.	HRS/UNIT)	SOURCES
	10-13	C.539E-02	0.000E 00	652	0.404E-02	654	0.135E-02	18,21,34
				617	0.135E-02			
	11-14	C.160E CO	0.000E 00	614	0.160E 00	644	0.160E 00	18,21,34
	12-15	0.616E-01	0.000E 00	616	0.616E-01	645	0.616E-01	18,21,34
	13-16	C.4C0E-01	0.000E 00	617	0.400E-01	654	0.400E-01	18,21,34
SPR/COMP (BCY)								
98%	11	0.336E-02	0.000E 00	536	0.829E-03	616	0.253E-02	18,21,34,57
				645	0.253E-02			
	12	C.434E-02	0.000E 00	503	C.363E-02	616	0.253E-02	18,21,34,57
				645	0.253E-02	653	C.181E-02	
	13	C.414E-02	0.000E 00	537	0.161E-02	616	0.253E-02	18,21,34
				645	0.253E-02			
	14	0.608E-02	0.000E 00	538	0.355E-02	616	0.253E-02	18,21,34,39
				645	0.253E-02			
	21	0.217E-02	0.000E 00	536	0.829E-03	617	0.134E-02	18,21,34,57
				654	C.134E-02			
	22	0.315E-02	0.000E 00	503	0.363E-02	617	0.134E-02	18,21,34,57
				653	0.181E-02	654	0.134E-02	
	23	C.295E-02	0.000E 00	537	0.161E-02	617	0.134E-02	18,21,34
				654	0.134E-02			
	24	0.489E-02	0.000E 00	538	0.355E-02	617	0.134E-02	18,21,34,39
				654	0.134E-02			
	31	0.182E-02	0.000E 00	425	0.990E-03	536	0.829E-03	18,21,34,57
	32	C.280E-02	0.000E 00	425	0.990E-03	503	0.363E-02	18,21,34,57
				653	C.181E-02			
	33	0.260E-02	0.000E 00	425	0.990E-03	537	0.161E-02	18,21,34,57
	34	C.454E-02	0.000E 00	425	0.990E-03	538	0.355E-02	18,21,34,39,57
	41	0.158E-02	0.000E 00	426	0.753E-03	536	0.829E-03	18,21,34,57
	42	C.256E-02	0.000E 00	426	0.753E-03	503	C.363E-02	18,21,34,57
				653	0.181E-02			
	43	0.236E-02	0.000E 00	426	0.753E-03	537	0.161E-02	18,21,34,57
	44	0.430E-02	0.000E 00	426	0.753E-03	538	0.355E-02	18,21,34,39,57

SURFACING

(TABLE B.1C CONTINUED)

TASK/TECHNICAL PACKAGE NUMBER		LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO.,	HRS/UNIT)	(NO.,	HRS/UNIT)	SOURCES
GRVL (CCY)	11	0.546E-02	0.000E 00	539	0.359E-02	616	0.187E-02	18,21,34,57
				645	0.187E-02			
	12	0.481E-02	0.000E 00	537	0.294E-02	616	0.187E-02	18,21,34,50
				645	0.187E-02			
	13	0.796E-02	0.000E 00	538	0.609E-02	616	0.187E-02	18,21,34,39,50
				645	0.187E-02			
	21	0.493E-02	0.000E 00	539	0.359E-02	617	0.134E-02	18,21,34,57
				654	0.134E-02			
	22	0.428E-02	0.000E 00	537	0.294E-02	617	0.134E-02	18,21,34,50
				654	0.134E-02			
	23	0.743E-02	0.000E 00	538	0.609E-02	617	0.134E-02	18,21,34,39,50
				654	0.134E-02			
	31	0.454E-02	0.000E 00	425	0.954E-03	539	0.359E-02	18,21,34,57
	32	0.389E-02	0.000E 00	425	0.954E-03	537	0.294E-02	18,21,34,50,57
	33	0.704E-02	0.000E 00	425	0.954E-03	538	0.609E-02	18,21,34,39,50,57
	41	0.445E-02	0.000E 00	426	0.858E-03	539	0.359E-02	18,21,34,57
	42	0.380E-02	0.000E 00	426	0.858E-03	537	0.294E-02	18,21,34,50,57
	43	0.695E-02	0.000E 00	426	0.858E-03	538	0.609E-02	18,21,34,39,50,57
	51	0.807E-02	0.242E-02	339	0.206E-02	410	0.242E-02	21,34,54,57,77
				427	0.242E-02	539	0.359E-02	
	52	0.742E-02	0.242E-02	339	0.206E-02	410	0.242E-02	21,34,50,54,57,77
				427	0.242E-02	537	0.294E-02	
	53	0.106E-01	0.242E-02	339	0.206E-02	410	0.242E-02	21,34,39,50,54,57,77
				427	0.242E-02	538	0.609E-02	
WBM (CCY)	111	0.523E-01	0.108E-01	539	0.480E-01	412	0.959E-02	15,18,21,34,40,54,57,77
				343	0.959E-02	427	0.118E-02	
				410	0.118E-02	339	0.110E-02	
				645	0.200E-02	616	0.200E-02	
	112	0.508E-01	0.105E-01	537	0.466E-01	412	0.931E-02	15,18,21,34,40,50,54,77
				343	0.931E-02	427	0.118E-02	
				410	0.118E-02	339	0.110E-02	
				645	0.200E-02	616	0.200E-02	
	113	0.676E-01	0.139E-01	538	0.633E-01	412	0.127E-01	15,18,21,34,39,40,50,54,77

(TABLE B.1C CONTINUED)

TASK/TECHNICAL PACKAGE NUMBER	LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO.	HRS/UNIT)	(NO.	HRS/UNIT)	SOURCES
			343	0.127E-01	427	0.118E-02	
			410	0.118E-02	339	0.110E-02	
			645	0.200E-02	616	0.200E-02	
121	0.578E-01	0.173E-01	539	0.480E-01	412	0.959E-02	15,18,21,34,40,54,57,77
			343	0.959E-02	337	0.775E-02	
			411	0.775E-02	410	0.775E-02	
			645	0.200E-02	616	0.200E-02	
122	0.564E-01	0.171E-01	537	0.466E-01	412	0.931E-02	15,18,21,34,40,50,54,77
			343	0.931E-02	337	0.775E-02	
			411	0.775E-02	410	0.775E-02	
			645	0.200E-02	616	0.200E-02	
123	0.731E-01	0.205E-01	538	0.633E-01	412	0.127E-01	15,18,21,34,39,40,50,54,77
			343	0.127E-01	337	0.775E-02	
			411	0.775E-02	410	0.775E-02	
			645	0.200E-02	616	0.200E-02	
211	0.517E-01	0.108E-01	539	0.480E-01	412	0.959E-02	15,18,21,34,40,54,57,77
			343	0.959E-02	427	0.118E-02	
			410	0.118E-02	339	0.110E-02	
			654	0.143E-02	617	0.143E-02	
212	0.503E-01	0.105E-01	537	0.466E-01	412	0.931E-02	15,18,21,34,40,50,54,77
			343	0.931E-02	427	0.118E-02	
			410	0.118E-02	339	0.110E-02	
			654	0.143E-02	617	0.143E-02	
213	0.670E-01	0.139E-01	538	0.633E-01	412	0.127E-01	15,18,21,34,39,40,50,54,77
			343	0.127E-01	427	0.118E-02	
			410	0.118E-02	339	0.110E-02	
			654	0.143E-02	617	0.143E-02	
221	0.572E-01	0.173E-01	539	0.480E-01	412	0.959E-02	15,18,21,34,40,54,57,77
			343	0.959E-02	337	0.775E-02	
			411	0.775E-02	410	0.775E-02	
			654	0.143E-02	617	0.143E-02	
222	0.558E-01	0.171E-01	537	0.466E-01	412	0.931E-02	15,18,21,34,40,50,54,77
			343	0.931E-02	337	0.775E-02	

(TABLE B.1C CONTINUED)

TASK/TECHNICAL PACKAGE NUMBER	LABOR (HRS/UNIT) SKILLED	LABOR (HRS/UNIT) UNSKILLED	EQUIPMENT (NO.,	HRS/UNIT)	(NO.,	HRS/UNIT)	SOURCES
			411	0.775E-02	410	0.775E-02	
			654	0.143E-02	617	0.143E-02	
223	0.725E-01	0.205E-01	538	0.633E-01	412	0.127E-01	15,18,21,34,39,40,50,54,77
			343	0.127E-01	337	0.775E-02	
			411	0.775E-02	410	0.775E-02	
			654	0.143E-02	617	0.143E-02	
311	0.512E-01	0.108E-01	539	0.480E-01	412	0.959E-02	15,18,21,34,40,54,57,77
			343	0.959E-02	427	0.118E-02	
			410	0.118E-02	339	0.110E-02	
			425	0.925E-03			
312	0.499E-01	0.105E-01	537	0.466E-01	412	0.931E-02	15,18,21,34,40,50,54,57,77
			343	0.931E-02	427	0.118E-02	
			410	0.118E-02	339	0.110E-02	
			425	0.925E-03			
313	0.666E-01	0.139E-01	538	0.633E-01	412	0.127E-01	15,18,21,34,39,40,50,54,57,
			343	0.127E-01	427	0.118E-02	77
			410	0.118E-02	339	0.110E-02	
			425	0.925E-03			
321	0.567E-01	0.173E-01	539	0.480E-01	412	0.959E-02	15,18,21,34,40,54,57,77
			343	0.959E-02	337	0.775E-02	
			411	0.775E-02	410	0.775E-02	
			425	0.925E-03			
322	0.553E-01	0.171E-01	537	0.466E-01	412	0.931E-02	15,18,21,34,40,50,54,57,77
			343	0.931E-02	337	0.775E-02	
			411	0.775E-02	410	0.775E-02	
			425	0.925E-03			
323	0.720E-01	0.205E-01	538	0.633E-01	412	0.127E-01	15,18,21,34,39,40,50,54,57,
			343	0.127E-01	337	0.775E-02	77
			411	0.775E-02	410	0.775E-02	
			425	0.925E-03			
411	0.511E-01	0.108E-01	539	0.480E-01	412	0.959E-02	15,18,21,34,40,54,57,77
			343	0.959E-02	427	0.118E-02	
			410	0.118E-02	339	0.110E-02	

(TABLE B.1C CONTINUED)

TASK/TECHNICAL PACKAGE NUMBER	LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO.,	HRS/UNIT)	(NO.,	HRS/UNIT)	SOURCES
			426	0.831E-03			
412	0.497E-01	0.105E-01	537	0.466E-01	412	0.931E-02	15,18,21,34,40,50,54,57,77
			343	0.931E-02	427	0.118E-02	
			410	0.118E-02	339	0.110E-02	
			426	0.831E-03			
413	0.664E-01	0.139E-01	538	0.633E-01	412	0.127E-01	15,18,21,34,39,40,50,54,57,
			343	0.127E-01	427	0.118E-02	77
			410	0.118E-02	339	0.110E-02	
			426	0.831E-03			
421	0.566E-01	0.173E-01	539	0.480E-01	412	0.959E-02	15,18,21,34,40,54,57,77
			343	0.959E-02	337	0.775E-02	
			411	0.775E-02	410	0.775E-02	
			426	0.831E-03			
422	0.552E-01	0.171E-01	537	0.466E-01	412	0.931E-02	15,18,21,34,40,50,54,57,77
			343	0.931E-02	337	0.775E-02	
			411	0.775E-02	410	0.775E-02	
			426	0.831E-03			
423	0.719E-01	0.205E-01	538	0.633E-01	412	0.127E-01	15,18,21,34,39,40,50,54,57,
			343	0.127E-01	337	0.775E-02	77
			411	0.775E-02	410	0.775E-02	
			426	0.831E-03			
511	0.548E-01	0.132E-01	539	0.480E-01	412	0.959E-02	15,21,34,40,54,57,77
			343	0.959E-02	427	0.364E-02	
			410	0.364E-02	339	0.320E-02	
512	0.534E-01	0.130E-01	537	0.466E-01	412	0.931E-02	15,21,34,40,50,54,57,77
			343	0.931E-02	427	0.364E-02	
			410	0.364E-02	339	0.320E-02	
513	0.701E-01	0.163E-01	538	0.633E-01	412	0.127E-01	15,21,34,39,40,50,54,57,77
			343	0.127E-01	427	0.364E-02	
			410	0.364E-02	339	0.320E-02	
521	0.603E-01	0.198E-01	539	0.480E-01	412	0.959E-02	15,21,34,40,54,57,77
			343	0.959E-02	337	0.775E-02	
			411	0.775E-02	410	0.102E-01	

(TABLE B.1C CONTINUED)

TASK/TECHNICAL PACKAGE NUMBER	LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO.,	HRS/UNIT)	(NO.,	HRS/UNIT)	SOURCES
			427	0.246E-02	339	0.210E-02	
522	0.589E-01	0.195E-01	537	0.466E-01	412	0.931E-02	15,21,34,40,50,54,57,77
			343	0.931E-02	337	0.775E-02	
			411	0.775E-02	410	0.102E-01	
			427	0.246E-02	339	0.210E-02	
523	0.756E-01	0.229E-01	538	0.633E-01	412	0.127E-01	15,21,34,39,40,50,54,57,77
			343	0.127E-01	337	0.775E-02	
			411	0.775E-02	410	0.102E-01	
			427	0.246E-02	339	0.210E-02	
DBST/G (SY) 1111	0.119E-02	0.528E-03	540	0.411E-03	339	0.334E-03	21,34,54,57,77,89
			427	0.334E-03	410	0.334E-03	
			454	0.116E-03	441	0.787E-04	
			655	0.787E-04			
1112	0.105E-02	0.528E-03	541	0.270E-03	339	0.334E-03	21,34,54,57,77,89
			427	0.334E-03	410	0.334E-03	
			454	0.116E-03	441	0.787E-04	
			655	0.787E-04			
1121	0.131E-02	0.977E-03	540	0.411E-03	337	0.782E-03	21,34,54,77,89
			411	0.782E-03	410	0.782E-03	
			454	0.116E-03	441	0.787E-04	
			655	0.787E-04			
1122	0.117E-02	0.977E-03	541	0.270E-03	337	0.782E-03	21,34,54,77,89
			411	0.782E-03	410	0.782E-03	
			454	0.116E-03	441	0.787E-04	
			655	0.787E-04			
1211	0.119E-02	0.526E-03	540	0.411E-03	339	0.334E-03	21,34,54,57,77,89
			427	0.334E-03	410	0.334E-03	
			453	0.114E-03	441	0.787E-04	
			655	0.787E-04			
1212	0.105E-02	0.526E-03	541	0.270E-03	339	0.334E-03	21,34,54,57,77,89
			427	0.334E-03	410	0.334E-03	
			453	0.114E-03	441	0.787E-04	
			655	0.787E-04			

(TABLE B.1C CONTINUED)

TASK/TECHNICAL PACKAGE NUMBER		LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO.	HRS/UNIT)	(NO.	HRS/UNIT)	SOURCES
	1221	0.131E-02	0.974E-03	540	0.411E-03	337	0.782E-03	21,34,54,77,89
				411	0.782E-03	410	0.782E-03	
				453	0.114E-03	441	0.787E-04	
				655	0.787E-04			
	1222	0.117E-02	0.974E-03	541	0.270E-03	337	0.782E-03	21,34,54,77,89
				411	0.782E-03	410	0.782E-03	
				453	0.114E-03	441	0.787E-04	
				655	0.787E-04			
OBST/W (SY)	1111	0.117E-02	0.510E-03	540	0.411E-03	339	0.334E-03	21,34,54,57,77,89
				427	0.334E-03	410	0.334E-03	
				454	0.941E-04	441	0.787E-04	
				655	0.787E-04			
	1112	0.103E-02	0.510E-03	541	0.270E-03	339	0.334E-03	21,34,54,57,77,89
				427	0.334E-03	410	0.334E-03	
				454	0.943E-04	441	0.787E-04	
				655	0.787E-04			
	1121	0.129E-02	0.955E-03	540	0.411E-03	337	0.782E-03	21,34,54,77,89
				411	0.782E-03	410	0.782E-03	
				454	0.941E-04	441	0.787E-04	
				655	0.787E-04			
	1122	0.115E-02	0.955E-03	541	0.270E-03	337	0.782E-03	21,34,54,77,89
				411	0.782E-03	410	0.782E-03	
				454	0.941E-04	441	0.787E-04	
				655	0.787E-04			
	1211	0.117E-02	0.505E-03	540	0.411E-03	339	0.334E-03	21,34,54,57,77,89
				427	0.334E-03	410	0.334E-03	
				453	0.919E-04	441	0.787E-04	
				655	0.787E-04			
	1212	0.103E-02	0.505E-03	541	0.270E-03	339	0.334E-03	21,34,54,57,77,89
				427	0.334E-03	410	0.334E-03	
				453	0.919E-04	441	0.787E-04	
				655	0.787E-04			
	1221	0.129E-02	0.953E-03	540	0.411E-03	337	0.782E-03	21,34,54,77,89

(TABLE B.1C CONTINUED)

TASK/TECHNICAL PACKAGE NUMBER	LABOR (HRS/UNIT) SKILLED	UNSKILLED	EQUIPMENT (NO.,HRS/UNIT)	(NO.,HRS/UNIT)	SOURCES
			411 0.782E-03	410 0.782E-03	
			453 0.919E-04	441 0.787E-04	
			655 0.787E-04		
1222	0.115E-02	0.953E-03	541 0.270E-03	337 0.782E-03	21,34,54,77,89
			411 0.782E-03	410 0.782E-03	
			453 0.919E-04	441 0.787E-04	
			655 0.787E-04		

NOTE: ALL TECHNICAL PACKAGES FOR SURFACING ALSO INCLUDE MATERIALS:

GRAVEL:	830-1.40 LCY/CCY
WATERBOUND MACADAM:	831-1.37 LCY/CCY
	832-0.32 LCY/CCY
	833-63 GAL/CCY
DOUBLE BITUMINOUS SURFACE TREATMENT ON GRAVEL:	835-0.93 GAL/SY
	834-0.0191 LCY/SY
DOUBLE BITUMINOUS SURFACE TREATMENT ON WATERBOUND MACADAM:	835-0.72 GAL/SY
	834-0.0191 LCY/SY

B.2 Resource Costs

Labor, equipment, and materials constitute the resources used in highway construction; the draft animal, a horse in this study, is in essence a piece of equipment, but it is treated separately here since its cost is derived somewhat differently. In Sections B.21 through B.24, the procedures for deriving the various resource costs, at different points in time (U.S. in 1930, 1956, and 1974) and under different conditions (a developing country today), are discussed, and the basic data and final prices of the various resources are given; Section B.21 covers equipment, B.22 the horse, B.23 labor, and B.24 materials. All references cited are given in Section B.3.

B.21 Equipment

The cost of equipment is estimated on an hourly basis, its hourly price involving ownership costs of depreciation and interest, maintenance, and miscellaneous items such as insurance, tax, and storage and operating costs of fuel and lubrication. A lack of data precludes explicit inclusion of mobilization and other fixed costs associated with equipment use; labor, too, experiences certain costs over and above the basic hourly wage and fringe benefits. Such costs for both resources are taken as included in overhead in the project-level analysis.

It was decided at the outset to estimate hourly equipment rates from scratch rather than to use those reported in the literature because of the various assumptions hidden in such figures and because of the difficulty of adjusting them to various time periods and economic conditions. The first step thus consists of developing the basic equation for calculating these hourly rates; the final form, derived with the help of various authors (21,25,26,59), is as follows:

$$\begin{array}{c}\text{HOURLY PRICE}\\ \text{OF EQUIPMENT}\\ \text{(in dollars/hour)}\end{array} = P_t \left[\frac{\text{index}}{\text{INDEX}_t}\right] \left[\frac{\dfrac{(1+i)^{N}i}{(1+i)^{N}-1}}{H} + \frac{\text{MAINT}}{NH} + 0.055\,\frac{N+1}{2NH} \right] +$$

$$1.35\ (\text{ccost} * \text{CREQ} + \text{gcost} * \text{GREQ} + \text{dcost} * \text{DREQ})$$

where small letters indicate economic variables

capital letters indicate engineering variables

subscript t = year of investment cost

P_t = investment cost in year t (in dollars)

index = index used to inflate or deflate investment cost in line with particular economic conditions under consideration

INDEX_t = investment cost index in year t

i = interest rate (in decimal form)

N = life (in years)

H = annual hours of utilization

MAINT = maintenance as a percentage of investment cost (in decimal form)

_cost = per unit quantity cost of fuel, with c = coal (in tons), g = gasoline (in gallons), d = diesel fuel (in gallons)

_REQ = quantity of fuel consumed per hour, with prefixes and units as for _cost

The first half of the equation is ownership costs and the second operating costs.

Before investigating the component parts of the equation, a couple of observations need to be made: (1) many items of equipment appear in only one or two of the three technology periods; and (2) as for those that appear in all three periods, they have likely undergone certain changes over time which have influenced their quality, productivity, and so forth, and are thus different pieces of equipment than they were originally. In light of this, a separate set of equipment is specified in each technology period, with a full complement of engineering variables defined for each item of equipment at the time of its use. In the first term of the equation then, $P_t \left[\frac{\text{index}}{\text{INDEX}_t}\right]$ is the investment or purchase price (P_t) of each item of equipment at the time of its use is inflated or deflated by means of an index ($\frac{\text{index}}{\text{INDEX}_t}$) to bring it in line with any given set of economic conditions. Although the use of an index over such a long time span (some 50 years) is to be discouraged, this appears as the most viable and consistent means of developing investment, and ultimately hourly, costs for equipment under various economic conditions; another point in favor of this is that the two construction equipment indexes (U.S. Office of Business Economics and U.S. Bureau of Labor Statistics) which are used in the research are felt to be reasonably reliable ones (e.g., they are price rather than cost-based).

Proceeding with the decomposition of the equation, the next term, $\left[\frac{(1 + i)^N i}{(1 + i)^N - 1}\right] / H$, is the capital recovery fractor expressed in hourly terms, which when multiplied by the investment cost represents the interest and depreciation costs associated with an item of equipment on an hourly basis. The final two terms in the ownership costs part of the equation, $\frac{MAINT}{NH}$ and $0.055\ \frac{N+1}{2NH}$, multiplied by the investment cost, respectively yield hourly charges for maintenance and repair of the equipment and for miscellaneous items like tax (1 - 5 % of average annual investment [AAI]), insurance (1 - 3 % of AAI), and storage ($\leq$ 1% of AAI). Tires are frequently included as a separate cost item; here they are assumed to be covered by the cost of maintenance and repair which includes both a labor and materials component. The operating costs part of the equation is simply the cost of the fuel the equipment uses in an hour, with an additional 35 percent included to cover the cost of grease and oil.

The full set of engineering variables required by the equation for each item of equipment is given in Table B.2, along with a brief description of the piece of equipment; Table B2a covers the 1920's set of equipment, B.2b the 1950's, and B.2c the 1970's. The basic data for each piece of equipment, with the possible exception of the rate of fuel consumption (and, of course, the index which is discussed below), by and large come from a single source for each technology period. The Associated General Contractors of America are responsible for the 1920's source (13), while Peurifoy authors both the 1950's and 1970's sources (56,57); the data presented in each are similar enough in form to suggest that there may be a certain amount of coordination. Whenever possible, additional sources substantiating these figures are also cited.

Table B.2a: Brief description, basic data, and sources for each piece of equipment appearing in the 1920's technical packages.

Number	Description	Purchase price (P_t) ($@year)	Index for year of purchase[a] ($INDEX_t$)	Life (N-yrs)	Life (H-hrs/yr)	Maintenance over life (MAINT-% of investment cost)	Fuel consumption[b] (CREQ,GREQ, DREQ-units/hour)	Source
201	Handtools for site prep[c]	0.85*@1913	20.8	0.5*	2000*	40*	-	15
202	Handtools for excavation[d]	0.75*@1913	20.8	0.5*	2000*	40*	-	15
203	Moldboard plow	40 @1930	30.1	3	1890	45	-	13,15,26
204	0.75cy power shovel dipper	2120 @1930	30.1	4	2430	40	-	5,13
205	Elevating grader	2600 @1930	30.1	5	1890	100	-	13,15,32
230	0.75cy power shovel	10600 @1930	30.1	7	2430	105	0.050c	5,13,48
301	Steel wheelbarrow (0.095 bcy)	7 @1913	20.8	1*	2000*	40*	-	15,26,58
302	Handcart (0.11 bcy)	10* @1913	20.8	1*	2000*	40*	-	15,26,58
303	1.5cy bottom-dump wood wagon	240 @1930	30.1	4	1620	56	-	13,15
304	5cy bottom-dump steel wagon	700 @1938	33.7	5	1920	75	-	13
330	3.5 ton rear-dump truck	4800 @1930	30.1	5.5	2360	88	3.0g	13,26
331	5 ton rear-dump truck	6000 @1930	30.1	5.5	2160	88	3.6g	13,26
401	Handtools for spreading[e]	0.60*@1913	20.8	0.5*	2000*	40*	-	12,15
402	7 ft blade grader	520 @1930	30.1	3	2160	45	-	13,14,15,48
403	12 ft blade grader	1800 @1938	33.7	5	1920	100	-	13,26
404	5 ft blade grader	300* @1930	30.1	3*	2160*	45*	-	13,26,48
405	450 gal sprinkler wagon	600 @1930	30.1	5	1620	50	-	13,26
406	7.5ft spreader box	400 @1930	30.1	5	1620	75	-	13,26
450	600 gal bitumen distributor	6000 @1930	30.1	4	1620	68	3.0*g	13,26
501	2.5 ton horse-drawn roller	300 @1913	20.8	6*	2000*	60*	-	15
530	6-8 ton 3-wheel roller	2900 @1930	30.1	7	1890	84	2.0g	13,26,35,80
531	10 ton 3-wheel roller	3000 @1930	30.1	9	1890	90	0.035c	13,15,26,27
602	Bulldozer blade-80hp tractor	1600 @1938	33.7	4	1920	60	-	13,26
603	4 ft fresno (0.33 bcy)	26 @1930	30.1	3	1890	60	-	13,15,26,30,48
604	0.175 bcy dragscraper	11 @1930	30.1	2	1890	30	-	13,15,58
605	No.2 wheelscraper (0.40bcy)	68 @1930	30.1	5	1890	75	-	13,30
606	Bulldozer blade-60hp tractor	1350 @1930	30.1	5	1350	60	-	9,13
630	80hp crawler tractor	4650 @1938	33.7	5	1920	75	5.9g	13,26
631	<20hp wheel tractor	700 @1930	30.1	2	2430	30	1.8*g	13
632	76hp crawler tractor	6480 @1938	33.7	5	1920	75*	3.5d	13,26
633	60hp crawler tractor	4300 @1930	30.1	5	2160	75	4.8g	13,26
634	30hp crawler tractor	2500 @1930	30.1	4	2160	75	2.4g	13,26

(Table B.2a continued)

<u>Note</u>: Asterisk (*) indicates that figure is an estimate.

[a]Source: 74,85.

[b]Type of fuel is indicated by letter after fuel consumption figure:

c - coal	-	tons/hour
g - gasoline	-	gallons/hour
d - diesel fuel	-	gallons/hour

[c]Include axes, crosscut saws, machetes, brushhooks, shovels, rakes, hoes, picks, mattocks.

[d]Include picks and shovels.

[e]Include shovels, rakes, hoes, potato hooks, and brooms.

Table B.2b: Brief description, basic data, and sources for each piece of equipment appearing in the 1950's technical packages.

Number	Description	Purchase price (P_t) ($ @ year)	Index for year of purchase[a] ($INDEX_t$)	Life (N-yrs)	Life (H-hrs/yr)	Maintenance over life (MAINT-% of investment cost)	Fuel consumption[b] (GREQ, DREQ-gals/hr)	Source
206	Handtools for brushing[c]	2.74* @ 1954	81.6	0.5*	2000*	40*	-	62
207	Handtools for tree removal[d]	5.21* @ 1954	81.6	0.5*	2000*	40*	-	62
208	Handtools for stump removal[e]	2.89* @ 1954	81.6	0.5*	2000*	40*	-	62
231	1.5cy power shovel	42000 @ 1951	77.8	5	2000	65	4.0d	46,56
232	2.0cy power shovel	56000 @ 1951	77.8	6	1600	80	5.0d	46,65
233	2.5cy power shovel	85000 @ 1958	100.0	6	2000	80	6.0d	46,56,63
234	Elevating grader	36000 @ 1951	77.8	5	2000	65	3.5d	46,56
235	36 in. chain saw	415 @ 1956	89.7	3	1200	45	0.5*g	56,62
305	8.5cy bottom-dump wagon	5000*@ 1951	77.8	5	2000	50	-	56,63
306	15cy bottom-dump wagon	8500 @ 1951	77.8	5	2000	50	-	56,63
332	10 ton rear-dump truck	12700 @ 1951	77.8	5	1800	65	3.2d	56,88
333	20 ton rear-dump truck	28500 @ 1951	77.8	5	1600	60	7.5d	56,88
334	3.5 ton stake truck	6000 @ 1951	77.8	4	2000	48	3.8g	56,88
335	0.5 ton stake truck	1600 @ 1951	77.8	3	2000	45	0.5g	46,56
407	1500 gal water tank	1000 @ 1954	81.6	6	2500	80	-	46,77
408	Handtools for spreading[f]	2.03* @ 1954	81.6	0.5*	2000*	40*	-	62
409	12 ft spreader box	1180 @ 1951	77.8	5	1600	75	-	56
420	10 ft blade grader	7500 @ 1951	77.8	4	2000	60	3.0g	46,56
421	13 ft blade grader	12800 @ 1951	77.8	5	2000	75	4.5d	56,63
422	12 ft wheel spreader	5900 @ 1951	77.8	4	1600	68	1.5g	56
423	8 ft blade grader	4150 @ 1951	77.8	4	2000	75	5.0g	18,46,56
440	Drag broom	75*@ 1951	77.8	1*	2000*	80*	-	-
451	Rotary broom	1800 @ 1951	77.8	5	1600	75	0.7g	56
452	1000 gal bitumen distributor	8100 @ 1951	77.8	5	1600	85	7.1g	56
502	Sheepsfoot roller	1800 @ 1951	77.8	4	2000	75	-	56
532	8 ton 3-wheel roller	7900 @ 1951	77.8	7	2000	100	1.0d	56
533	10 ton pneumatic roller	9100 @ 1974	176.3	3	1400	90	2.2d	57
534	12 ton 3-wheel roller	9500 @ 1951	77.8	7	2000	100	1.7d	56
535	5-8 ton tandem roller	5300 @ 1951	77.8	7	2000	100	1.9g	56
607	8 ft bulldozer blade	1350 @ 1951	77.8	5	2000	65	-	56
608	10 ft bulldozer blade	1600 @ 1951	77.8	5	2000	65	-	56
609	11.5 ft bulldozer blade	2000 @ 1951	77.8	5	2000	65	-	56
610	1.5 in. diameter steel cable(100 ft)	57 @ 1938	33.7	3	1440	45	-	13
611	6 cy 4-wheel scraper	6000 @ 1951	77.8	5	2000	65	-	56
612	9 cy 4-wheel scraper	8000 @ 1951	77.8	5	2000	65	-	56
613	15 cy 4-wheel scraper	13000 @ 1951	77.8	5	2000	65	-	56
638	125 fwhp wheel tractor	13000 @ 1951	77.8	5	2000	65	5.0d	56,63
639	185 fwhp wheel tractor	17000 @ 1951	77.8	5	2000	65	5.0d	56,63
640	250 fwhp wheel tractor	20000 @ 1951	77.8	5	2000	65	7.0d	56,63
641	70 dbhp crawler tractor	8300 @ 1951	77.8	5	2000	65	2.4d	56,63
642	90 dbhp crawler tractor	11000 @ 1951	77.8	5	2000	65	3.5d	56,63
643	130 dbhp crawler tractor	15000 @ 1951	77.8	5	2000	65	5.0d	56,63

(Table B.2b continued)

Note: Asterisk (*) indicates that figure is an estimate.

[a]Source: 74,85.

[b]Type of fuel is indicated by letter after fuel consumption figure:

g - gasoline
d - diesel fuel

[c]Include axes, scythes, pruning saws, pole saws, shovels, and mattock hoes.

[d]Include crosscut saws, pole saws and extensions, and axes.

[e]Include post hole diggers and shovels.

[f]Include shovels, hoes, and rakes.

Table B.2c: Brief description, basic data, and sources for each piece of equipment appearing in the 1970's technical packages.

Number	Description	Purchase price (P_t) ($ @ year)	Index for year of purchase[a] ($INDEX_t$)	Life (N-yrs)	Life (H-hrs/yr)	Maintenance over life (MAINT-% of investment cost)	Fuel consumption[b] (GREQ, DREQ-gals/hr)	Source
209	Handtools for site prep[c]	4.84*@ 1974	176.3	0.5*	2000*	40*	-	62
236	36 in. chain saw	490 @ 1974	176.3	3	1200	45	0.3g	57
237	1 cy backhoe	54900*@ 1974	176.3	6	2000	60	5.0d	18,21,49,57,89
238	1.5 cy power shovel	88500 @ 1974	176.3	5	2000	75	4.8d	18,57
239	2.5 cy power shovel	165000 @ 1974	176.3	10	2000	125	9.0d	18,21,47,89
240	3.5 cy power shovel	146180 @ 1970	135.9	8	2500	155	13.0d	18,47
241	6 in. brush saw	65 @ 1974	176.3	3	1400	45	-	57
336	0.5 ton pickup truck	3150 @ 1974	176.3	3	2000	45	1.5*g	57
337	10 ton rear-dump truck	24800 @ 1974	176.3	5	1800	75	3.7d	57
338	15 ton rear-dump truck	38200 @ 1974	176.3	5	1800	60	6.0d	57
339	20 ton rear-dump truck	55600 @ 1974	176.3	5	1600	60	9.8d	57
340	35 ton rear-dump truck	84950 @ 1974	176.3	5	1600	60	10.5d	18,57
341	20 ton bottom-dump wagon w/ tractor	60500 @ 1974	176.3	5	2000	75	5.1d	34,57
342	40 ton bottom-dump wagon w/ tractor	88400 @ 1974	176.3	5	2000	75	7.7d	34,57
343	4 ton stake truck	12450 @ 1974	176.3	4	2000	48	4.0g	57
410	Handtools for spreading[d]	4.36*@ 1974	176.3	0.5*	2000*	40*	-	62
411	12 ft spreader box	2000 @ 1974	176.3	6	2000	85*	-	89
412	1000 gal water tank	600 @ 1974	176.3	8	2000	80*	-	89
424	12 ft 80 hp motor grader	24150 @ 1974	176.3	4	2000	60	2.1d	57
425	12 ft 115 hp motor grader	27750 @ 1974	176.3	4	2000	60	3.6d	18,57
426	14 ft 150 hp motor grader	36550 @ 1974	176.3	4	2000	60	4.7d	18,57
427	5-12 ft crawler spreader	12850 @ 1974	176.3	4	1600	60	2.6g	57
441	Rotary broom	2000 @ 1974	176.3	4	2000	80*	-	89
453	1500 gal bitumen distributor	16950 @ 1974	176.3	5	1600	85	7.8g	57
454	1000 gal bitumen distributor	15225 @ 1974	176.3	5	1600	85	6.4g	57
503	Sheepsfoot roller	5975 @ 1974	176.3	6	2000	90	-	57
536	220 hp sheepsfoot roller	28100 @ 1974	176.3	4	2000	60	5.9d	57
537	25 ton pneumatic roller	17450 @ 1974	176.3	3	1400	90	3.6d	57
538	7 ton vibratory roller	20250 @ 1974	176.3	4	1600	60	2.9d	57
539	10-12 ton 3-wheel roller	15720 @ 1974	176.3	7	2000	100	2.0d	57
540	8-10 ton tandem roller	16220 @ 1974	176.3	7	2000	100	2.1d	57
541	12 ton pneumatic roller	9720 @ 1974	176.3	3	1400	90	2.5d	57
614	8 ft bulldozer blade	4050 @ 1974	176.3	5	2000	75	-	57
615	10 ft bulldozer blade	4800 @ 1974	176.3	5	2000	75	-	57
616	12 ft bulldozer blade	5975 @ 1974	176.3	5	2000	75	-	57
617	14 ft bulldozer blade	10150 @ 1974	176.3	5	2000	75	-	57
644	70 dbhp crawler tractor	19500 @ 1974	176.3	4	2000	60	3.1d	18,57
645	180 fwhp crawler tractor	50000 @ 1974	176.3	5	2000	75	6.0d	18,57
646	1.75cy front end crawler loader	27000 @ 1971	142.2	5	2000	90	4.8d	34
647	3 cy front end wheel loader	36000 @ 1971	142.2	5	2000	84	4.8d	34
648	5 cy front end wheel loader	65000 @ 1971	142.2	5	2000	96	7.4d	34
649	11.5cy elevating scraper w/ tractor	51400*@ 1974	176.3	6	2000	90*	4.5d	21,57,89
650	21.5cy elevating scraper w/ tractor	89340*@ 1974	176.3	6	2000	90*	7.8d	21,57,89
651	14/20cy scraper w/tractor	74450 @ 1974	176.3	5	2000	75	8.1d	57
652	21/30cy scraper w/tractor	109900 @ 1974	176.3	5	2000	75	10.8d	57
653	270 fwhp crawler tractor	68500 @ 1974	176.3	5	2000	75	9.2d	18,57
654	385 fwhp crawler tractor	106000 @ 1974	176.3	5	2000	75	12.9d	18,57
655	60fwhp agricultural tractor	11500*@ 1974	176.3	5	2000	75	1.0g	21,57,89

(Table B.2c continued)

Note: Asterisk (*) indicates that figure is an estimate.

[a]Source: 74,85.

[b]Type of fuel is indicated by letter after fuel consumption figure:

g - gasoline
d - diesel fuel

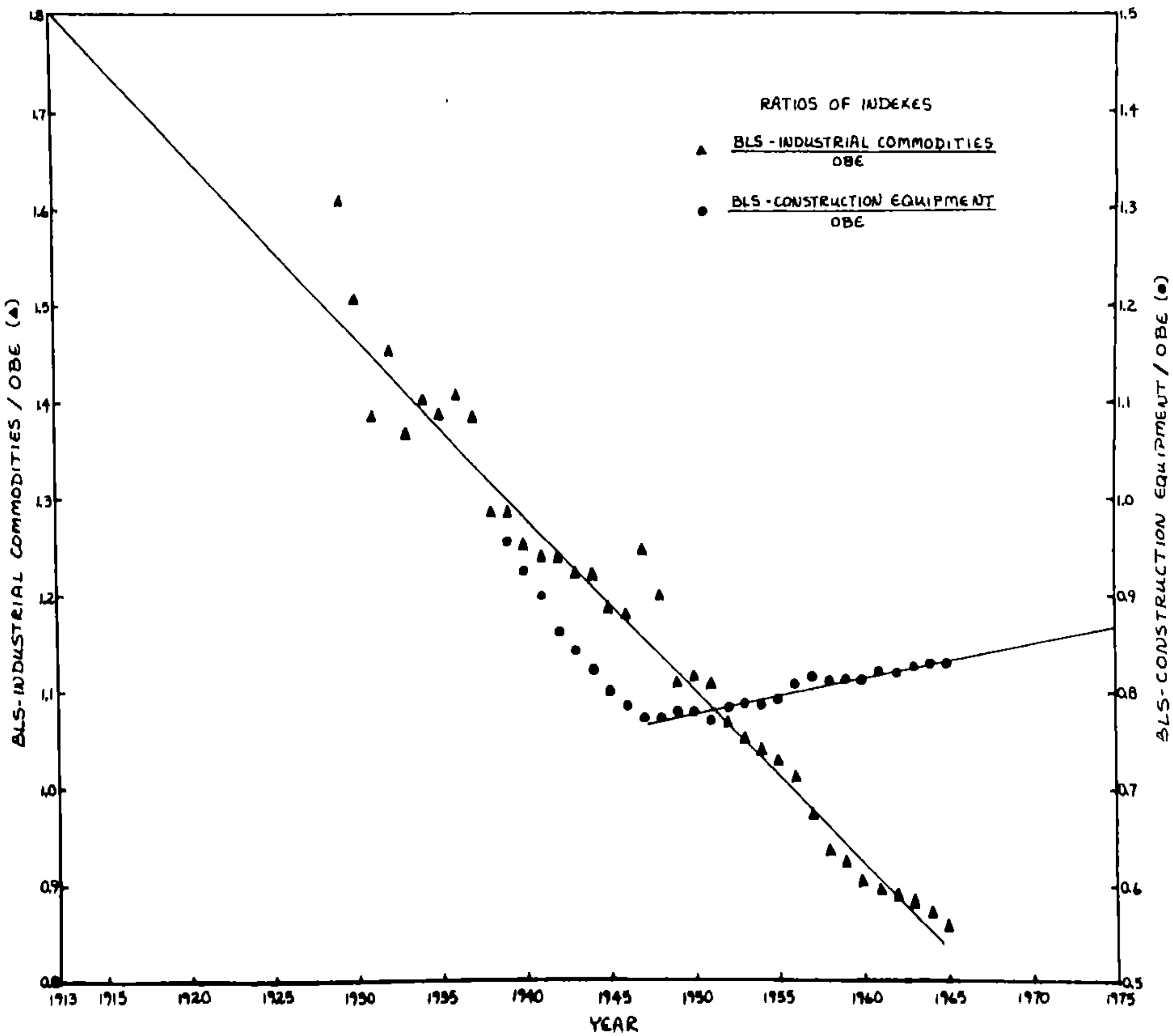
[c]Include rakes and shovels.

[d]Include shovels, rakes, and hoes.

It is the economic variables, index, i, and ccost, gcost, and dcost, that change with economic conditions and allow equipment to be priced under varying conditions. Going in reverse order, fuel costs (ccost, gcost, dcost) are treated in Section B.24 with the rest of the materials used in highway construction. Interest rates (i) for 1930, 1956, and 1974 are, respectively, 5.0%, 4.5%, and 11.5%, coming from the statistical tables on rates for business loans in various issues of the Federal Reserve Bulletin (24). Rates of 20% and 30% are assumed for developing conditions; the former is used as the usual figure, representing a distinctly capital-scarce, developing nation, while the latter is used to represent an even more extreme situation.

As for the index, values for both index and $INDEX_t$ come directly from the U.S. Office of Business Economics (OBE) index for private purchases of construction machinery (85) in the period 1929-1965; the U.S. Bureau of Labor Statistics (BLS) wholesale price index (74) for construction machinery and equipment is used to extrapolate the index forward from 1965, and the same index for industrial commodities to extrapolate it backward from 1929. In Figure B.1, the ratio of the BLS index for construction machinery and equipment to the OBE index for construction machinery is plotted for their overlapping years. The relationship between these two indexes is reasonably linear from the late forties to 1965, and this line is thus extrapolated forward to 1974. The BLS index for construction machinery and equipment divided by the appropriate figure from the graph yields the extrapolated version of the OBE index from 1966-1974. Prior to 1929, the OBE index is similarly

Figure B.1: Data used in the extrapolation of the OBE index for construction machinery, and the final index, spanning 1913-1974, used for inflating/deflating construction equipment investment costs (Source: ref. 74,85).



(Figure B.1 continued)

Note: As described in the text, the graph provides the factors for extrapolating the OBE index forward from 1965 and backward from 1929. The final index used in the analysis (extrapolated years in parentheses), as well as the OBE and two BLS indexes used in its derivation are listed below:

Year	Final index used in analysis	OBE-construction machinery	BLS-construction equipment and machinery	BLS-industrial commodities
1913	(20.8)	-	-	37.2
1914	(19.9)	-	-	35.2
1915	(20.7)	-	-	36.1
1916	(27.1)	-	-	46.8
1917	(35.7)	-	-	61.0
1918	(38.9)	-	-	65.9
1919	(41.0)	-	-	68.6
1920	(51.8)	-	-	85.7
1921	(34.0)	-	-	55.7
1922	(33.6)	-	-	54.4
1923	(34.7)	-	-	55.6
1924	(33.5)	-	-	53.1
1925	(34.9)	-	-	54.6
1926	(34.4)	-	-	53.2
1927	(32.7)	-	-	50.0
1928	(32.7)	-	-	49.3
1929	30.2	30.2	-	48.6
1930	30.1	30.1	-	45.2
1931	28.8	28.8	-	39.9
1932	26.0	26.0	-	37.3
1933	27.6	27.6	-	37.8
1934	29.6	29.6	-	41.6
1935	29.8	29.8	-	41.4
1936	29.9	29.9	-	42.2
1937	32.6	32.6	-	45.2
1938	33.7	33.7	-	43.4
1939	33.5	33.5	32.1	43.3
1940	35.0	35.0	32.5	44.0
1941	38.1	38.1	34.3	47.3
1942	40.8	40.8	35.4	50.7
1943	42.0	42.0	35.4	51.5
1944	43.0	43.0	35.5	52.3
1945	44.5	44.5	35.7	53.0
1946	49.1	49.1	38.8	58.0

(Figure B.1 continued)

Year	Final index used in analysis	OBE-construction machinery	BLS-construction equipment and machinery	BLS-industrial commodities
1947	56.7	56.7	44.0	70.8
1948	64.1	64.1	49.8	76.9
1949	67.9	67.9	53.0	75.3
1950	69.8	69.8	54.5	78.0
1951	77.8	77.8	60.5	86.1
1952	78.5	78.5	61.4	84.1
1953	80.2	80.2	63.2	84.8
1954	81.6	81.6	64.4	85.0
1955	84.2	84.2	67.0	86.9
1956	89.7	89.7	72.6	90.8
1957	95.5	95.5	78.2	93.3
1958	100.0	100.0	81.2	93.6
1959	103.1	103.1	84.1	95.3
1960	105.5	105.5	85.9	95.3
1961	106.0	106.0	87.3	94.8
1962	106.4	106.4	87.5	94.8
1963	107.7	107.7	89.0	94.7
1964	109.8	109.8	91.2	95.2
1965	112.4	112.4	93.6	96.4
1966	(115.4)	-	96.5	98.5
1967	(119.0)	-	100.0	100.0
1968	(125.4)	-	105.7	102.5
1969	(130.5)	-	110.4	106.0
1970	(135.9)	-	115.5	110.0
1971	(142.2)	-	121.4	114.0
1972	(146.7)	-	125.7	117.9
1973	(152.0)	-	130.7	125.9
1974	(176.3)	-	152.3	153.8

extrapolated using the BLS index for industrial commodities; in this case, the linearity of the relationship is not so strong, but this is not too serious in that only for a half dozen or so pieces of the 1920's equipment are purchase prices prior to 1929 the only ones available. The final index (1913-1974), used throughout the research for adjusting the purchase price or investment cost of equipment, is given in the note to Figure B.1, along with the OBE index and two BLS indexes used in its development. The economic variable, index, thus takes the respective values of 30.1, 89.7, and 176.3 for 1930, 1956, and 1974 price conditions.

In the case of developing conditions, an index of 350, roughly twice that experienced in the U.S. in 1974, is used for heavy equipment (i.e., powered equipment or unpowered equipment attached to powered equipment), under the assumption that the equipment has to be imported and foreign exchange is costly. An index of 15, about half that experienced in the U.S. in 1930, is used for light equipment (i.e., unpowered equipment or that which may be animal-powered) under the assumption that it is locally produced by cheap labor.

In order to arrive at the full set of hourly equipment costs as presented in Table B.3, these engineering and economic variables are combined, by means of the equation given at the beginning of this section, under each set of price conditions, for each item of equipment in the three technology periods. In addition to the total hourly rate, its various components, hourly interest and depreciation, maintenance and miscellaneous items, and operating (fuel) costs, as well as the

TABLE B.3AA: HOURLY COSTS OF THE 1920'S EQUIPMENT AT THE PRICES OF 1930.

EQUIPMENT NUMBER	INVESTMENT COST ($)	INT/DEP ($/HP)	MAINT/MISC ($/HP)	FUEL ($/HP)	TOTAL ($/HP)
2 1	1.230	0.00128	0.00054	0.0	0.00182
2 2	1.085	0.00113	0.00048	0.0	0.00160
2 3	40.000	0.00777	0.00395	0.0	0.01172
2 4	2120.000	0.24603	0.11723	0.0	0.36327
2 5	2599.999	0.31774	0.32053	0.0	0.63827
230	10599.996	0.75386	0.79142	0.2700	1.81528
3 1	10.130	0.00532	0.00230	0.0	0.00762
3 2	14.471	0.00760	0.00329	0.0	0.01089
3 3	240.000	0.04178	0.02583	0.0	0.06761
3 4	625.223	0.07521	0.05959	0.0	0.13481
330	4799.996	0.43209	0.39153	0.7857	1.60931
331	5999.996	0.59012	0.53472	0.9428	2.06768
4 1	0.868	0.00090	0.00038	0.0	0.00128
4 2	520.000	0.08840	0.04494	0.0	0.13334
4 3	1607.715	0.19341	0.19510	0.0	0.38851
4 4	300.000	0.05100	0.02593	0.0	0.07693
4 5	600.000	0.08555	0.04926	0.0	0.13481
4 6	400.000	0.05703	0.04519	0.0	0.10222
450	5999.996	1.04448	0.75694	0.7857	2.58713
5 1	434.135	0.04277	0.02867	0.0	0.07144
530	2899.999	0.26517	0.23235	0.5238	1.02132
531	2999.999	0.22332	0.20723	0.1890	0.61955
6 2	1429.080	0.20990	0.13723	0.0	0.34714
6 3	26.000	0.00505	0.00326	0.0	0.00831
6 4	11.000	0.00313	0.00111	0.0	0.00424
6 5	68.000	0.00831	0.00658	0.0	0.01489
6 6	1350.000	0.23097	0.15300	0.0	0.38397
630	4153.262	0.49963	0.39586	1.5452	2.44070
631	700.000	0.15492	0.05509	0.4714	0.68144
632	5787.773	0.69626	0.55165	0.4300	1.67789
633	4299.996	0.45981	0.36431	1.2571	2.08123
634	2499.999	0.32640	0.25680	0.6286	1.21176

TABLE B.3AB: HOURLY COSTS OF THE 1920'S EQUIPMENT AT THE PRICES OF 1956.

EQUIPMENT NUMBER	INVESTMENT COST ($)	INT/DEP ($/HR)	MAINT/MISC ($/HR)	FUEL ($/HR)	TOTAL ($/HR)
2 1	3.666	0.00379	0.00162	0.0	0.00541
2 2	3.234	0.00334	0.00143	0.0	0.00477
2 3	119.203	0.02294	0.01177	0.0	0.03472
2 4	6317.734	0.72470	0.34936	0.0	1.07406
2 5	7748.168	0.93384	0.95520	0.0	1.88904
230	31588.695	2.20602	2.35847	0.6014	5.16592
3 1	30.187	0.01577	0.00687	0.0	0.02264
3 2	43.125	0.02253	0.00981	0.0	0.03234
3 3	715.216	0.12306	0.07698	0.0	0.20005
3 4	1863.205	0.22105	0.17759	0.0	0.39864
330	14304.312	1.26851	1.16677	1.0125	3.44778
331	17880.391	1.73246	1.59351	1.2150	4.54096
4 1	2.587	0.00267	0.00114	0.0	0.00382
4 2	1549.634	0.26098	0.13392	0.0	0.39490
4 3	4791.094	0.56842	0.58142	0.0	1.14984
4 4	894.020	0.15056	0.07726	0.0	0.22783
4 5	1788.039	0.25142	0.14680	0.0	0.39821
4 6	1192.026	0.16761	0.13465	0.0	0.30227
450	17880.391	3.07656	2.25574	1.0125	6.34481
5 1	1293.750	0.12541	0.08544	0.0	0.21086
530	8642.187	0.77597	0.69242	0.6750	2.14339
531	8940.195	0.65076	0.61756	0.4210	1.68932
6 2	4258.750	0.61828	0.40896	0.0	1.02724
6 3	77.482	0.01491	0.00970	0.0	0.02462
6 4	32.781	0.00926	0.00332	0.0	0.01258
6 5	202.644	0.02442	0.01962	0.0	0.04404
6 6	4023.087	0.67883	0.45595	0.0	1.13478
630	12377.000	1.46842	1.17968	1.9912	4.63935
631	2086.046	0.45841	0.16418	0.6075	1.23009
632	17247.949	2.04632	1.64394	0.7087	4.39901
633	12814.277	1.35138	1.08565	1.6200	4.05703
634	7450.160	0.96143	0.76528	0.8100	2.53671

TABLE B.3AC: HOURLY COSTS OF THE 1920'S EQUIPMENT AT THE PRICES OF 1974.

EQUIPMENT NUMBER	INVESTMENT COST ($)	INT/DEP ($/HR)	MAINT/MISC ($/HR)	FUEL ($/HR)	TOTAL ($/HR)
2 1	7.205	0.00782	0.00318	0.0	0.01100
2 2	6.357	0.00690	0.00281	0.0	0.00971
2 3	234.286	0.05117	0.02314	0.0	0.07431
2 4	12417.137	1.66468	0.68665	0.0	2.35133
2 5	15228.566	2.20759	1.87738	0.0	4.08497
230	62085.699	5.50991	4.63544	2.2255	12.37082
3 1	59.332	0.03308	0.01350	0.0	0.04658
3 2	84.760	0.04725	0.01928	0.0	0.06654
3 3	1405.714	0.28268	0.15131	0.0	0.43399
3 4	3662.018	0.52257	0.34904	0.0	0.87160
330	28114.277	3.04118	2.29322	1.7253	7.05970
331	35142.848	4.15346	3.13194	2.0704	9.35577
4 1	5.086	0.00552	0.00224	0.0	0.00776
4 2	3045.714	0.58204	0.26321	0.0	0.84525
4 3	9416.617	1.34374	1.14275	0.0	2.48648
4 4	1757.142	0.33579	0.15185	0.0	0.48764
4 5	3514.285	0.59435	0.28852	0.0	0.88287
4 6	2342.856	0.39623	0.26466	0.0	0.66089
450	35142.848	7.06704	4.43353	1.7253	13.22587
5 1	2542.788	0.30487	0.16793	0.0	0.47280
530	16985.707	1.93812	1.36091	1.1502	4.44923
531	17571.422	1.71182	1.21378	1.5578	4.48344
6 2	8370.324	1.42022	0.80379	0.0	2.22401
6 3	152.286	0.03326	0.01907	0.0	0.05233
6 4	64.429	0.02004	0.00652	0.0	0.02656
6 5	398.285	0.05774	0.03856	0.0	0.09630
6 6	7907.141	1.60475	0.89614	0.0	2.50089
630	24326.262	3.47132	2.31860	3.3931	9.18301
631	4099.996	0.99178	0.32268	1.0352	2.34965
632	33899.824	4.83746	3.23108	1.6774	9.74591
633	25185.707	3.19464	2.13379	2.7605	8.08890
634	14642.852	2.20845	1.50411	1.3802	5.09280

TABLE B.3AD: HOURLY COSTS OF THE 1920'S EQUIPMENT AT THE PRICES OF A TYPICAL DEVELOPING COUNTRY.

EQUIPMENT NUMBER	INVESTMENT COST ($)	INT/DEP ($/HR)	MAINT/MISC ($/HR)	FUEL ($/HR)	TOTAL ($/HR)
2 1	0.613	0.00070	0.00027	0.0	0.00097
2 2	0.541	0.00062	0.00024	0.0	0.00086
2 3	19.934	0.00501	0.00197	0.0	0.00698
2 4	24651.156	3.91871	1.36317	0.0	5.28187
2 5	1295.742	0.22924	0.15974	0.0	0.38898
230	123255.750	14.07163	9.20251	2.7000	25.97412
3 1	5.048	0.00303	0.00115	0.0	0.00418
3 2	7.212	0.00433	0.00164	0.0	0.00597
3 3	119.607	0.02852	0.01287	0.0	0.04139
3 4	7270.027	1.26612	0.69292	0.0	1.95904
330	55813.941	7.47072	4.55262	8.1000	20.12332
331	69767.375	10.20306	6.21769	9.7200	26.14073
4 1	0.433	0.00050	0.00019	0.0	0.00069
4 2	259.148	0.05696	0.02240	0.0	0.07935
4 3	18694.363	3.25573	2.26864	0.0	5.52437
4 4	149.509	0.03286	0.01292	0.0	0.04578
4 5	299.017	0.06172	0.02455	0.0	0.08627
4 6	4651.160	0.96003	0.52541	0.0	1.48544
450	69767.375	16.63602	8.80167	8.1000	33.53767
5 1	216.361	0.03253	0.01429	0.0	0.04682
530	33720.922	4.94972	2.70175	5.4000	13.05147
531	34883.711	4.57880	2.40966	1.8900	8.87846
6 2	16617.211	3.34325	1.59573	0.0	4.93898
6 3	12.957	0.00325	0.00162	0.0	0.00488
6 4	5.482	0.00190	0.00055	0.0	0.00245
6 5	33.889	0.00600	0.00328	0.0	0.00928
6 6	15697.668	3.88813	1.77907	0.0	5.66720
630	48293.770	8.41065	4.60300	15.9300	28.94363
631	8139.531	2.19246	0.64061	4.8600	7.69307
632	67299.687	11.72064	6.41450	7.0875	25.22263
633	49999.988	7.74026	4.23611	12.9600	24.93636
634	29069.758	5.19876	2.98604	6.4800	14.66480

TABLE B.3BA: HOURLY COSTS OF THE 1950'S EQUIPMENT AT THE PRICES OF 1930.

EQUIPMENT NUMBER	INVESTMENT COST ($)	INT/DEP ($/HR)	MAINT/MISC ($/HR)	FUEL ($/HR)	TOTAL ($/HR)
2 6	1.011	0.00105	0.00045	0.0	0.00149
2 7	1.922	0.00199	0.00085	0.0	0.00284
2 8	1.066	0.00111	0.00047	0.0	0.00158
231	16249.355	1.87659	1.32432	0.4914	3.69231
232	21665.809	2.66783	2.23993	0.6142	5.52201
233	25585.000	2.52034	2.11609	0.7371	5.37353
234	13928.020	1.60851	1.13513	0.4300	3.17362
235	139.259	0.04261	0.02166	0.1309	0.19523
3 5	1934.447	0.22340	0.12864	0.0	0.35204
3 6	3288.560	0.37979	0.21869	0.0	0.59848
332	4913.496	0.63050	0.44494	0.3931	1.46856
333	11026.348	1.59175	1.05439	0.9214	3.56752
334	2321.336	0.32732	0.17918	0.9952	1.50172
335	619.023	0.11366	0.05778	0.1309	0.30238
4 7	368.873	0.02907	0.02441	0.0	0.05348
4 8	0.749	0.00078	0.00033	0.0	0.00111
4 9	456.530	0.06590	0.05222	0.0	0.11812
420	2901.671	0.40915	0.26750	0.7857	1.46235
421	4952.184	0.57191	0.45312	0.5528	1.57786
422	2282.648	0.40233	0.29157	0.4190	1.11294
423	1605.591	0.22640	0.17812	1.3095	1.71402
440	29.017	0.01523	0.01240	0.0	0.02764
451	696.401	0.10053	0.07965	0.1833	0.36351
452	3133.804	0.45239	0.39760	1.8595	2.70948
5 2	696.401	0.09820	0.07726	0.0	0.17545
532	3056.427	0.26410	0.26635	0.2619	0.79235
533	1553.658	0.40751	0.37362	0.2703	1.05140
534	3675.450	0.31759	0.32029	0.2088	0.84673
535	2050.514	0.17718	0.17869	0.4976	0.85348
6 7	522.301	0.06032	0.04257	0.0	0.10289
6 8	619.023	0.07149	0.05045	0.0	0.12194
6 9	773.779	0.08936	0.06306	0.0	0.15242
610	50.911	0.01298	0.00660	0.0	0.01958
611	2321.336	0.26808	0.18919	0.0	0.45727
612	3095.115	0.35745	0.25225	0.0	0.60970
613	5029.562	0.58085	0.40991	0.0	0.99076
638	5029.562	0.58085	0.40991	0.6142	1.60501
639	6577.121	0.75957	0.53603	0.6142	1.90986
640	7737.789	0.89362	0.63063	0.8599	2.38419
641	3211.182	0.37085	0.26171	0.2948	0.92740
642	4255.781	0.49149	0.34685	0.4300	1.26831
643	5803.340	0.67021	0.47297	0.6142	1.75743

TABLE B.3BB: HOURLY COSTS OF THE 1950'S EQUIPMENT AT THE PRICES OF 1956.

EQUIPMENT NUMBER	INVESTMENT COST ($)	INT/DEP ($/HR)	MAINT/MISC ($/HR)	FUEL ($/HR)	TOTAL ($/HR)
2 6	3.012	0.00311	0.00133	0.0	0.00444
2 7	5.727	0.00592	0.00253	0.0	0.00845
2 8	3.177	0.00328	0.00140	0.0	0.00469
231	48424.148	5.51529	3.94657	0.8100	10.27186
232	64565.535	7.82364	6.67513	1.0125	15.51127
233	76244.937	7.39110	6.30609	1.2150	14.91218
234	41506.410	4.72739	3.38277	0.7087	8.81891
235	415.000	0.12580	0.06456	0.1687	0.35911
3 5	5764.777	0.65658	0.38336	0.0	1.03994
3 6	9800.125	1.11619	0.65171	0.0	1.76790
332	14642.531	1.85302	1.32596	0.6480	3.82698
333	32859.238	4.67815	3.14216	1.5187	9.33906
334	6917.734	0.96413	0.53396	1.2825	2.78060
335	1844.729	0.33553	0.17217	0.1687	0.67646
4 7	1099.264	0.08525	0.07273	0.0	0.15798
4 8	2.232	0.00231	0.00098	0.0	0.00329
4 9	1360.488	0.19369	0.15561	0.0	0.34930
420	8647.168	1.20517	0.79716	1.0125	3.01483
421	14757.824	1.68085	1.35034	0.9112	3.94244
422	6802.437	1.18508	0.86890	0.5400	2.59398
423	4784.766	0.66686	0.53081	1.6875	2.88517
440	86.472	0.04518	0.03697	0.0	0.08215
451	2075.320	0.29546	0.23736	0.2362	0.76908
452	9338.941	1.32958	1.18488	2.3962	4.91070
5 2	2075.320	0.28924	0.23023	0.0	0.51947
532	9108.352	0.77285	0.79373	0.3375	1.90407
533	4630.004	1.20305	1.11340	0.4455	2.76196
534	10953.082	0.92937	0.95448	0.3442	2.22810
535	6110.664	0.51849	0.53250	0.6412	1.69224
6 7	1556.490	0.17728	0.12685	0.0	0.30413
6 8	1844.729	0.21011	0.15035	0.0	0.36045
6 9	2305.912	0.26263	0.18793	0.0	0.45056
610	151.718	0.03833	0.01967	0.0	0.05799
611	6917.734	0.78790	0.56379	0.0	1.35169
612	9223.648	1.05053	0.75173	0.0	1.80226
613	14988.418	1.70711	1.22155	0.0	2.92867
638	14988.418	1.70711	1.22155	1.0125	3.94117
639	19600.242	2.23238	1.59742	1.0125	4.84230
640	23059.109	2.62633	1.87932	1.4175	5.92314
641	9569.535	1.08993	0.77992	0.4860	2.35584
642	12682.516	1.44448	1.03362	0.7087	3.18685
643	17294.328	1.96975	1.40949	1.0125	4.39173

TABLE B.38C: HOURLY COSTS OF THE 1950'S EQUIPMENT AT THE PRICES OF 1974.

EQUIPMENT NUMBER	INVESTMENT COST ($)	INT/DEP ($/HR)	MAINT/MISC ($/HR)	FUEL ($/HR)	TOTAL ($/HR)
2 6	5.920	0.00643	0.00261	0.0	0.00904
2 7	11.256	0.01222	0.00497	0.0	0.01719
2 8	6.244	0.00678	0.00276	0.0	0.00953
231	95174.750	13.03806	7.75674	1.9170	22.71179
232	126899.687	19.01837	13.11957	2.3962	34.53418
233	149855.000	17.96693	12.39426	2.8755	33.23666
234	81578.375	11.17548	6.64863	1.6774	19.50148
235	815.658	0.28057	0.12688	0.2875	0.69500
3 5	11330.332	1.55215	0.75347	0.0	2.30562
3 6	19261.566	2.63866	1.28089	0.0	3.91955
332	28779.047	4.38051	2.60610	1.5336	8.52022
333	64582.902	11.05907	6.17574	3.5944	20.82916
334	13596.398	2.21467	1.04947	2.1854	5.44952
335	3625.707	0.74830	0.33840	0.2875	1.37425
4 7	2160.539	0.20723	0.14296	0.0	0.35019
4 8	4.386	0.00476	0.00194	0.0	0.00670
4 9	2673.959	0.45788	0.30583	0.0	0.76372
420	16995.500	2.76834	1.56677	1.7253	6.06041
421	29005.652	3.97351	2.65402	2.1566	8.78415
422	13369.793	2.72220	1.70778	0.9202	5.35014
423	9404.176	1.53182	1.04327	2.8755	5.45059
440	169.955	0.09475	0.07266	0.0	0.16741
451	4078.920	0.69847	0.46653	0.4026	1.56756
452	18355.141	3.14310	2.32881	4.0832	9.55512
5 2	4078.920	0.66440	0.45251	0.0	1.11691
532	17901.926	1.93032	1.56002	0.5751	4.06544
533	9099.996	2.68304	2.18833	1.0543	5.92572
534	21527.633	2.32127	1.87598	0.8147	5.01197
535	12010.152	1.29502	1.04660	1.0927	3.43431
6 7	3059.190	0.41908	0.24932	0.0	0.66840
6 8	3625.707	0.49669	0.29549	0.0	0.79218
6 9	4532.133	0.62086	0.36937	0.0	0.99023
610	298.193	0.08548	0.03865	0.0	0.12413
611	13596.398	1.86258	1.10811	0.0	2.97069
612	18128.531	2.48344	1.47747	0.0	3.96092
613	29458.867	4.03559	2.40090	0.0	6.43649
638	29458.867	4.03559	2.40090	2.3962	8.83274
639	38523.133	5.27731	3.13963	2.3962	10.81319
640	45321.332	6.20860	3.69369	3.3547	13.25704
641	18808.352	2.57657	1.53288	1.1502	5.25965
642	24926.730	3.41473	2.03153	1.6774	7.12363
643	33991.000	4.65645	2.77027	2.3962	9.82296

TABLE B.3BD: HOURLY COSTS OF THE 1950'S EQUIPMENT AT THE PRICES OF A TYPICAL DEVELOPING COUNTRY.

EQUIPMENT NUMBER	INVESTMENT COST ($)	INT/DEP ($/HR)	MAINT/MISC ($/HR)	FUEL ($/HR)	TOTAL ($/HR)
2 6	0.504	0.00058	0.00022	0.0	0.00080
2 7	0.958	0.00110	0.00042	0.0	0.00152
2 8	0.531	0.00061	0.00023	0.0	0.00084
231	188946.000	31.58981	15.39910	8.1000	55.08890
232	251928.000	47.34756	26.04565	10.1250	83.51820
233	297500.000	44.72993	24.60571	12.1500	81.48564
234	161953.687	27.07698	13.19922	7.0875	47.36369
235	1619.286	0.64060	0.25189	1.3500	2.24248
3 5	22493.570	3.76069	1.49582	0.0	5.25651
3 6	38239.070	6.39318	2.54290	0.0	8.93607
332	57133.672	10.61351	5.17377	6.4800	22.26727
333	128213.312	26.79494	12.26039	15.1875	54.24280
334	26992.285	5.21341	2.08347	10.2600	17.55685
335	7197.941	1.70852	0.67181	1.3500	3.73033
4 7	4289.215	0.51592	0.28380	0.0	0.79972
4 8	0.373	0.00043	0.00016	0.0	0.00059
4 9	5308.480	1.10940	0.60716	0.0	1.71656
420	33740.355	6.51676	3.11044	8.1000	17.72719
421	57583.543	9.62737	5.26889	9.1125	24.00876
422	26542.414	6.40815	3.39038	4.3200	14.11852
423	18669.664	3.60594	2.07117	13.5000	19.17709
440	337.404	0.20244	0.14424	0.0	0.34668
451	8097.684	1.69231	0.92617	1.8900	4.50848
452	36439.586	7.61541	4.62327	19.1700	31.40865
5 2	8097.684	1.56402	0.89834	0.0	2.46236
532	35539.844	4.92980	3.09704	2.7000	10.72684
533	18065.793	6.12591	4.34439	4.4550	14.92530
534	42737.785	5.92824	3.72429	3.4425	13.09503
535	23843.184	3.30733	2.07776	5.1300	10.51509
6 7	6073.262	1.01539	0.49497	0.0	1.51036
6 8	7197.941	1.20342	0.58663	0.0	1.79005
6 9	8997.426	1.50428	0.73329	0.0	2.23757
610	591.988	0.19516	0.07674	0.0	0.27190
611	26992.285	4.51283	2.19987	0.0	6.71270
612	35989.715	6.01711	2.93316	0.0	8.95027
613	58483.285	9.77780	4.76639	0.0	14.54419
638	58483.285	9.77780	4.76639	10.1250	24.66917
639	76478.125	12.78636	6.23296	10.1250	29.14430
640	89974.250	15.04277	7.33290	14.1750	36.55066
641	37339.328	6.24275	3.04315	4.8600	14.14590
642	49485.855	8.27353	4.03310	7.0875	19.39410
643	67480.687	11.28208	5.49967	10.1250	26.90672

TABLE B.3CA: HOURLY COSTS OF THE 1970'S EQUIPMENT AT THE PRICES OF 1930.

EQUIPMENT NUMBER	INVESTMENT COST ($)	INT/DEP ($/HR)	MAINT/MISC ($/HR)	FUEL ($/HR)	TOTAL ($/HR)
2 9	0.826	0.00086	0.00036	0.0	0.00122
236	83.659	0.02560	0.01301	0.0786	0.11718
237	9373.168	0.92334	0.61902	0.6142	2.15660
238	15109.754	1.74498	1.38254	0.5897	3.71720
239	28170.734	1.82411	2.18675	1.1056	5.11651
240	32376.879	2.00376	2.90987	1.5970	6.51068
241	11.098	0.00291	0.00148	0.0	0.00439
336	537.805	0.09874	0.05020	0.3928	0.54179
337	4234.145	0.54332	0.43047	0.4545	1.42834
338	6521.949	0.83689	0.55437	0.7371	2.12836
339	9492.680	1.37035	0.90774	1.2039	3.48202
340	14503.656	2.09373	1.38691	1.2899	4.77057
341	10329.266	1.19290	0.94513	0.6265	2.76456
342	15092.680	1.74301	1.38098	0.9459	4.06993
343	2125.610	0.29972	0.16407	1.0476	1.51139
410	0.744	0.00077	0.00033	0.0	0.00110
411	341.463	0.03364	0.02966	0.0	0.06330
412	102.439	0.00792	0.00671	0.0	0.01463
424	4123.168	0.58139	0.38010	0.2580	1.21948
425	4737.805	0.66806	0.43677	0.4423	1.54708
426	6240.242	0.87991	0.57527	0.5774	2.03258
427	2193.903	0.38669	0.25281	0.6809	1.32044
441	341.463	0.04815	0.04002	0.0	0.08816
453	2893.903	0.41776	0.36716	2.0428	2.82774
454	2599.390	0.37525	0.32980	1.6762	2.38120
5 3	1020.122	0.10049	0.09287	0.0	0.19336
536	4797.559	0.67648	0.44227	0.7248	1.84357
537	2979.269	0.78144	0.71644	0.4423	1.94014
538	3457.317	0.60938	0.39840	0.3563	1.36404
539	2683.903	0.23192	0.23388	0.2457	0.71150
540	2837.561	0.24519	0.24727	0.2580	0.75045
541	1659.512	0.43528	0.39907	0.3071	1.14147
614	691.463	0.07986	0.06327	0.0	0.14312
615	819.512	0.09464	0.07499	0.0	0.16963
616	1020.122	0.11781	0.09334	0.0	0.21115
617	1732.927	0.20013	0.15856	0.0	0.35869
644	3329.269	0.46945	0.30692	0.3808	1.15720
645	8536.582	0.98587	0.78110	0.7371	2.50406
646	5715.187	0.66003	0.60867	0.5897	1.85838
647	7620.250	0.88004	0.76583	0.5897	2.23556
648	13758.789	1.58896	1.54786	0.9091	4.04592
649	8775.609	0.86447	0.79895	0.5528	2.21624
650	15253.168	1.50257	1.38867	0.9582	3.84947
651	12710.973	1.46795	1.16305	0.9951	3.62609
652	18763.414	2.16693	1.71685	1.3268	5.21056
653	11695.121	1.35064	1.07010	1.1302	3.55096
654	13097.559	2.09004	1.65592	1.5848	5.33072
655	1963.415	0.22675	0.17965	0.2619	0.66830

TABLE B.3CB: HOURLY COSTS OF THE 1970'S EQUIPMENT AT THE PRICES OF 1956.

EQUIPMENT NUMBER	INVESTMENT COST ($)	INT/DEP ($/HR)	MAINT/MISC ($/HR)	FUEL ($/HR)	TOTAL ($/HR)
2 9	2.463	0.00255	0.00109	0.0	0.00363
236	249.308	0.07558	0.03878	0.1012	0.21561
237	27932.664	2.70776	1.84472	1.0125	5.56498
238	45028.070	5.12850	4.12007	0.9720	10.22056
239	83950.625	5.30476	6.51666	1.8225	13.64392
240	96485.250	5.85121	8.67161	2.6325	17.15530
241	33.071	0.00859	0.00441	0.0	0.01300
336	1602.694	0.29151	0.14958	0.5062	0.94734
337	12618.031	1.59682	1.28283	0.7492	3.62890
338	19435.840	2.45962	1.65205	1.2150	5.32666
339	28298.816	4.02746	2.70512	1.9845	8.71707
340	43221.859	6.15347	4.13309	2.1262	12.41281
341	30781.898	3.50592	2.81654	1.0327	7.35521
342	44977.191	5.12270	4.11541	1.5592	10.79736
343	6334.449	0.88284	0.48894	1.3500	2.72178
410	2.218	0.00229	0.00098	0.0	0.00327
411	1017.583	0.09864	0.08840	0.0	0.18705
412	305.275	0.02314	0.01999	0.0	0.04313
424	12287.316	1.71250	1.13274	0.4252	3.27049
425	14118.965	1.96778	1.30159	0.7290	3.99837
426	18596.332	2.59180	1.71435	0.9517	5.25790
427	6537.969	1.13901	0.75340	0.8775	2.76991
441	1017.583	0.14182	0.11925	0.0	0.26107
453	8624.016	1.22779	1.09417	2.6325	4.95446
454	7746.352	1.10284	0.98282	2.1600	4.24566
5 3	3040.031	0.29470	0.27677	0.0	0.57147
536	14297.043	1.99260	1.31801	1.1947	4.50536
537	8878.410	2.30695	2.13505	0.7290	5.17099
538	10303.027	1.79494	1.18726	0.5872	3.56945
539	7998.199	0.67865	0.69699	0.4050	1.78063
540	8456.113	0.71750	0.73689	0.4252	1.87964
541	4945.453	1.28502	1.18926	0.5062	2.98053
614	2060.606	0.23469	0.18855	0.0	0.42324
615	2442.200	0.27816	0.22346	0.0	0.50162
616	3040.031	0.34625	0.27816	0.0	0.62441
617	5164.234	0.58818	0.47253	0.0	1.06071
644	9921.434	1.38276	0.91463	0.6277	2.92515
645	25439.582	2.89745	2.32772	1.2150	6.44017
646	17031.637	1.93983	1.81387	0.9720	4.72569
647	22708.852	2.58644	2.28224	0.9720	5.84067
648	41002.102	4.66995	4.61273	1.4985	10.78119
649	26151.891	2.53513	2.38091	0.9112	5.82729
650	45455.453	4.40640	4.13834	1.5795	10.12423
651	37879.543	4.31431	3.46598	1.6402	9.42053
652	55916.215	6.36860	5.11633	2.1870	13.67193
653	34852.230	3.96951	3.18898	1.8630	9.02149
654	53931.926	6.14260	4.93477	2.6122	13.68962
655	5851.105	0.66641	0.53538	0.3375	1.53929

TABLE B.3CC: HOURLY COSTS OF THE 1970'S EQUIPMENT AT THE PRICES OF 1974.

EQUIPMENT NUMBER	INVESTMENT COST ($)	INT/DEP ($/HR)	MAINT/MISC ($/HR)	FUEL ($/HR)	TOTAL ($/HR)
2 9	4.840	0.00525	0.00214	0.0	0.00739
236	490.000	0.16855	0.07622	0.1725	0.41730
237	54899.996	6.58226	3.62569	2.3962	12.60419
238	88499.937	12.12367	8.09774	2.3004	22.52179
239	164999.875	14.30359	12.80811	4.3132	31.42494
240	189635.875	15.00390	17.04352	6.2302	38.27765
241	65.000	0.01916	0.00867	0.0	0.02783
336	3150.000	0.65012	0.29400	0.8626	1.80677
337	24799.996	3.77485	2.52133	1.7732	8.06941
338	38199.996	5.81449	3.24700	2.8755	11.93699
339	55599.996	9.52086	5.31675	4.6966	19.53424
340	84949.937	14.54670	8.12334	5.0321	27.70215
341	60499.996	8.28794	5.53575	2.4442	16.26785
342	88399.937	12.10997	8.08859	3.6902	23.88878
343	12449.996	2.02794	0.96098	2.3004	5.28932
410	4.360	0.00473	0.00192	0.0	0.00666
411	2000.000	0.23979	0.17375	0.0	0.41354
412	600.000	0.05934	0.03928	0.0	0.09862
424	24149.996	3.93371	2.22633	1.0064	7.16646
425	27749.996	4.52010	2.55820	1.7253	8.80360
426	36549.996	5.95350	3.36945	2.2525	11.57543
427	12849.996	2.61637	1.48076	1.4953	5.59238
441	2000.000	0.32577	0.23437	0.0	0.56015
453	16949.996	2.90249	2.15053	4.4858	9.53880
454	15224.996	2.60710	1.93167	3.6806	8.21941
5 3	5974.996	0.71637	0.54397	0.0	1.26035
536	28099.996	4.57711	2.59047	2.8276	9.99515
537	17449.996	5.14495	4.19631	1.7253	11.06656
538	20249.996	4.12307	2.33349	1.3898	7.84639
539	15719.996	1.69505	1.36988	0.9585	4.02343
540	16619.996	1.79209	1.44831	1.0064	4.24683
541	9719.996	2.86584	2.33743	1.1981	6.40139
614	4050.000	0.55481	0.37057	0.0	0.92539
615	4799.996	0.65756	0.43920	0.0	1.09675
616	5974.996	0.81852	0.54671	0.0	1.36523
617	10149.996	1.39046	0.92872	0.0	2.31918
644	19499.996	3.17629	1.79765	1.4857	6.45962
645	49999.996	6.84953	4.57500	2.8755	14.30003
646	33474.684	4.58572	3.56505	2.3004	10.45117
647	44632.910	6.11429	4.48561	2.3004	12.90030
648	80587.167	11.03970	9.06606	3.5464	23.65219
649	51399.996	6.16262	4.67954	2.1566	12.99879
650	89339.937	10.71145	8.13366	3.7381	22.58324
651	74449.937	10.19895	6.81217	3.8819	20.89302
652	109899.937	15.05528	10.05584	5.1759	30.28702
653	68499.937	9.38386	6.26774	4.4091	20.06070
654	105999.937	14.52101	9.69899	6.1823	30.40231
655	11499.996	1.57539	1.05225	0.5751	3.20274

TABLE B.3CD: HOURLY COSTS OF THE 1970'S EQUIPMENT AT THE PRICES OF A TYPICAL DEVELOPING COUNTRY.

EQUIPMENT NUMBER	INVESTMENT COST ($)	INT/DEP ($/HR)	MAINT/MISC ($/HR)	FUEL ($/HR)	TOTAL ($/HR)
2 9	0.412	0.00047	0.00018	0.0	0.00065
236	972.773	0.38483	0.15132	0.8100	1.34615
237	108990.250	16.38698	7.19790	10.1250	33.70985
238	175694.750	29.37433	16.07607	9.7200	55.17038
239	327566.625	39.06399	25.42734	18.2250	82.71832
240	376475.250	39.24512	33.83571	26.3250	99.40581
241	129.041	0.04376	0.01721	0.0	0.06096
336	6253.543	1.48436	0.58366	4.0500	6.11802
337	49234.258	9.14607	5.00548	7.4925	21.64404
338	75836.625	14.08789	6.44611	12.1500	32.68399
339	110380.000	23.06799	10.55509	19.8450	53.46806
340	168647.125	35.24507	16.12688	21.2625	72.63443
341	120107.687	20.08076	10.98985	10.3275	41.39809
342	175496.250	29.34116	16.05789	15.5925	60.99153
343	24716.391	4.77383	1.90779	10.8000	17.48161
410	0.371	0.00043	0.00016	0.0	0.00059
411	3970.505	0.59698	0.34494	0.0	0.94191
412	1191.151	0.15521	0.07798	0.0	0.23320
424	47943.844	9.26008	4.41982	4.2525	17.93240
425	55090.750	10.64047	5.07868	7.2900	23.00914
426	72560.937	14.01474	6.68921	9.5175	30.22144
427	25510.492	6.15901	2.93968	7.0200	16.11869
441	3970.505	0.76688	0.46529	0.0	1.23217
453	33650.027	7.03242	4.26935	21.0600	32.36174
454	30225.465	6.31673	3.83486	17.2800	27.43156
5 3	11861.883	1.78347	1.07992	0.0	2.86339
536	55785.590	10.77468	5.14273	11.9475	27.86490
537	34642.652	11.74695	8.33073	7.2900	27.36766
538	40201.359	9.70583	4.63258	5.8725	20.21091
539	31208.164	4.32894	2.71957	4.0500	11.09851
540	32994.891	4.57678	2.87527	4.2525	11.70455
541	19296.652	6.54328	4.64038	5.0625	16.24615
614	8040.270	1.34425	0.73568	0.0	2.07993
615	9529.211	1.59319	0.87192	0.0	2.46511
616	11861.883	1.98318	1.08536	0.0	3.06855
617	20150.309	3.36892	1.84375	0.0	5.21268
644	38712.418	7.47708	3.56880	6.2775	17.32338
645	99262.562	16.59567	9.08252	12.1500	37.82817
646	66455.687	11.11070	7.07753	9.7200	27.90822
647	88607.562	14.81427	8.90505	9.7200	33.43930
648	159985.937	26.74799	17.99840	14.9850	59.73137
649	102041.937	15.34229	9.29006	9.1125	33.74483
650	177362.375	26.66692	16.14735	15.7950	58.60925
651	147801.937	24.71095	13.52387	16.4025	54.63730
652	218179.187	36.47728	19.96338	21.8700	78.31064
653	135989.687	22.73605	12.44305	18.6300	53.80908
654	210436.750	35.18283	19.25494	26.1225	80.56024
655	22830.398	3.81701	2.08898	2.7000	8.60598

investment cost $\left\{ P_t \left[\frac{\text{index}}{\text{INDEX}_t} \right] \right\}$ of the item of equipment under the stated economic conditions are given. Table B.3A thus covers the 1920's equipment at 1930 (B.3AA), 1956 (B.3AB), 1974 (B.3AC), and developing countries (B.3AD) prices; similarly B.3B covers the 1950's equipment and B.3C the 1970's.

B.22 <u>The Horse</u>

The draft animal, a horse in this case, is part of many of the 1920's technical packages; it is in essence a piece of equipment and has an equipment number of 601. Based on several of the 1920's sources (14,15,26,48), an hourly rate, including upkeep, of some $0.10 seems reasonable for sometime around 1913. This price is inflated over time by means of an index, this time the BLS wholesale price index (74) for farm products; thus, prices of $0.12/hr, $0.22/hr, and $0.44/hr are used for 1930, 1956, and 1974, respectively.

As for an investment cost, a figure of $70.69 is given by the U.S. Department of Agriculture (81) as the purchase price for a work horse in 1930; using the BLS wholesale price index (74) for livestock, this inflates to $128.66 in 1956 and $277.81 in 1974. A work horse's life is estimated at 12 years with 2700 hours of use per year (9 hours/ day x 6 days/week x 50 weeks/year).

Assuming that a draft animal of some sort (not necessarily a horse) is reasonably available in developing countries as they are often largely agriculturally based, an hourly rate of $0.05 and an investment cost of $40.00 are used for the horse. The investment cost is taken as somewhat more than half of the 1930's and the hourly rate somewhat less, in that purchasing a draft animal in a developing country is a relatively expensive venture for a peasant, while keeping one is less of a problem.

B.23 Labor

Labor is divided into two categories: (1) skilled which includes all heavy equipment operators, drivers of trucks over five cubic yards in capacity, and personnel acting in a supervisory capacity on operations done predominantly by unskilled labor; and (2) unskilled which also includes semiskilled and thus involves common heavy construction laborers, operators of small power tools, drivers of trucks five cubic yards and under in capacity,* and drivers of horses. Labor is assumed paid on an hourly basis, with its hourly cost estimate including the basic wage and fringe benefits, but none of the additional items such as social security (FICA), workmen's compensation insurance, and unemployment (amounting to some 15 percent in 1974 [49]) which are more standardly included in project overhead. It is assumed that labor's quality has remained relatively uniform over time, and labor is priced at individual points in time rather than by means of an index as for equipment.

Labor prices for 1930 are derived from a number of articles in Gillette and Black (26). The figure for skilled labor is the average of wages reported by the U.S. Bureau of Public Roads (BPR) as paid to skilled

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*This is treated as a skilled operation in the 1920's, as at that time it was skilled relative to driving a horse.

workers in works program highway and grade-crossing elimination projects in the 48 states, the District of Columbia, and Hawaii as of January 1937; this is indexed back to 1930 by means of a BPR average hourly earnings index for common labor in road building. The final result is a skilled wage of $0.88 per hour. The wage rate for unskilled labor is arrived at by averaging figures from three sources and indexing as necessary using the BPR index above; the three sources include that cited above for skilled labor but which also gives wages for unskilled and intermediate grade labor, another set of figures for all of the U.S. for average hourly earnings for common labor in road building from 1913 to 1936 also reported by the BPR, and finally a set of figures for all of the U.S. for average hourly entrance rates for common labor in general contracting from 1931 to 1934 reported by the U.S. Bureau of Labor Statistics. The final rate determined for unskilled labor in 1930 is $0.46 per hour. It is suspected that these wage rates include both union and nonunion employees,* while figures for 1956 and 1974 are all union.

The 1956 and 1974 prices for labor are from the same source, Engineering News-Record (23c,e), at the two different points in time. These are union rates averaged over ten cities (Baltimore, Boston, Cincinnati, Detroit, Los Angeles, Minneapolis, Philadelphia, Pittsburgh, St. Louis, and Seattle) and over various occupations. The skilled wage

*An average over ten cities of the minimum wage rates for nonunion labor in construction other than building, reported by Engineering News-Record (23a) in May 1930, is $0.447/hour, which is close to, but lower than, the $0.46/hour derived above.

rates, $3.17 per hour in 1956 and $9.86 per hour in 1974, include hoist operators, tractor operators, tractor-scraper operators, power crane operators, and motor grader operators. The unskilled wage rates are $2.36 per hour for 1956 and $7.88 per hour for 1974 and include common heavy construction labor, air compressor operators, air tool operators, and truck drivers.

In the case of developing country conditions, two sets of wage rates are developed. The first, which is the standardly used one, gives unskilled labor at $0.05 per hour and skilled at $0.20 per hour; such rates definitely reflect a labor-abundant country ($0.50 per day is not an uncommon wage for unskilled labor in road construction in India for example), but it is also one which has a certain amount of skilled labor available as well. The second set of wage rates, $0.01 per hour for unskilled and $0.75 per hour for skilled labor, reflects a more extreme situation of unskilled labor abundance and skilled labor shortage; these latter rates might be interpreted as shadow prices in a sense.

B.24 Materials

Materials consist of three categories: (1) equipment consumables (e.g., fuel); (2) materials used as aids in construction (e.g., explosives); and (3) construction materials (e.g., aggregate). Prices for materials are generally those quoted as wholesale, or at least as being representative of quantity-purchases; for materials requiring delivery to the site, such as coal and all construction materials, and materials encountering a special tax, such as gasoline and diesel fuel, the price includes these additional items.* As in the case of labor, the quality of the material is assumed to be reasonably constant over time. Prices are obtained for each period with only occasional use of indexes, and the same basic source is used to price a particular item over as many periods as possible, with additional sources substantiating the information cited as well whenever possible. Prices for materials in 1930, 1956, and 1974, along with their units of measure and sources, are given in Table B.4.

Prices for materials under developing conditions are, by and large, estimates based on logic and a certain amount of fact. Oil-based materials, including gasoline, diesel fuel, kerosene, and bitumen, are priced in line with European conditions today, while the rest of the equipment consumables and materials assisting in construction are priced as a rounded-up version of U.S. prices in 1974; such prices suggest these materials are generally imported using costly foreign exchange. Prices for aggregate are estimated with the help of two IBRD studies investigating alternative means of aggregate production in India and Indonesia (42,43), with all except the finer crushed stone being produced by hand techniques; the price of water is estimated in line with these prices relative to those of 1930. The prices of materials so

*For example, screenings in 1974 cost some $2.00/lcy at the pit (22), but their total cost delivered is some $3.50/lcy due to an estimated $1.50/lcy delivery charge for a 10 mile haul (49). As for gasoline, an average retail price without taxes in 1974 is $0.404/gal (51,64,82); its wholesale price is some 78% of this or $0.316/gal (90), but taxes add an average of $0.11/gal (51,82,90), yielding a final price of $0.426/gal)

Table B.4: Unit prices ($/unit) and their sources for the various materials used in highway construction under 1930, 1956, 1974, and developing country economic conditions.

			Economic Conditions						
			1930		1956		1974		Developing Country
No.	Description	Units	Price	Source	Price	Source	Price	Source	Price[a]
801	Coal	ton	4.00	26	8.91	64,74,76	32.97	26,64,71,74,84	40.00
802	Gasoline	gal	0.194	26	0.25	56	0.426	51,64,82,90	2.00
803	Diesel Fuel	gal	0.091*	26	0.15	56,63,88	0.355	51,76,82,90	1.50
820	Dynamite, 40%	lb	0.206	23b	0.248	23d	0.321	23d,55,76	0.500
821	Fuse, double tape	100ft	0.71	26,74	1.22*	26,74	3.44	26,74,76	4.00
822	Cap, nonelectric	100ct	1.08	26,74	1.85	76	5.22*	26,74,76	6.00
823	Kerosene	gal	0.057	84	0.103	76	0.232	76	0.700
830	Gravel,0.75 in. max	lcy[b]	2.93	23b	3.68	23d	5.59	19,23d,49,76	1.50
831	Crushed rock,1.5in.max	lcy[b]	3.05	23b	3.68	23d	5.29	19,22,23d,49,76	2.00
832	Screenings, fine	lcy	2.00*	22,49	2.43*	22,49	3.50	22,49	1.25
833	Water	100gal	0.12	26	0.15	77	0.20	22,67	0.08
834	Crushed rock 0.75in.max 0.50in.max	lcy[b]	3.07	23b	3.74	23d	5.37	23d,49	3.25
835	Bitumen	gal	0.06	23b	0.10	23d	0.30	23d,49	0.90

Note: Asterisk (*) indicates that figure is an estimate. The underlining (_) of the sources indicates those from which the data was actually taken, the others being substantiating sources.

[a]See text for description of derivation of prices.

[b]Units converted from tons if necessary by factor of 1.35 tons/lcy (22).

derived as representative of developing conditions are also given in Table B.4.

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B.4 Tables of Results

Applying factor prices at each of the price periods to the resource requirements of each of the technical packages in each technology period yields the full set of unit costs for all stages of construction as given in Table B.5. Table B.5A covers the 1920's technical packages at the prices of 1930 (B.5AA), 1956 (B.5AB), 1974 (B.5AC), and a developing country (B.5AD); similarly B.5B covers the 1950's technical packages and B.5C the 1970's.

Table B.6 presents the full set of labor and capital requirements of each technical package used throughout the analysis of the results; that is, for each technology period, it gives the amount of capital, measured in terms of investment cost at 1974, and the amount of labor, measured in terms of unskilled men, required to achieve a certain rate of production for each technical package in each stage of construction. The capital component is simply:

$$\sum_{\substack{\text{all}\\ \text{equipment}\\ \text{in}\\ \text{technical}\\ \text{package}}} \left[\begin{matrix}\text{investment}\\ \text{cost}\\ \text{of the}\\ \text{piece of}\\ \text{equipment}\\ \text{in 1974}\\ \text{dollars}\end{matrix} \quad \text{X} \quad \begin{matrix}\text{hours}\\ \text{required}\\ \text{by the}\\ \text{piece of}\\ \text{equipment}\\ \text{to}\\ \text{produce}\\ \text{a unit of}\\ \text{output}\end{matrix} \right] = \begin{matrix}\text{investment}\\ \text{required to}\\ \text{produce so}\\ \text{many units}\\ \text{of output}\\ \text{per hour}\end{matrix}$$

$$(\$) \quad \text{x} \quad (\text{hours/output}) \quad = (\$/\text{output per hour})$$

The labor component is simply:

$$\left\{ \begin{array}{c}\text{skilled}\\ \text{labor}\\ \text{hours}\\ \text{required}\\ \text{to}\\ \text{produce}\\ \text{a unit of}\\ \text{output}\end{array} \times \begin{array}{c}\left[\dfrac{\text{skilled wage}}{\text{unskilled wage}}\right]\\ \\ \text{at period of}\\ \text{technology}\end{array} \right\} + \begin{array}{c}\text{unskilled}\\ \text{labor}\\ \text{hours}\\ \text{required}\\ \text{to}\\ \text{produce}\\ \text{a unit of}\\ \text{output}\end{array} = \begin{array}{c}\text{unskilled}\\ \text{labor}\\ \text{required}\\ \text{to}\\ \text{produce}\\ \text{so many}\\ \text{units of}\\ \text{output}\\ \text{per hour}\end{array}$$

$$\left(\begin{array}{c}\text{skilled man-}\\ \text{hours/output}\end{array}\right) \times \left(\frac{\text{\$/skilled man-hour}}{\text{\$/unskilled man-hour}}\right) + \left(\begin{array}{c}\text{unskilled man-}\\ \text{hours/output}\end{array}\right) = \left(\begin{array}{c}\text{unskilled men/}\\ \text{output per hour}\end{array}\right)$$

Table B.6A covers the 1920's technology, B.6B the 1950's, and B.6C the 1970's. It might be noted that in the case of Figure 4.1b, where the skilled labor component for both the 1920's and 1970's is weighted by the wage ratio of 1974, the labor component for the 1920's technology is calculated by multiplying the figure for skilled labor in Table B.6A by 0.654 (i.e., $\frac{1.25}{1.91} = 0.654$ which is the wage ratio for the 1970's over that for the 1920's) and adding this to the figure for unskilled labor in the table.

Table B.7 is a collection of data used in plotting Figures 4.1c, e, and f, where the sensitivity of the results to the measurement of capital requirements is being tested; the figures for the labor component in these plots come in all cases from Table B.6. Table B.7a gives the 1920's technical packages for excavation/hauling at 100 meters with capital measured in terms of depreciation cost at 1974,* investment cost at 1930, and investment cost under developing conditions; Table B.7b similarly covers the 1970's technical packages.

*Investment cost ($) in the equation above is replaced by hourly depreciation cost at 1974 ($/hour - investment cost at 1974 divided by lifetime in hours); the result becomes depreciation cost per unit of output ($/output). Labor's units of measure get switched around slightly to read unskilled man-hours per unit of output (unskilled man-hours/output).

TABLE B.5AA: UNIT COSTS OF THE 1920'S TECHNICAL PACKAGES FOR ALL STAGES AT THE PRICES OF 1930.

STAGE/TECHNICAL PACKAGE NUMBER	LABOR			EQUIPMENT				HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
	SKILLED	UNSKILLED	TOTAL	INT/DEP	MAINT/MISC	FUEL	TOTAL				
SITE PREP ($/HA)											
11	97.243	396.3645	493.607	1.0668	0.4538	0.0	1.5206	6.138	7.659	35.68	536.743
21	19.222	9.9799	29.202	13.5980	10.2074	29.5529	53.3583	0.0	53.358	0.0	82.561
EXC/HAUL ($/100BCM)											
2M											
1-1	12.823	68.1462	80.969	0.7677	0.3314	0.0	1.0992	0.0	1.099	0.0	92.068
1-2	12.880	68.3087	81.189	1.0321	0.4460	0.0	1.4780	0.0	1.478	0.0	92.067
2-1	10.440	55.8118	66.252	0.7556	0.3284	0.0	1.0840	0.755	1.859	0.0	69.121
2-2	10.497	55.9743	66.472	1.0199	0.4429	0.0	1.4629	0.785	2.249	0.0	69.719
3-1	10.325	55.2101	65.535	1.1558	0.4699	1.2332	2.8590	0.0	2.859	0.0	69.394
3-2	10.382	55.3726	65.755	1.4201	0.5845	1.2332	3.2378	0.0	3.238	0.0	69.991
4-3	1.508	8.3032	9.811	0.0614	0.0257	0.0	0.0877	3.547	3.634	0.0	11.445
5-4	1.404	6.8315	8.236	0.0674	0.0400	0.0	0.1074	3.776	3.884	0.0	12.120
6-5	3.315	22.6891	26.004	0.1636	0.1224	0.0	0.2859	7.128	7.411	0.0	33.419
6M											
1-1	12.823	70.4567	83.279	0.7945	0.3430	0.0	1.1375	0.0	1.137	0.0	84.417
1-2	12.880	70.3364	83.217	1.0655	0.4605	0.0	1.5260	0.0	1.526	0.0	84.743
2-1	10.440	59.1223	69.562	0.7823	0.3400	0.0	1.1223	0.785	1.907	0.0	70.467
2-2	10.497	58.0019	68.499	1.0534	0.4574	0.0	1.5108	0.785	2.296	0.0	70.795
3-1	10.325	57.5206	67.845	1.1825	0.4815	1.2332	2.8972	0.0	2.897	0.0	70.743
3-2	10.382	57.4003	67.783	1.4536	0.5990	1.2332	3.2858	0.0	3.286	0.0	71.065
4-3	1.508	9.0974	10.605	0.0668	0.0277	0.0	0.0945	3.962	4.056	0.0	14.661
5-4	1.404	7.2262	8.630	0.0717	0.0428	0.0	0.1145	4.086	4.200	0.0	12.831
6-5	3.315	22.9180	26.233	0.1677	0.1256	0.0	0.2933	7.248	7.542	0.0	33.775
7-6	0.435	0.0	0.435	0.3415	0.2558	0.6215	1.2189	0.0	1.219	0.0	1.654
10-7	2.360	3.4693	5.829	2.2976	2.0464	0.5827	4.9267	0.774	5.701	0.0	11.529
10-8	2.353	3.5018	5.855	2.9214	2.3411	2.1366	7.3991	0.0	7.399	0.0	13.254
10-9	6.262	1.9855	8.247	4.3048	3.9040	4.4777	12.6865	0.0	12.687	0.0	20.934
9M											
1-1	12.823	72.2377	85.060	0.8151	0.3519	0.0	1.1670	0.0	1.167	0.0	96.227
1-2	12.880	71.9007	84.781	1.0913	0.4716	0.0	1.5629	0.0	1.563	0.0	96.344
2-1	10.440	59.9032	70.343	0.8029	0.3489	0.0	1.1519	0.785	1.937	0.0	72.280
2-2	10.497	59.5663	70.064	1.0791	0.4686	0.0	1.5477	0.785	2.331	0.0	72.396
3-1	10.325	59.3016	69.626	1.2031	0.4904	1.2332	2.9268	0.0	2.927	0.0	72.553
3-2	10.392	58.9646	69.347	1.4793	0.6101	1.2332	3.3227	0.0	3.323	0.0	72.670
4-3	1.508	9.7111	11.219	0.0710	0.0291	0.0	0.1002	4.282	4.382	0.0	15.601
5-4	1.404	7.5330	8.937	0.0751	0.0449	0.0	0.1200	4.324	4.444	0.0	13.382
6-5	3.315	23.0985	26.413	0.1710	0.1282	0.0	0.2992	7.341	7.640	0.0	34.054
7-6	0.509	0.0	0.509	0.3994	0.2991	0.7268	1.4252	0.0	1.425	0.0	1.934
10-7	2.360	3.5433	5.903	2.3043	2.0506	0.5827	4.9376	0.813	5.751	0.0	11.654
10-8	2.353	3.5258	5.879	2.9334	2.3471	2.1613	7.4418	0.0	7.442	0.0	13.320
10-9	6.296	1.9855	8.282	4.3218	3.9194	4.5085	12.7497	0.0	12.750	0.0	21.031
60M											
1-1	12.823	102.4781	115.301	1.1647	0.5034	0.0	1.6681	0.0	1.668	0.0	116.969
1-2	12.880	98.3987	111.279	1.5290	0.6613	0.0	2.1904	0.0	2.190	0.0	113.469

(TABLE B.5AA CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
2-1	10.440	90.1437	100.584	1.1525	0.5004	0.0	1.6529	0.785	2.438	0.0	103.021
2-1	10.497	86.0643	96.562	1.5169	0.6503	0.0	2.1752	0.785	2.960	0.0	99.522
3-1	10.325	89.5420	99.867	1.5527	0.6419	1.2332	3.4279	0.0	3.428	0.0	103.295
3-2	10.382	85.4626	95.845	1.9171	0.7998	1.2332	3.9501	0.0	3.950	0.0	99.795
4-3	1.508	20.1021	21.610	0.1417	0.0543	0.0	0.1960	9.703	9.899	0.0	31.509
5-4	1.404	12.6954	14.100	0.1319	0.0815	0.0	0.2133	8.166	8.579	0.0	22.679
6-5	3.315	26.1249	29.440	0.2256	0.1716	0.0	0.3972	8.920	9.317	0.0	38.757
7-6	1.761	0.0	1.761	1.3924	1.0353	2.5158	4.9335	0.0	4.933	0.0	6.695
8-7	0.944	5.3429	6.287	0.7175	0.6332	0.0	1.3507	4.257	5.607	0.0	11.894
9-7	1.796	3.2792	5.075	1.2539	1.0578	0.9948	3.3055	1.331	4.637	0.0	9.711
10-7	2.360	4.8014	7.161	2.4186	2.1212	0.5827	5.1225	1.469	6.592	0.0	13.753
10-8	2.353	3.9350	6.288	3.1381	2.4491	2.5806	8.1678	0.0	8.168	0.0	14.456
10-9	6.883	1.9855	8.869	4.6100	4.1806	5.0326	13.8232	0.0	13.823	0.0	22.692
100M											
1-1	12.823	125.6067	138.429	1.4321	0.6193	0.0	2.0514	0.0	2.051	0.0	140.481
1-2	12.880	118.6633	131.543	1.8637	0.8064	0.0	2.6701	0.0	2.670	0.0	134.213
2-1	10.440	113.2722	123.712	1.4199	0.6163	0.0	2.0362	0.785	2.821	0.0	126.533
2-2	10.497	106.3289	116.826	1.8516	0.8033	0.0	2.6549	0.785	3.440	0.0	120.266
3-1	10.325	112.6706	122.995	1.8201	0.7578	1.2332	3.8111	0.0	3.811	0.0	126.807
3-2	10.382	105.7272	116.110	2.2518	0.9448	1.2332	4.4298	0.0	4.430	0.0	120.539
4-3	1.508	28.0503	29.558	0.1958	0.0735	0.0	0.2693	13.849	14.118	0.0	43.676
5-4	1.404	16.6425	18.047	0.1751	0.1094	0.0	0.2846	11.455	11.739	0.0	29.786
6-5	3.315	28.4354	31.750	0.2674	0.2046	0.0	0.4720	10.127	10.599	0.0	42.349
7-6	2.716	0.0	2.716	2.1324	1.5969	3.8806	7.6098	0.0	7.610	0.0	10.326
8-7	0.944	6.3056	7.249	0.8049	0.6872	0.0	1.4922	4.759	6.251	0.0	13.501
9-7	1.796	4.2418	6.037	1.3404	1.1118	0.9948	3.4470	1.833	5.280	0.0	11.318
10-7	2.360	5.7641	8.124	2.5060	2.1753	0.5827	5.2640	1.971	7.235	0.0	15.359
10-8	2.353	4.2479	6.601	3.2947	2.5271	2.9012	8.7230	0.0	8.723	0.0	15.324
10-9	7.332	1.9855	9.318	4.8304	4.3803	5.4334	14.6441	0.0	14.644	0.0	23.962
165M											
1-1	12.823	162.9590	175.782	1.8639	0.8064	0.0	2.6703	0.0	2.670	0.0	178.452
1-2	12.880	151.3947	164.275	2.4043	1.0406	0.0	3.4449	0.0	3.445	0.0	167.720
2-1	10.440	150.6245	161.064	1.8518	0.8034	0.0	2.6551	0.785	3.440	0.0	164.504
2-2	10.497	139.0603	149.558	2.3922	1.0376	0.0	3.4297	0.785	4.215	0.0	153 772
3-1	10.325	150.0229	160.348	2.2520	0.9447	1.2332	4.4301	0.0	4.430	0.0	164.778
3-2	10.382	138.4586	148.841	2.7924	1.1791	1.2332	5.2047	0.0	5.205	0.0	154.046
4-3	1.508	40.8841	42.392	0.2831	0.1046	0.0	0.3077	20.546	20.934	0.0	63.326
5-4	1.404	23.0263	24.431	0.2452	0.1546	0.0	0.3998	16.451	16.851	0.0	41.281
6-5	3.315	32.1718	35.487	0.3349	0.2581	0.0	0.5930	12.078	12.671	0.0	48.158
7-6	4.270	0.0	4.270	3.3522	2.5103	6.1004	11.9629	0.0	11.963	0.0	16.233
8-7	0.944	7.8579	8.802	0.9459	0.7744	0.0	1.7203	5.569	7.289	0.0	16.091
9-7	1.796	5.7942	7.590	1.4814	1.1990	0.9948	3.6752	2.643	6.318	0.0	13.908
10-7	2,360	7.3164	9.676	2.6470	2.2625	0.5827	5.4922	2.781	8.274	0.0	17.950
10-8	2.353	4.7533	7.106	3.5475	2.6531	3.4192	9.6198	0.0	9.620	0.0	16.726
10-9	8.057	1.9855	10.043	5.1865	4.7029	6.0809	15.9703	0.0	15.970	0.0	26.013
500M											
1-1	12.823	358.6431	371.466	4.1262	1.7868	0.0	5.9130	0.0	5.913	0.0	377.379

(TABLE A.5AA CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
1-2	12.880	322.8672	335.747	5.2363	2.2679	0.0	7.5042	0.0	7.504	0.0	343.251
2-1	10.440	346.3086	356.749	4.1141	1.7837	0.0	5.8978	0.785	6.683	0.0	363.431
2-2	10.497	310.5327	321.030	5.2242	2.2648	0.0	7.4890	0.785	8.274	0.0	329.304
3-1	10.325	345.7070	356.032	4.5143	1.9253	1.2332	7.6728	0.0	7.673	0.0	363.705
3-2	10.382	309.9312	320.313	5.6244	2.4063	1.2332	9.2640	0.0	9.264	0.0	329.577
4-3	1.508	108.1219	109.630	0.7407	0.2673	0.0	1.0079	55.625	56.633	0.0	166.263
5-4	1.404	56.4496	57.854	0.6123	0.3912	0.0	1.0034	42.608	43.612	0.0	101.466
6-5	3.315	51.7505	55.065	0.6886	0.5383	0.0	1.2269	22.291	23.518	0.0	78.584
7-6	12.374	0.0	12.374	9.7131	7.2738	17.6763	34.6633	0.0	34.663	0.0	47.037
8-7	0.944	15.9987	16.943	1.6853	1.2316	0.0	2.9169	9.816	12.733	0.0	29.676
9-7	1.796	13.9349	15.731	2.2208	1.6562	0.9948	4.8717	6.891	11.762	0.0	27.493
10-7	2.360	15.4572	17.817	3.3864	2.7197	0.5827	6.6888	7.029	13.717	0.0	31.534
10-8	2.353	7.4007	9.753	4.8720	3.3132	6.1323	14.3174	0.0	14.317	0.0	24.071
10-9	11.856	1.9855	13.841	7.0515	6.3929	9.4723	22.9167	0.0	22.917	0.0	36.759
800M											
1-1	12.823	533.8643	546.687	6.1520	2.6646	0.0	8.8166	0.0	8.817	0.0	555.503
1-2	12.880	476.4158	489.296	7.7724	3.3669	0.0	11.1393	0.0	11.139	0.0	500.435
2-1	10.440	521.5298	531.970	6.1399	2.6616	0.0	8.8014	0.785	9.586	0.0	541.556
2-2	10.497	464.0813	474.579	7.7602	3.3637	0.0	11.1239	0.785	11.909	0.0	486.488
3-1	10.325	520.9282	531.253	6.5401	2.8031	1.2332	10.5764	0.0	10.576	0.0	541.829
3-2	10.382	463.4797	473.862	8.1604	3.5053	1.2332	12.8989	0.0	12.899	0.0	486.761
4-3	1.508	168.3259	169.834	1.1503	0.4129	0.0	1.5633	87.039	88.602	0.0	258.436
5-4	1.404	86.3771	87.781	0.9409	0.6030	0.0	1.5439	66.031	67.575	0.0	155.357
6-5	3.315	69.2834	72.598	1.0053	0.7893	0.0	1.7946	31.439	33.234	0.0	105.832
7-6	19.625	0.0	19.625	15.4055	11.5366	28.0355	54.9776	0.0	54.978	0.0	74.603
8-7	0.944	23.2910	24.235	2.3476	1.6411	0.0	3.9889	13.621	17.610	0.0	41.845
9-7	1.796	21.2272	23.023	2.8831	2.0657	0.9949	5.9436	10.695	16.639	0.0	39.662
10-7	2.360	22.7495	25.109	4.0487	3.1292	0.5827	7.7606	10.933	18.694	0.0	43.703
10-8	2.353	9.7653	12.118	6.0550	3.9027	8.5556	18.5133	0.0	18.513	0.0	30.631
10-9	15.251	1.9855	17.237	8.7188	7.9036	12.5040	29.1264	0.0	29.126	0.0	46.363
SPR/COMP ($/100BCM)											
93%											
11	4.270	22.3163	26.587	0.0957	0.0537	0.0	0.1495	0.596	0.746	0.0	27.333
21	2.670	1.9675	4.638	0.3214	0.1720	0.0	0.4934	2.053	2.546	0.0	7.184
98%											
11	5.203	24.4703	29.673	0.2960	0.1880	0.0	0.4840	2.844	3.328	0.0	33.001
21	2.670	4.1215	6.792	0.5217	0.3063	0.0	0.8279	4.301	5.129	0.0	11.921
12	4.512	21.7447	26.257	0.2611	0.2096	0.4316	0.9023	0.0	0.902	0.0	27.159
22	3.396	1.3959	4.791	0.4868	0.3278	0.4316	1.2462	1.457	2.703	0.0	7.494
32	2.222	0.0	2.222	0.9749	0.8264	0.7972	2.5985	0.0	2.598	0.0	4.820
SURFACING GRAVEL ($/100CCM)											
11	3.787	21.7327	25.520	0.2200	0.1380	0.0	0.3580	2.034	2.392	536.54	554.453
21	1.220	7.6413	8.861	0.3211	0.1921	0.0	0.5132	2.662	3.175	536.54	548.573
12	5.629	19.7832	25.412	0.4688	0.3933	0.8496	1.7117	0.0	1.712	536.54	563.665
22	2.636	5.6919	8.328	0.5699	0.4474	0.8496	1.8669	0.628	2.495	536.54	547.364
WBM ($/100CCM)											

(TABLE B.5AA CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
211	19.464	34.4161	53.880	5.6042	4.5796	3.2951	13.4792	5.001	18.480	640.15	712.508
DBST/G ($/100SM)											
1111	1.070	4.6690	5.740	0.2861	0.2072	0.2295	0.7228	0.0	0.723	13.70	20.163
1121	0.806	2.1059	2.912	0.5604	0.4554	0.6365	1.6522	0.0	1.652	13.70	19.265
DBST/W ($/100SM)											
1111	1.070	4.6690	5.740	0.2861	0.2072	0.2295	0.7228	0.0	0.723	12.19	18.657
1121	0.806	2.1059	2.912	0.5604	0.4554	0.6365	1.6522	0.0	1.652	12.19	16.759

TABLE B.5AB: UNIT COSTS OF THE 1920'S TECHNICAL PACKAGES FOR ALL STAGES AT THE PRICES OF 1956.

STAGE/TECHNICAL	LABOR			EQUIPMENT					EQUIPMENT		
PACKAGE NUMBER	SKILLED	UNSKILLED	TOTAL	INT/DEP	MAINT/MISC	FUEL	TOTAL	HORSE	AND HORSE	MATERIALS	TOTAL
SITE PREP ($/HA)											
11	350.295	2033.5222	2383.817	3.1678	1.3523	0.0	4.5202	11.253	15.773	46.15	2445.735
21	69.244	51.2011	120.445	39.9915	30.4188	38.0837	108.4939	0.0	108.494	0.0	228.939
EXC/HAUL ($/100BCM)											
2M											
1-1	46.190	349.6196	395.810	2.2776	0.9877	0.0	3.2653	0.0	3.265	0.0	399.075
1-2	46.399	350.4531	396.851	3.0615	1.3290	0.0	4.3905	0.0	4.391	0.0	401.241
2-1	37.607	286.3386	323.946	2.2411	0.9786	0.0	3.2197	1.439	4.659	0.0	328.605
2-2	37.815	287.1721	324.987	3.0250	1.3199	0.0	4.3450	1.439	5.784	0.0	330.771
3-1	37.193	283.2520	320.445	3.4253	1.4004	1.5892	6.4149	0.0	6.415	0.0	326.860
3-2	37.400	284.0854	321.486	4.2092	1.7417	1.5892	7.5402	0.0	7.540	0.0	329.026
4-3	5.432	42.5989	48.031	0.1816	0.0767	0.0	0.2583	6.503	6.762	0.0	54.792
5-4	5.059	35.0484	40.107	0.1990	0.1191	0.0	0.3181	6.924	7.242	0.0	47.349
6-5	11.942	116.4062	128.348	0.4811	0.3647	0.0	0.8459	13.067	13.913	0.0	142.261
6M											
1-1	46.190	361.4731	407.664	2.3568	1.0222	0.0	3.3790	0.0	3.379	0.0	411.043
1-2	46.398	360.8557	407.254	3.1608	1.3723	0.0	4.5331	0.0	4.533	0.0	411.787
2-1	37.607	298.1921	335.800	2.3203	1.0131	0.0	3.3334	1.439	4.772	0.0	340.572
2-2	37.815	297.5747	335.390	3.1244	1.3632	0.0	4.4875	1.439	5.926	0.0	341.316
3-1	37.193	295.1055	332.298	3.5045	1.4349	1.5892	6.5286	0.0	6.529	0.0	338.827
3-2	37.400	294.4980	331.888	4.3086	1.7850	1.5892	7.6827	0.0	7.683	0.0	339.571
4-3	5.432	46.6736	52.105	0.1976	0.0824	0.0	0.2800	7.263	7.543	0.0	59.649
5-4	5.059	37.0734	42.132	0.2118	0.1275	0.0	0.3392	7.490	7.830	0.0	49.962
6-5	11.942	117.5792	129.521	0.4932	0.3744	0.0	0.8676	13.289	14.156	0.0	143.677
7-6	1.567	0.0	1.567	1.0038	0.7622	0.8010	2.5670	0.0	2.567	0.0	4.134
10-7	8.500	17.7989	26.299	6.7365	6.0985	1.2980	14.1330	1.419	15.552	0.0	41.851
10-8	8.475	17.9656	26.441	8.5791	6.9767	3.3004	18.8562	0.0	18.856	0.0	45.297
10-9	22.556	10.1867	32.743	12.6279	11.6343	6.3173	30.5794	0.0	30.579	0.0	63.322
9M											
1-1	46.190	370.6104	416.801	2.4179	1.0488	0.0	3.4667	0.0	3.467	0.0	420.263
1-2	46.398	368.8816	415.280	3.2372	1.4055	0.0	4.6427	0.0	4.643	0.0	419.922
2-1	37.607	307.3293	344.937	2.3814	1.0397	0.0	3.4211	1.439	4.860	0.0	349.797
2-2	37.815	305.6006	343.416	3.2007	1.3964	0.0	4.5971	1.439	6.036	0.0	349.451
3-1	37.193	304.2427	341.436	3.5656	1.4615	1.5892	6.6163	0.0	6.616	0.0	348.052
3-2	37.400	302.5139	339.914	4.3849	1.8192	1.5892	7.7923	0.0	7.792	0.0	347.706
4-3	5.432	49.8222	55.254	0.2100	0.0869	0.0	0.2968	7.850	8.147	0.0	63.401
5-4	5.059	38.6477	43.706	0.2217	0.1339	0.0	0.3556	7.928	8.283	0.0	51.990
6-5	11.942	118.5053	130.447	0.5028	0.3821	0.0	0.8849	13.459	14.343	0.0	144.790
7-6	1.833	0.0	1.833	1.1737	0.8913	0.9366	3.0016	0.0	3.002	0.0	4.834
10-7	8.500	18.1786	26.679	6.7562	6.1109	1.2980	14.1651	1.491	15.656	0.0	42.334
10-8	8.475	18.0891	26.564	8.6147	6.9946	3.3322	18.9415	0.0	18.941	0.0	45.506
10-9	22.681	10.1867	32.867	12.6777	11.6800	6.3570	30.7147	0.0	30.715	0.0	63.582
60M											
1-1	46.190	525.7568	571.948	3.4548	1.5003	0.0	4.9551	0.0	4.955	0.0	576.902
1-2	[illegible]	[illegible]	[illegible]	[illegible]	1.9708	0.0	[illegible]	0.0	[illegible]	0.0	[illegible]

(TABLE B.5AB CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
2-1	37.607	462.4758	500.093	3.4183	1.4912	0.0	4.9095	1.439	6.348	0.0	506.432
2-1	37.815	441.5469	479.362	4.4990	1.9617	0.0	6.4606	1.439	7.899	0.0	487.261
3-1	37.193	459.3892	496.582	4.6025	1.9130	1.5892	8.1047	0.0	8.105	0.0	504.687
3-2	37.400	438.4602	475.860	5.6832	2.3835	1.5892	9.6559	0.0	9.656	0.0	485.516
4-3	5.432	103.1326	108.564	0.4192	0.1618	0.0	0.5810	17.789	18.370	0.0	126.935
5-4	5.059	65.1331	70.192	0.3891	0.2428	0.0	0.6319	15.338	15.969	0.0	86.161
6-5	11.942	134.0323	145.974	0.6635	0.5112	0.0	1.1747	16.353	17.528	0.0	163.502
7-6	6.344	0.0	6.344	4.0629	3.0851	3.2420	10.3901	0.0	10.390	0.0	16.734
8-7	3.400	27.4115	30.811	2.1103	1.8869	0.0	3.9972	7.804	11.801	0.0	42.613
9-7	6.468	16.8235	23.292	3.6874	3.1522	1.2820	8.1215	2.440	10.562	0.0	33.854
10-7	8.500	24.6333	33.133	7.0928	6.3215	1.2980	14.7123	2.693	17.406	0.0	50.539
10-8	8.475	20.1882	28.663	9.2190	7.2986	3.8725	20.3901	0.0	20.390	0.0	49.053
10-9	24.795	10.1867	34.982	13.5239	12.4584	7.0324	33.0147	0.0	33.015	0.0	67.997
100M											
1-1	46.190	644.4165	690.607	4.2478	1.8456	0.0	6.0934	0.0	6.093	0.0	696.700
1-2	46.398	608.7939	655.192	5.5281	2.4030	0.0	7.9311	0.0	7.931	0.0	663.123
2-1	37.607	581.1355	618.743	4.2114	1.8365	0.0	6.0478	1.439	7.487	0.0	626.229
2-2	37.815	545.5129	583.328	5.4916	2.3939	0.0	7.8855	1.439	9.324	0.0	592.652
3-1	37.193	578.0488	615.241	5.3956	2.2583	1.5892	9.2431	0.0	9.243	0.0	624.484
3-2	37.400	542.4263	579.826	6.6758	2.8157	1.5892	11.0807	0.0	11.081	0.0	590.907
4-3	5.432	143.9103	149.342	0.5792	0.2191	0.0	0.7983	25.389	26.187	0.0	175.529
5-4	5.059	85.3831	90.442	0.5170	0.3261	0.0	0.8431	21.001	21.844	0.0	112.285
6-5	11.942	145.8859	157.827	0.7861	0.6098	0.0	1.3959	18.566	19.962	0.0	177.790
7-6	9.785	0.0	9.785	6.2670	4.7587	5.0007	16.0265	0.0	16.026	0.0	25.812
8-7	3.400	32.3505	35.750	2.3678	2.0480	0.0	4.4158	8.725	13.141	0.0	48.891
9-7	6.468	21.7625	28.231	3.9449	3.3133	1.2820	8.5402	3.361	11.901	0.0	40.132
10-7	8.500	29.5723	38.072	7.3504	6.4826	1.2980	15.1309	3.614	18.745	0.0	56.813
10-8	8.475	21.7934	30.269	9.6812	7.5310	4.2057	21.4979	0.0	21.498	0.0	51.765
10-9	26.412	10.1867	36.599	14.1710	13.0536	7.5489	34.7735	0.0	34.773	0.0	71.372
165M											
1-1	46.190	836.0500	882.240	5.5286	2.4032	0.0	7.9318	0.0	7.932	0.0	890.172
1-2	46.398	776.7202	823.118	7.1314	3.1011	0.0	10.2325	0.0	10.233	0.0	833.351
2-1	37.607	772.7690	810.376	5.4921	2.3941	0.0	7.8863	1.439	9.325	0.0	819.701
2-2	37.815	713.4392	751.254	7.0949	3.0920	0.0	10.1869	1.439	11.626	0.0	762.880
3-1	37.193	769.6824	806.875	6.6763	2.8159	1.5892	11.0815	0.0	11.081	0.0	817.956
3-2	37.400	710.3525	747.753	8.2791	3.5139	1.5892	13.3821	0.0	13.382	0.0	761.135
4-3	5.432	209.7534	215.185	0.8376	0.3116	0.0	1.1493	37.668	38.817	0.0	254.002
5-4	5.059	118.1349	123.193	0.7240	0.4607	0.0	1.1847	30.160	31.345	0.0	154.538
6-5	11.942	165.0554	176.997	0.9845	0.7692	0.0	1.7537	22.143	23.897	0.0	200.894
7-6	15.383	0.0	15.383	9.8520	7.4809	7.8613	25.1942	0.0	25.194	0.0	40.577
8-7	3.400	40.3146	43.715	2.7831	2.3078	0.0	5.0909	10.210	15.301	0.0	59.015
9-7	6.468	29.7266	36.195	4.3602	3.5731	1.2820	9.2153	4.846	14.061	0.0	50.256
10-7	8.500	37.5364	46.036	7.7657	6.7424	1.2980	15.8060	5.099	20.905	0.0	66.942
10-8	8.475	24.3863	32.861	10.4277	7.9065	4.9532	23.2874	0.0	23.287	0.0	56.149
10-9	29.024	10.1867	39.211	15.2163	14.0150	8.3833	37.6146	0.0	37.615	0.0	76.826
500M											
1-1	46.190	1839.9958	1886.187	12.2384	5.3247	0.0	17.5631	0.0	17.563	0.0	1903.750

(TABLE B.5AB CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
1-2	46.398	1656.4502	1702.848	15.5309	6.7583	0.0	22.2891	0.0	22.289	0.0	1725.137
2-1	37.607	1776.7148	1814.323	12.2020	5.3156	0.0	17.5176	1.439	18.956	0.0	1833.279
2-2	37.815	1593.1692	1630.984	15.4944	6.7492	0.0	22.2436	1.439	23.682	0.0	1654.665
3-1	37.193	1773.6282	1810.821	13.3962	5.7374	1.5892	20.7128	0.0	20.713	0.0	1831.534
3-2	37.400	1590.0825	1627.483	16.6786	7.1710	1.5892	25.4388	0.0	25.439	0.0	1652.921
4-3	5.432	554.7122	560.144	2.1914	0.7965	0.0	2.9879	101.979	104.967	0.0	665.111
5-4	5.059	289.6108	294.669	1.8076	1.1657	0.0	2.9733	78.115	81.089	0.0	375.759
6-5	11.942	265.5024	277.444	2.0241	1.6043	0.0	3.6283	40.868	44.496	0.0	321.940
7-6	44.573	0.0	44.573	28.5468	21.6765	22.7789	73.0020	0.0	73.002	0.0	117.575
8-7	3.400	82.0801	85.480	4.9610	3.6702	0.0	8.6312	17.997	26.628	0.0	112.108
9-7	6.468	71.4921	77.960	6.5381	4.9355	1.2820	12.7556	12.633	25.388	0.0	103.349
10-7	8.530	79.3019	87.802	9.9435	8.1048	1.2980	19.3463	12.986	32.232	0.0	120.034
10-8	8.475	37.9686	46.444	14.3382	9.8735	8.4495	32.6611	0.0	32.661	0.0	79.105
10-9	42.707	10.1867	52.894	20.6917	19.0513	12.7536	52.4966	0.0	52.497	0.0	105.391
800M											
1-1	46.190	2738.9563	2785.147	18.2466	7.9407	0.0	26.1873	0.0	26.187	0.0	2811.334
1-2	46.398	2444.2212	2490.617	23.0523	10.0332	0.0	33.0855	0.0	33.086	0.0	2523.702
2-1	37.607	2675.6753	2713.281	18.2101	7.9316	0.0	26.1417	1.439	27.581	0.0	2740.863
2-2	37.815	2380.9402	2418.753	23.0159	10.0241	0.0	33.0399	1.439	34.479	0.0	2453.231
3-1	37.193	2672.5886	2709.781	19.3943	8.3534	1.5892	29.3369	0.0	29.337	0.0	2739.118
3-2	37.400	2377.8535	2415.252	24.2001	10.4459	1.5892	36.2352	0.0	36.235	0.0	2451.486
4-3	5.432	863.5852	869.017	3.4036	1.2306	0.0	4.6342	159.572	164.206	0.0	1033.222
5-4	5.059	443.1521	448.211	2.7778	1.7969	0.0	4.5747	121.058	125.632	0.0	573.843
6-5	11.942	355.4541	367.396	2.9550	2.3521	0.0	5.3071	57.638	62.945	0.0	430.341
7-6	70.695	0.0	70.695	45.2765	34.3799	36.1282	115.7847	0.0	115.785	0.0	186.480
8-7	3.400	119.4931	122.893	6.9119	4.8907	0.0	11.8026	24.972	36.774	0.0	159.667
9-7	6.468	108.9051	115.373	8.4890	6.1559	1.2820	15.9269	19.608	35.535	0.0	150.908
10-7	8.500	116.7149	125.215	11.8944	9.3252	1.2980	22.5176	19.861	42.379	0.0	167.594
10-8	8.475	50.1000	58.575	17.8309	11.6303	11.5723	41.0335	0.0	41.033	0.0	99.609
10-9	54.939	10.1867	65.126	25.5863	23.5534	16.6604	65.8002	0.0	65.800	0.0	130.926
SPR/COMP ($/100BCM)											
93%											
11	15.393	114.4923	129.875	0.2823	0.1601	0.0	0.4424	1.093	1.536	0.0	131.411
21	9.620	10.0941	19.714	0.9478	0.5126	0.0	1.4604	3.764	5.224	0.0	24.938
98%											
11	18.742	125.5434	144.285	0.8695	0.5602	0.0	1.4298	5.214	6.644	0.0	150.929
21	9.620	21.1451	30.765	1.5351	0.9126	0.0	2.4477	7.885	10.332	0.0	41.097
12	16.254	111.5598	127.814	0.7659	0.6246	0.5562	1.9466	0.0	1.947	0.0	129.760
22	12.232	7.1616	19.393	1.4314	0.9770	0.5562	2.9646	2.670	5.635	0.0	25.028
32	8.002	0.0	8.002	2.8625	2.4626	1.1588	6.4839	0.0	6.484	0.0	14.486
SURFACING											
GRAVEL ($/100CCM)											
11	13.642	111.4981	125.140	0.6465	0.4112	0.0	1.0577	3.729	4.787	673.88	803.808
21	4.395	39.2034	43.598	0.9445	0.5724	0.0	1.5168	4.880	6.397	673.88	723.877
12	20.276	101.4966	121.772	1.3736	1.1722	1.0948	3.6405	0.0	3.641	673.88	799.294
22	9.495	29.2019	38.697	1.6715	1.3333	1.0948	4.0997	1.151	5.251	673.88	717.829
WBM ($/100CCM)											
111	83.466	294.2720	377.738	16.0169	13.4495	7.3404	36.8068	7.672	44.478	773.51	1195.728

(TABLE B.5AB CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
211	70.115	176.5694	246.684	16.3774	13.6475	7.3404	37.3653	9.168	46.533	773.51	1066.729
DBST/G ($/100SM)											
1111	3.856	23.9542	27.810	0.8425	0.6175	0.2958	1.7557	0.0	1.756	19.68	49.250
1121	2.902	10.8041	13.707	1.6477	1.3570	0.8202	3.8250	0.0	3.825	19.68	37.216
DBST/W ($/100SM)											
1111	3.856	23.9542	27.810	0.8425	0.6175	0.2958	1.7557	0.0	1.756	17.17	46.739
1121	2.902	10.8041	13.707	1.6477	1.3570	0.8202	3.8250	0.0	3.825	17.17	34.704

TABLE B.5AC: UNIT COSTS OF THE 1920'S TECHNICAL PACKAGES FOR ALL STAGES AT THE PRICES OF 1974.

STAGE/TECHNICAL	LABOR			EQUIPMENT					EQUIPMENT		
PACKAGE NUMBER	SKILLED	UNSKILLED	TOTAL	INT/DEP	MAINT/MISC	FUEL	TOTAL	HORSE	AND HORSE	MATERIALS	TOTAL
SITE PREP(\$/HA)											
11	1089.560	6789.8945	7879.457	6.5384	2.6579	0.0	9.1964	22.506	31.702	76.07	7987.230
21	215.378	170.9595	386.338	93.7231	59.7862	64.8946	218.4039	0.0	218.404	0.0	604.742
EXC/HAUL (\$/100BCM)											
2M											
1-1	143.671	1167.3748	1311.046	4.7609	1.9413	0.0	6.7022	0.0	6.702	0.0	1317.748
1-2	144.316	1170.1577	1314.474	6.4048	2.6121	0.0	9.0170	0.0	9.017	0.0	1323.491
2-1	116.975	956.0806	1073.055	4.6981	1.9234	0.0	6.6214	2.878	9.499	0.0	1082.554
2-2	117.620	958.8635	1076.483	6.3420	2.5942	0.0	8.9362	2.878	11.814	0.0	1089.297
3-1	115.685	945.7737	1061.459	7.2591	2.7524	2.7080	12.7195	0.0	12.720	0.0	1074.178
3-2	116.330	948.5566	1064.886	8.9030	3.4232	2.7080	15.0343	0.0	15.034	0.0	1079.921
4-3	16.895	142.2371	159.132	0.3980	0.1507	0.0	0.5487	13.007	13.555	0.0	172.687
5-4	15.734	117.0261	132.760	0.4437	0.2342	0.0	0.6779	13.847	14.525	0.0	147.285
6-5	37.143	388.6782	425.821	1.1272	0.7168	0.0	1.8440	26.134	27.978	0.0	453.800
6M											
1-1	143.671	1206.9539	1350.625	4.9270	2.0091	0.0	6.9361	0.0	6.936	0.0	1357.561
1-2	144.316	1204.8926	1349.208	6.6131	2.6971	0.0	9.3103	0.0	9.310	0.0	1358.519
2-1	116.975	995.6597	1112.634	4.8642	1.9912	0.0	6.8554	2.878	9.733	0.0	1122.367
2-2	117.620	993.5984	1111.218	6.5503	2.6792	0.0	9.2295	2.878	12.107	0.0	1123.325
3-1	115.685	985.3528	1101.038	7.4252	2.8202	2.7080	12.9534	0.0	12.953	0.0	1113.991
3-2	116.330	983.2915	1099.621	9.1113	3.5082	2.7080	15.3276	0.0	15.328	0.0	1114.949
4-3	16.895	155.8424	172.737	0.4326	0.1620	0.0	0.5945	14.526	15.121	0.0	187.858
5-4	15.734	123.7875	139.522	0.4723	0.2505	0.0	0.7228	14.981	15.704	0.0	155.225
6-5	37.143	392.5950	429.738	1.1559	0.7359	0.0	1.8918	26.577	28.469	0.0	458.207
7-6	4.875	0.0	4.875	2.3729	1.4981	1.3648	5.2358	0.0	5.236	0.0	10.111
10-7	26.439	59.4304	85.869	16.4258	11.9863	4.8030	33.2151	2.837	36.052	0.0	121.921
10-8	26.361	59.9870	86.348	20.5055	13.7123	8.2151	42.4329	0.0	42.433	0.0	128.781
10-9	70.159	34.0132	104.172	30.5901	22.8664	13.3559	66.8124	0.0	66.812	0.0	170.985
9M											
1-1	143.671	1237.4626	1381.134	5.0551	2.0613	0.0	7.1164	0.0	7.116	0.0	1388.250
1-2	144.316	1231.6907	1376.007	6.7732	2.7625	0.0	9.5357	0.0	9.536	0.0	1385.542
2-1	116.975	1026.1685	1143.143	4.9923	2.0434	0.0	7.0357	2.878	9.913	0.0	1153.057
2-2	117.620	1020.3965	1138.016	6.7104	2.7446	0.0	9.4549	2.878	12.333	0.0	1150.349
3-1	115.685	1015.8616	1131.546	7.5533	2.8724	2.7080	13.1338	0.0	13.134	0.0	1144.680
3-2	116.330	1010.0896	1126.419	9.2714	3.5736	2.7080	15.5530	0.0	15.553	0.0	1141.972
4-3	16.895	166.3556	183.250	0.4593	0.1707	0.0	0.6300	15.700	16.330	0.0	199.581
5-4	15.734	129.0441	144.778	0.4945	0.2632	0.0	0.7577	15.856	16.613	0.0	161.392
6-5	37.143	395.6870	432.830	1.1785	0.7511	0.0	1.9296	26.917	28.847	0.0	461.677
7-6	5.700	0.0	5.700	2.7747	1.7517	1.5959	6.1223	0.0	6.122	0.0	11.823
10-7	26.439	60.6981	87.137	16.4712	12.0106	4.8030	33.2849	2.981	36.266	0.0	123.403
10-8	26.361	60.3992	86.760	20.5847	13.7475	8.2693	42.6015	0.0	42.601	0.0	129.362
10-9	70.546	34.0132	104.559	30.7094	22.9564	13.4236	67.0894	0.0	67.089	0.0	171.648
60M											
1-1	143.671	1755.4946	1899.166	7.2296	2.9487	0.0	10.1783	0.0	10.178	0.0	1909.344
1-2	144.316	1685.6128	1829.929	9.4958	3.8735	0.0	13.3693	0.0	13.369	0.0	1843.298

(TABLE B.5AC CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
2-1	116.975	1544.2004	1661.175	7.1668	2.9308	0.0	10.0976	2.878	12.975	0.0	1674.150
2-1	117.620	1474.3186	1591.938	9.4330	3.8556	0.0	13.2886	2.878	16.166	0.0	1608.104
3-1	115.685	1533.8936	1649.578	9.7278	3.7590	2.7080	16.1956	0.0	16.196	0.0	1665.774
3-2	116.330	1464.0117	1580.341	11.9940	4.6846	2.7080	19.3866	0.0	19.387	0.0	1579.728
4-3	16.895	344.3582	361.253	0.9119	0.3179	0.0	1.2298	35.579	36.808	0.0	398.062
5-4	15.734	217.4785	233.213	0.8677	0.4772	0.0	1.3450	30.675	32.020	0.0	265.233
6-5	37.143	447.5315	484.675	1.5584	1.0048	0.0	2.5632	32.707	35.270	0.0	519.944
7-6	19.732	0.0	19.732	9.6047	6.0636	5.5244	21.1927	0.0	21.193	0.0	40.925
8-7	10.575	91.5265	102.102	4.9419	3.7096	0.0	8.6505	15.600	24.259	0.0	126.361
9-7	20.119	56.1733	76.292	8.5678	6.1954	2.1845	16.9477	4.980	21.928	0.0	98.221
10-7	26.439	82.2502	108.689	17.2444	12.4245	4.8030	34.4719	5.387	39.859	0.0	148.547
10-8	26.361	67.4080	93.769	21.9316	14.3449	9.1900	45.4666	0.0	45.467	0.0	139.236
10-9	77.123	34.0132	111.137	32.7381	24.4862	14.5745	71.7988	0.0	71.799	0.0	182.935
100M											
1-1	143.671	2151.6970	2295.368	8.8927	3.6274	0.0	12.5201	0.0	12.520	0.0	2307.888
1-2	144.316	2032.7539	2177.070	11.5775	4.7229	0.0	16.3004	0.0	16.300	0.0	2193.370
2-1	116.975	1940.4028	2057.377	8.8299	3.6095	0.0	12.4393	2.878	15.317	0.0	2072.695
2-2	117.620	1821.4597	1939.079	11.5147	4.7051	0.0	16.2197	2.878	19.097	0.0	1958.177
3-1	115.685	1930.0959	2045.781	11.3909	4.4385	2.7080	18.5374	0.0	18.537	0.0	2064.319
3-2	116.330	1811.1529	1927.482	14.0757	5.5341	2.7080	22.3178	0.0	22.318	0.0	1949.800
4-3	16.895	480.5139	497.409	1.2582	0.4306	0.0	1.6888	50.778	52.467	0.0	549.875
5-4	15.734	285.0925	300.827	1.1531	0.6409	0.0	1.7940	42.001	43.795	0.0	344.622
6-5	37.143	487.1106	524.254	1.8484	1.1995	0.0	3.0469	37.133	40.179	0.0	564.433
7-6	30.437	0.0	30.437	14.8151	9.3530	8.5213	32.6894	0.0	32.689	0.0	63.126
8-7	10.575	108.0178	118.593	5.5335	4.0253	0.0	9.5588	17.450	27.009	0.0	145.602
9-7	20.119	72.6646	92.784	9.1594	6.5121	2.1845	17.8560	6.722	24.578	0.0	117.362
10-7	26.439	98.7414	125.180	17.8360	12.7411	4.8030	35.3801	7.229	42.609	0.0	167.789
10-8	26.361	72.7677	99.129	22.9616	14.8018	9.8941	47.6575	0.0	47.658	0.0	146.786
10-9	82.153	34.0132	116.166	34.2895	25.6560	15.4546	75.4001	0.0	75.400	0.0	191.566
165M											
1-1	143.671	2791.5581	2935.229	11.5786	4.7234	0.0	16.3020	0.0	16.302	0.0	2951.531
1-2	144.316	2593.4570	2737.773	14.9398	6.0950	0.0	21.0348	0.0	21.035	0.0	2758.809
2-1	116.975	2580.2639	2697.239	11.5153	4.7055	0.0	16.2213	2.878	19.099	0.0	2716.338
2-2	117.620	2382.1628	2499.782	14.8770	6.0771	0.0	20.9541	2.878	23.832	0.0	2523.614
3-1	115.685	2569.9570	2685.642	14.0768	5.5345	2.7080	22.3194	0.0	22.319	0.0	2707.961
3-2	116.330	2371.8560	2488.186	17.4380	6.9061	2.7080	27.0522	0.0	27.052	0.0	2515.238
4-3	16.895	700.3633	717.258	1.8172	0.6125	0.0	2.4297	75.336	77.765	0.0	795.023
5-4	15.734	394.4502	410.184	1.6147	0.9055	0.0	2.5202	60.320	62.840	0.0	473.025
6-5	37.143	551.1172	588.260	2.3174	1.5117	0.0	3.8291	44.286	48.115	0.0	636.375
7-6	47.847	0.0	47.847	23.2899	14.7033	13.3957	51.3888	0.0	51.389	0.0	99.236
8-7	10.575	134.6099	145.185	6.4874	4.5359	0.0	11.0233	20.419	31.443	0.0	176.624
9-7	20.119	99.2568	119.376	10.1134	7.0227	2.1845	19.3205	9.692	29.012	0.0	148.388
10-7	26.439	125.3336	151.772	18.7899	13.2517	4.8030	36.8447	10.198	47.043	0.0	198.815
10-8	26.361	81.4256	107.787	24.6255	15.5398	11.0315	51.1968	0.0	51.197	0.0	158.984
10-9	90.278	34.0132	124.291	36.7955	27.5457	16.8763	81.2176	0.0	81.218	0.0	205.509
500M											
1-1	143.671	6143.7109	6287.383	25.6498	10.4654	0.0	36.1152	0.0	36.115	0.0	6323.496

(TABLE B.5PC CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
1-2	144.316	5530.8555	5675.168	32.5544	13.2930	0.0	45.8374	0.0	45.837	0.0	5721.005
2-1	116.975	5932.4180	6049.395	25.5869	10.4475	0.0	36.0345	2.878	38.912	0.0	6088.305
2-2	117.620	5319.5625	5437.180	32.4915	13.2651	0.0	45.7566	2.878	48.634	0.0	5485.816
3-1	115.695	5922.1094	6037.797	28.1480	11.2766	2.7080	42.1326	0.0	42.133	0.0	6079.926
3-2	116.330	5309.2539	5425.582	35.0526	14.0941	2.7080	51.8547	0.0	51.855	0.0	5477.437
4-3	16.895	1852.1748	1869.070	4.7462	1.5654	0.0	6.3116	203.958	210.270	0.0	2079.340
5-4	15.734	967.0063	982.740	4.0313	2.2911	0.0	6.3223	156.231	162.553	0.0	1145.293
6-5	37.143	886.5083	923.651	4.7748	3.1531	0.0	7.9279	81.735	89.663	0.0	1013.314
7-6	138.641	0.0	138.641	67.4841	42.6038	38.8151	148.9030	0.0	148.903	0.0	287.544
8-7	10.575	274.0640	284.639	11.4901	7.2136	0.0	18.7038	35.993	54.697	0.0	339.336
9-7	20.119	238.7110	258.830	15.1161	9.7004	2.1845	27.0010	25.265	52.266	0.0	311.096
10-7	26.439	264.7876	291.226	23.7926	15.9295	4.8030	44.5251	25.772	70.297	0.0	361.523
10-8	26.361	126.7766	153.138	33.3408	19.4057	16.9891	69.7357	0.0	69.736	0.0	222.874
10-9	132.838	34.0132	166.851	49.9225	37.4441	24.3234	111.6900	0.0	111.690	0.0	278.541
800m											
1-1	143.671	9145.3281	9289.000	38.2495	15.6070	0.0	53.8565	0.0	53.857	0.0	9342.852
1-2	144.316	8161.2109	8305.527	48.3276	19.7196	0.0	68.0473	0.0	68.047	0.0	8373.574
2-1	116.975	8934.0352	9051.012	38.1866	15.5891	0.0	53.7758	2.878	56.653	0.0	9107.660
2-2	117.620	7949.9180	8067.539	48.2648	19.7017	0.0	67.9665	2.879	70.844	0.0	8138.383
3-1	115.685	8923.7266	9039.414	40.7477	16.4181	2.7080	59.9739	0.0	59.974	0.0	9094.281
3-2	116.330	7939.6094	8055.941	50.8258	20.5307	2.7080	74.0646	0.0	74.065	0.0	8130.004
4-3	16.895	2883.4956	2900.390	7.3687	2.4187	0.0	9.7874	319.143	328.930	0.0	3229.319
5-4	15.734	1479.6782	1495.412	6.1951	3.5317	0.0	9.7268	242.115	251.842	0.0	1747.255
6-5	37.143	1186.8555	1223.999	6.9754	4.6230	0.0	11.5984	115.277	126.875	0.0	1350.874
7-6	219.892	0.0	219.892	107.0330	67.5717	61.5625	236.1671	0.0	236.167	0.0	456.059
8-7	10.575	398.9854	409.561	15.9715	9.6123	0.0	25.5838	49.944	75.527	0.0	485.088
9-7	20.119	363.6321	383.751	19.5974	12.0991	2.1845	33.8810	39.216	73.097	0.0	456.848
10-7	26.439	389.7090	416.147	28.2739	18.3282	4.8030	51.4052	39.722	91.128	0.0	507.275
10-8	26.361	167.2832	193.644	41.1252	22.8586	22.3104	86.2944	0.0	86.294	0.0	279.939
10-9	170.884	34.0132	204.897	61.6572	46.2927	30.9806	138.9306	0.0	138.931	0.0	343.827
SPR/COMP ($/100BCM)											
93%											
11	47.847	382.2878	430.135	0.6398	0.3147	0.0	0.9545	2.187	3.141	0.0	433.277
21	29.921	33.7040	63.625	2.1451	1.0074	0.0	3.1524	7.528	10.690	0.0	74.305
98%											
11	58.294	419.1873	477.481	2.0674	1.1011	0.0	3.1685	10.429	13.597	0.0	491.078
21	29.921	70.6032	100.524	3.5726	1.7937	0.0	5.3664	15.769	21.136	0.0	121.660
12	50.556	372.4963	423.052	1.8580	1.2275	0.9478	4.0334	0.0	4.033	0.0	427.085
22	38.046	23.9123	61.958	3.3633	1.9202	0.9478	6.2313	5.341	11.572	0.0	73.530
32	24.891	0.0	24.891	6.8523	4.8401	2.3739	14.0663	0.0	14.066	0.0	38.957
SURFACING GRAVEL ($/100CCM)											
11	42.431	372.2900	414.721	1.5294	0.8082	0.0	2.3376	7.459	9.796	1023.64	1448.157
21	13.671	130.8993	144.570	2.2099	1.1249	0.0	3.3348	9.761	13.096	1023.64	1181.306
12	63.066	338.8953	401.961	3.3809	2.3038	1.8655	7.5502	0.0	7.550	1023.64	1433.152
22	29.534	97.5046	127.038	4.0613	2.6206	1.8655	8.5474	2.302	10.849	1023.64	1161.529
WBM ($/100CCM)											
111	259.614	982.5701	1242.184	40.8017	26.4342	27.1618	94.3977	15.343	109.741	1110.92	2462.848

(TABLE 8.5AC CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
211	218.086	589.5625	807.649	41.6308	26.8234	27.1618	95.6160	18.336	113.952	1110.92	2032.524
DBST/G ($/100SM)											
1111	11.994	79.9826	91.977	1.9391	1.2136	0.5040	3.6567	0.0	3.657	45.66	141.295
1121	9.028	36.0746	45.102	3.8722	2.6672	1.3976	7.9370	0.0	7.937	45.66	98.701
DBST/W ($/100SM)											
1111	11.994	79.9826	91.977	1.9391	1.2136	0.5040	3.6567	0.0	3.657	38.13	133.761
1121	9.028	36.0746	45.102	3.8722	2.6672	1.3976	7.9370	0.0	7.937	38.13	91.167

TABLE B.5AD: UNIT COSTS OF THE 1920'S TECHNICAL PACKAGES FOR ALL STAGES AT THE PRICES OF A TYPICAL DEVELOPING COUNTRY.

STAGE/TECHNICAL PACKAGE NUMBER	LABOR			EQUIPMENT					EQUIPMENT		
	SKILLED	UNSKILLED	TOTAL	INT/DEP	MAINT/MISC	FUEL	TOTAL	HORSE	AND HORSE	MATERIALS	TOTAL
SITE PREP ($/HA)											
11	22.101	43.0831	65.184	0.5883	0.2262	0.0	0.8144	2.557	3.372	106.39	174.944
21	4.369	1.0848	5.453	224.8147	118.5598	304.6694	648.0437	0.0	648.044	0.0	653.497
EXC/HAUL ($/100BCM)											
2M											
1-1	2.914	7.4072	10.321	0.4344	0.1652	0.0	0.5996	0.0	0.600	0.0	10.921
1-2	2.927	7.4249	10.352	0.5850	0.2223	0.0	0.8072	0.0	0.807	0.0	11.159
2-1	2.373	6.0665	8.439	0.4301	0.1637	0.0	0.5938	0.327	0.921	0.0	9.360
2-2	2.386	6.0842	8.470	0.5806	0.2207	0.0	0.8014	0.327	1.128	0.0	9.598
3-1	2.347	6.0011	8.348	6.1623	1.8382	12.7137	20.7142	0.0	20.714	0.0	29.062
3-2	2.360	6.0188	8.378	6.3128	1.8953	12.7137	20.9219	0.0	20.922	0.0	29.300
4-3	0.343	0.9025	1.245	0.0382	0.0128	0.0	0.0510	1.478	1.529	0.0	2.774
5-4	0.319	0.7426	1.062	0.0434	0.0199	0.0	0.0633	1.574	1.637	0.0	2.699
6-5	0.753	2.4662	3.220	0.1160	0.0610	0.0	0.1770	2.970	3.147	0.0	6.366
6M											
1-1	2.914	7.6583	10.573	0.4496	0.1709	0.0	0.6206	0.0	0.621	0.0	11.193
1-2	2.927	7.6453	10.573	0.6040	0.2295	0.0	0.8335	0.0	0.834	0.0	11.406
2-1	2.373	6.3176	8.690	0.4453	0.1694	0.0	0.6147	0.327	0.942	0.0	9.632
2-2	2.386	6.3046	8.690	0.5997	0.2280	0.0	0.8277	0.327	1.155	0.0	9.845
3-1	2.347	6.2522	8.599	6.1775	1.8440	12.7137	20.7352	0.0	20.735	0.0	29.334
3-2	2.360	6.2392	8.599	6.3319	1.9025	12.7137	20.9482	0.0	20.948	0.0	29.547
4-3	0.343	0.9888	1.332	0.0415	0.0138	0.0	0.0553	1.651	1.706	0.0	3.038
5-4	0.319	0.7855	1.105	0.0462	0.0213	0.0	0.0675	1.702	1.770	0.0	2.874
6-5	0.753	2.4911	3.244	0.1190	0.0626	0.0	0.1816	3.020	3.202	0.0	6.446
7-6	0.099	0.0	0.099	5.7494	2.9740	6.4077	15.1311	0.0	15.131	0.0	15.230
10-7	0.536	0.3771	0.913	38.9214	22.8454	5.8271	67.5939	0.322	67.916	0.0	68.833
10-8	0.535	0.3806	0.915	50.2294	27.1994	21.8464	99.2753	0.0	99.275	0.0	100.191
10-9	1.423	0.2158	1.639	75.8641	45.3726	45.9814	167.2181	0.0	167.218	0.0	168.857
9M											
1-1	2.914	7.8519	10.766	0.4614	0.1754	0.0	0.6368	0.0	0.637	0.0	11.403
1-2	2.927	7.9153	10.743	0.6187	0.2351	0.0	0.8538	0.0	0.854	0.0	11.596
2-1	2.373	6.5112	8.884	0.4570	0.1739	0.0	0.6309	0.327	0.958	0.0	9.842
2-2	2.386	6.4746	8.860	0.6144	0.2335	0.0	0.8479	0.327	1.175	0.0	10.035
3-1	2.347	6.4458	8.792	6.1892	1.8484	12.7137	20.7514	0.0	20.751	0.0	29.544
3-2	2.360	6.4092	8.769	6.3466	1.9081	12.7137	20.9684	0.0	20.968	0.0	29.737
4-3	0.343	1.0556	1.398	0.0440	0.0145	0.0	0.0586	1.784	1.843	0.0	3.241
5-4	0.319	0.8188	1.138	0.0484	0.0224	0.0	0.0709	1.802	1.873	0.0	3.011
6-5	0.753	2.5107	3.264	0.1214	0.0639	0.0	0.1853	3.059	3.244	0.0	6.508
7-6	0.116	0.0	0.116	6.7228	3.4776	7.4926	17.6930	0.0	17.693	0.0	17.909
10-7	0.536	0.3851	0.921	38.9260	22.8474	5.8271	67.6005	0.339	67.939	0.0	68.961
10-8	0.535	0.3832	0.918	50.4104	27.2692	22.1007	99.7803	0.0	99.780	0.0	100.698
10-9	1.431	0.2158	1.647	76.1573	45.5513	46.2992	168.0078	0.0	168.008	0.0	169.655
60M											
1-1	2.914	11.1389	14.053	0.6605	0.2509	0.0	0.9114	0.0	0.911	0.0	14.965
1-2	2.927	10.6955	13.623	0.8680	0.3296	0.0	1.1976	0.0	1.198	0.0	14.820

(TABLE B.5AD CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
2-1	2.371	9.7982	12.171	0.6562	0.2494	0.0	0.9055	0.327	1.233	0.0	13.401
2-1	2.386	9.3548	11.741	0.8637	0.3281	0.0	1.1918	0.327	1.519	0.0	13.259
3-1	2.347	9.7328	12.079	6.3884	1.9239	12.7137	21.0260	0.0	21.026	0.0	33.105
3-2	2.360	9.2894	11.649	6.5959	2.0026	12.7137	21.3123	0.0	21.312	0.0	32.961
4-3	0.343	2.1850	2.528	0.0869	0.0271	0.0	0.1140	4.043	4.157	0.0	6.685
5-4	0.319	1.3799	1.699	0.0849	0.0406	0.0	0.1255	3.486	3.611	0.0	5.310
6-5	0.753	2.8397	3.593	0.1608	0.0855	0.0	0.2463	3.717	3.963	0.0	7.556
7-6	0.400	0.0	0.400	23.2712	12.0378	25.9361	61.2450	0.0	61.245	0.0	61.645
8-7	0.215	0.5808	0.795	0.5085	0.3156	0.0	0.8240	1.774	2.598	0.0	3.393
9-7	0.408	0.3564	0.765	8.7493	5.0505	10.2558	24.0562	0.555	24.611	0.0	25.375
10-7	0.536	0.5219	1.058	39.0040	22.8826	5.8271	67.7138	0.612	68.326	0.0	69.384
10-8	0.535	0.4277	0.962	53.4866	28.4553	26.4234	108.3652	0.0	108.365	0.0	109.329
10-9	1.564	0.2158	1.780	81.1408	48.5892	51.7026	181.4116	0.0	181.432	0.0	183.212
100M											
1-1	2.914	13.6529	16.567	0.8128	0.3086	0.0	1.1214	0.0	1.121	0.0	17.689
1-2	2.927	12.8982	15.825	1.0587	0.4019	0.0	1.4605	0.0	1.461	0.0	17.286
2-1	2.373	12.3122	14.685	0.8085	0.3071	0.0	1.1156	0.327	1.443	0.0	16.127
2-2	2.386	11.5575	13.943	1.0541	0.4003	0.0	1.4547	0.327	1.782	0.0	15.725
3-1	2.347	12.2468	14.593	6.5407	1.9817	12.7137	21.2361	0.0	21.236	0.0	35.829
3-2	2.360	11.4921	13.852	6.7865	2.0749	12.7137	21.5752	0.0	21.575	0.0	35.427
4-3	0.343	3.0489	3.392	0.1197	0.0366	0.0	0.1564	5.770	5.927	0.0	9.318
5-4	0.319	1.8090	2.128	0.1129	0.0545	0.0	0.1674	4.773	4.940	0.0	7.068
6-5	0.753	3.0908	3.844	0.1909	0.1020	0.0	0.2929	4.220	4.513	0.0	8.357
7-6	0.617	0.0	0.617	35.8954	18.5681	40.0059	94.4695	0.0	94.469	0.0	95.087
8-7	0.215	0.6854	0.900	0.5681	0.3425	0.0	0.9106	1.983	2.894	0.0	3.793
9-7	0.408	0.4611	0.869	8.8096	5.0775	10.2558	24.1429	0.764	24.907	0.0	25.776
10-7	0.536	0.6265	1.163	39.0637	22.9096	5.8271	67.8004	0.821	68.622	0.0	69.785
10-8	0.535	0.4617	0.996	55.8390	29.3623	29.7290	114.9302	0.0	114.930	0.0	115.927
10-9	1.666	0.2158	1.882	84.9518	50.9106	55.8345	191.6969	0.0	191.697	0.0	193.579
165M											
1-1	2.914	17.7129	20.627	1.0588	0.4019	0.0	1.4607	0.0	1.461	0.0	22.088
1-2	2.927	16.4559	19.383	1.3666	0.5186	0.0	1.8852	0.0	1.885	0.0	21.269
2-1	2.373	16.3722	18.745	1.0544	0.4004	0.0	1.4548	0.327	1.782	0.0	20.527
2-2	2.386	15.1152	17.501	1.3622	0.5171	0.0	1.8793	0.327	2.206	0.0	19.707
3-1	2.347	16.3068	18.653	6.7866	2.0749	12.7137	21.5753	0.0	21.575	0.0	40.229
3-2	2.360	15.0498	17.409	7.0944	2.1916	12.7137	21.9998	0.0	22.000	0.0	39.409
4-3	0.343	4.4439	4.787	0.1727	0.0521	0.0	0.2248	8.561	8.786	0.0	13.572
5-4	0.319	2.5029	2.822	0.1580	0.0770	0.0	0.2351	6.855	7.090	0.0	9.912
6-5	0.753	3.4969	4.250	0.2396	0.1286	0.0	0.3683	5.033	5.401	0.0	9.651
7-6	0.971	0.0	0.971	56.4288	29.1897	62.8907	148.5092	0.0	148.509	0.0	149.480
8-7	0.215	0.8541	1.069	0.6644	0.3859	0.0	1.0503	2.320	3.371	0.0	4.439
9-7	0.408	0.6298	1.038	8.9059	5.1209	10.2558	24.2825	1.101	25.384	0.0	26.422
10-7	0.536	0.7953	1.332	39.1599	22.9530	5.8271	67.9401	1.159	69.099	0.0	70.431
10-8	0.535	0.5167	1.051	59.6390	30.8275	35.0687	125.5352	0.0	125.535	0.0	126.587
10-9	1.831	0.2158	2.047	91.1080	54.6622	62.5093	208.2793	0.0	208.279	0.0	210.326
500M											
1-1	2.914	38.9830	41.897	2.3473	0.8905	0.0	3.2378	0.0	3.238	0.0	45.135

(TABLE B.5AD CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR			EQUIPMENT					EQUIPMENT		
	SKILLED	UNSKILLED	TOTAL	INT/DEP	MAINT/MISC	FUEL	TOTAL	HORSE	AND HORSE	MATERIALS	TOTAL
1-2	2.927	35.0943	38.022	2.9796	1.1302	0.0	4.1098	0.0	4.110	0.0	43.131
2-1	2.373	37.6423	40.015	2.3430	0.8890	0.0	3.2319	0.327	3.559	0.0	43.574
2-2	2.386	33.7536	36.139	2.9753	1.1297	0.0	4.1040	0.327	4.431	0.0	40.570
3-1	2.347	37.5769	39.923	8.0752	2.5635	12.7137	23.3524	0.0	23.352	0.0	63.276
3-2	2.360	33.6882	36.048	8.7075	2.8033	12.7137	24.2245	0.0	24.224	0.0	60.272
4-3	0.343	11.7524	12.095	0.4502	0.1332	0.0	0.5834	23.177	23.760	0.0	35.856
5-4	0.319	6.1358	6.455	0.3945	0.1949	0.0	0.5894	17.753	18.343	0.0	24.798
6-5	0.753	5.6251	6.378	0.4948	0.2683	0.0	0.7631	9.288	10.051	0.0	16.429
7-6	2.812	0.0	2.812	163.5067	84.5794	182.2304	430.3162	0.0	430.316	0.0	433.128
8-7	0.215	1.7390	1.953	1.1691	0.6138	0.0	1.7829	4.090	5.873	0.0	7.827
9-7	0.408	1.5147	1.923	9.4106	5.3488	10.2558	25.0151	2.871	27.886	0.0	29.809
10-7	0.536	1.6801	2.216	39.6646	23.1809	5.9271	68.6727	2.929	71.601	0.0	73.818
10-8	0.535	0.8044	1.339	79.5438	38.5022	61.0390	181.0850	0.0	181.085	0.0	182.424
10-9	2.694	0.2158	2.910	123.3546	74.3131	97.4721	295.1394	0.0	295.139	0.0	298.050
800M											
1-1	2.914	58.0287	60.943	3.5011	1.3280	0.0	4.8291	0.0	4.829	0.0	65.772
1-2	2.927	51.7844	54.712	4.4240	1.6779	0.0	6.1019	0.0	6.102	0.0	60.814
2-1	2.373	56.6880	59.061	3.4968	1.3264	0.0	4.8232	0.327	5.150	0.0	64.211
2-2	2.386	50.4437	52.829	4.4197	1.6764	0.0	6.0961	0.327	6.423	0.0	59.253
3-1	2.347	56.6227	58.969	9.2290	3.0010	12.7137	24.9437	0.0	24.944	0.0	83.913
3-2	2.360	50.3783	52.738	10.1519	3.3509	12.7137	26.2166	0.0	26.217	0.0	78.954
4-3	0.343	18.2963	18.639	0.6987	0.2059	0.0	0.9045	36.266	37.171	0.0	55.810
5-4	0.319	9.3888	9.708	0.6062	0.3005	0.0	0.9067	27.513	28.420	0.0	38.128
6-5	0.753	7.5308	8.284	0.7234	0.3934	0.0	1.1167	13.100	14.216	0.0	22.501
7-6	4.460	0.0	4.460	259.3289	134.1469	289.0256	682.5017	0.0	682.502	0.0	686.962
8-7	0.215	2.5316	2.746	1.6212	0.8179	0.0	2.4391	5.675	8.115	0.0	10.861
9-7	0.409	2.3073	2.715	9.8627	5.5529	10.2558	25.6713	4.456	30.128	0.0	32.843
10-7	0.536	2.4728	3.009	40.1168	23.3850	5.8271	69.3289	4.514	73.843	0.0	76.852
10-8	0.535	1.0614	1.596	97.3224	45.3572	88.0215	230.7011	0.0	230.701	0.0	232.297
10-9	3.466	0.2158	3.682	152.1811	91.8798	128.7267	372.7874	0.0	372.787	0.0	376.469
SPR/COMP ($/100BCM)											
93%											
11	0.971	2.4257	3.396	0.0639	0.0268	0.0	0.0907	0.249	0.339	0.0	3.735
21	0.607	0.2139	0.821	0.2133	0.0857	0.0	0.2990	0.855	1.154	0.0	1.975
98%											
11	1.192	2.6598	3.842	0.2162	0.0937	0.0	0.3099	1.185	1.495	0.0	5.337
21	0.607	0.4480	1.055	0.3656	0.1526	0.0	0.5182	1.792	2.310	0.0	3.365
12	1.025	2.3636	3.389	4.1022	2.2354	4.4498	10.7874	0.0	10.787	0.0	14.176
22	0.772	0.1517	0.923	4.2516	2.2943	4.4498	10.9957	0.607	11.603	0.0	12.526
32	0.505	0.0	0.505	16.8117	9.6087	10.4756	36.8960	0.0	36.896	0.0	37.401
SURFACING GRAVEL ($/100CCM)											
11	0.861	2.3622	3.223	0.1592	0.0688	0.0	0.2280	0.848	1.076	274.68	278.978
21	0.277	0.8306	1.108	0.2274	0.0957	0.0	0.3231	1.109	1.432	274.68	277.220
12	1.279	2.1504	3.430	8.0494	4.3902	8.7584	21.1980	0.0	21.198	274.68	299.307
22	0.599	0.6187	1.218	8.1176	4.4172	8.7584	21.2931	0.262	21.555	274.68	297.452
WBM ($/100CCM)											
111	5.266	6.2346	11.501	80.9636	42.4625	32.9533	156.3793	1.744	158.123	417.30	586.927

(TABLE B.5AD CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
211	4.424	3.7409	8.165	81.0472	42.4956	32.9533	156.4961	2.084	158.590	417.30	584.048
DBST/G ($/100SM)											
1111	0.243	0.5075	0.751	4.4631	2.3660	2.3662	9.1953	0.0	9.195	107.55	117.494
1121	0.183	0.2289	0.412	9.2788	5.2755	6.5617	21.1160	0.0	21.116	107.55	129.076
DBST/W ($/100SM)											
1111	0.243	0.5075	0.751	4.4631	2.3660	2.3662	9.1953	0.0	9.195	94.95	[illegible]
1121	0.183	0.2289	0.412	9.2788	5.2755	6.5617	21.1160	0.0	21.116	84.95	106.474

TABLE D.5BA: UNIT COSTS OF THE 1950'S TECHNICAL PACKAGES FOR ALL STAGES AT THE PRICES OF 1930.

STAGE/TECHNICAL PACKAGE NUMBER	LABOR			EQUIPMENT				HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
	SKILLED	UNSKILLED	TOTAL	INT/DEP	MAINT/MISC	FUEL	TOTAL				
SITE PREP ($/HA)											
11	135.063	564.8074	699.870	2.4323	1.1000	2.4221	5.9543	0.0	5.954	75.40	781.229
21	17.130	9.9799	27.110	9.4515	6.6636	7.2012	23.3162	0.0	23.316	0.0	50.426
31	11.694	9.9799	21.674	5.6257	3.9453	4.5451	14.1161	0.0	14.116	0.0	35.790
EXC/HAUL ($/100BCM)											
2M											
11-0	0.373	0.0	0.373	0.0955	0.0755	0.5550	0.7264	0.0	0.726	0.0	1.099
6M											
1-1	2.051	0.0	2.051	2.5516	1.8008	1.0017	5.3544	0.0	5.354	0.0	7.406
1-2	1.773	0.0	1.773	3.4537	2.3583	1.4825	7.2945	0.0	7.295	0.0	9.067
1-3	1.733	0.0	1.733	2.5156	1.7433	1.1033	5.3622	0.0	5.362	0.0	7.096
1-4	1.645	0.0	1.645	2.7699	1.9054	1.0414	5.7167	0.0	5.717	0.0	7.362
2-1	2.113	0.0	2.113	3.3555	2.6909	1.1439	7.1903	0.0	7.190	0.0	9.304
2-2	1.835	0.0	1.835	4.2913	3.2699	1.6434	9.2046	0.0	9.205	0.0	11.039
2-3	1.796	0.0	1.796	3.3254	2.6367	1.2534	7.2154	0.0	7.215	0.0	9.011
2-4	1.707	0.0	1.707	3.5916	2.8064	1.1915	7.5894	0.0	7.589	0.0	9.296
3-1	1.710	0.0	1.710	2.5010	1.9927	0.9963	5.4900	0.0	5.490	0.0	7.200
3-2	1.432	0.0	1.432	3.2167	2.4322	1.3748	7.0238	0.0	7.024	0.0	8.456
3-3	1.393	0.0	1.393	2.4311	1.9171	1.0551	5.4033	0.0	5.403	0.0	6.796
3-4	1.304	0.0	1.304	2.6209	2.0373	0.9932	5.6511	0.0	5.651	0.0	6.955
5-5	1.413	0.0	1.413	1.1401	0.8046	0.8157	2.7604	0.0	2.760	0.0	4.174
6-6	1.321	0.0	1.321	1.3997	0.9878	0.8300	3.2176	0.0	3.218	0.0	4.539
7-7	0.618	0.0	0.618	0.8752	0.6177	0.5521	2.0450	0.0	2.045	0.0	2.663
8-8	0.412	0.0	0.412	0.2019	0.1425	0.1381	0.4824	0.0	0.482	0.0	0.895
9-9	0.224	0.0	0.224	0.1436	0.1013	0.1097	0.3546	0.0	0.355	0.0	0.579
10-10	0.183	0.0	0.183	0.1580	0.1115	0.1277	0.3972	0.0	0.397	0.0	0.580
9M											
1-1	2.064	0.0	2.064	2.5609	1.8073	1.0073	5.3755	0.0	5.375	0.0	7.439
1-2	1.778	0.0	1.778	3.4641	2.3652	1.4805	7.3178	0.0	7.318	0.0	9.096
1-3	1.744	0.0	1.744	2.5251	1.7497	1.1105	5.3852	0.0	5.385	0.0	7.129
1-4	1.651	0.0	1.651	2.7774	1.9103	1.0454	5.7331	0.0	5.733	0.0	7.384
2-1	2.126	0.0	2.126	3.3646	2.6973	1.1496	7.2115	0.0	7.211	0.0	9.337
2-2	1.841	0.0	1.841	4.3017	3.2768	1.6495	9.2280	0.0	9.228	0.0	11.068
2-3	1.806	0.0	1.806	3.3349	2.6430	1.2606	7.2385	0.0	7.238	0.0	9.044
2-4	1.713	0.0	1.713	3.5990	2.8113	1.1955	7.6058	0.0	7.606	0.0	9.319
3-1	1.723	0.0	1.723	2.5101	1.9991	1.0019	5.5111	0.0	5.511	0.0	7.234
3-2	1.438	0.0	1.438	3.2272	2.4391	1.3809	7.0472	0.0	7.047	0.0	8.485
3-3	1.403	0.0	1.403	2.4406	1.9234	1.0623	5.4263	0.0	5.426	0.0	6.829
3-4	1.310	0.0	1.310	2.6280	2.0422	0.9972	5.6675	0.0	5.667	0.0	6.977
5-5	1.430	0.0	1.430	1.1527	0.8135	0.8247	2.7909	0.0	2.791	0.0	4.220
6-6	1.333	0.0	1.333	1.4117	0.9963	0.8371	3.2451	0.0	3.245	0.0	4.578
7-7	0.624	0.0	0.624	0.8766	0.6186	0.5518	2.0471	0.0	2.047	0.0	2.671
8-8	0.542	0.0	0.542	0.2656	0.1875	0.1816	0.6347	0.0	0.635	0.0	1.177
9-9	0.295	0.0	0.295	0.1885	0.1330	0.1440	0.4655	0.0	0.466	0.0	0.760
10-10	0.236	0.0	0.236	0.2037	0.1437	0.1647	0.5121	0.0	0.512	0.0	0.748
60M											

(TABLE B.5MA CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
1-1	2.284	0.0	2.284	2.7184	1.9184	1.1055	5.7424	0.0	5.742	0.0	8.026
1-2	1.881	0.0	1.881	3.6494	2.4880	1.5958	7.7331	0.0	7.733	0.0	9.614
1-3	1.926	0.0	1.926	2.6913	1.8610	1.2375	5.7897	0.0	5.790	0.0	7.715
1-4	1.753	0.0	1.753	2.9100	1.9982	1.1169	6.0251	0.0	6.025	0.0	7.778
2-1	2.346	0.0	2.346	3.5221	2.8084	1.2478	7.5784	0.0	7.578	0.0	9.924
2-2	1.943	0.0	1.943	4.4870	3.3995	1.7567	9.6433	0.0	9.643	0.0	11.586
2-3	1.988	0.0	1.988	3.5011	2.7543	1.3875	7.6429	0.0	7.643	0.0	9.631
2-4	1.815	0.0	1.815	3.7316	2.8991	1.2670	7.8978	0.0	7.898	0.0	9.713
3-1	1.943	0.0	1.943	2.6676	2.1103	1.1001	5.8780	0.0	5.878	0.0	7.821
3-2	1.540	0.0	1.540	3.4125	2.5619	1.4881	7.4625	0.0	7.462	0.0	9.003
3-3	1.585	0.0	1.585	2.6066	2.0347	1.1892	5.8308	0.0	5.831	0.0	7.416
3-4	1.412	0.0	1.412	2.7606	2.1301	1.0687	5.9595	0.0	5.959	0.0	7.372
4-2	0.792	0.0	0.792	1.5594	1.0557	0.8138	3.4289	0.0	3.429	0.0	4.221
4-4	0.664	0.0	0.664	1.0995	0.7513	0.5250	2.3761	0.0	2.376	0.0	3.040
5-5	1.701	0.0	1.701	1.3718	0.9681	0.9815	3.3214	0.0	3.321	0.0	5.023
6-6	1.525	0.0	1.525	1.6156	1.1401	0.9580	3.7137	0.0	3.714	0.0	5.239
7-7	0.725	0.0	0.725	1.0185	0.7187	0.6410	2.3782	0.0	2.378	0.0	3.103
8-8	2.753	0.0	2.753	1.3490	0.9520	0.9225	3.2235	0.0	3.223	0.0	5.977
9-9	1.499	0.0	1.499	0.9588	0.6766	0.7323	2.3676	0.0	2.368	0.0	3.866
10-10	1.146	0.0	1.146	0.9895	0.6983	0.8002	2.4881	0.0	2.488	0.0	3.635
100M											
1-1	2.453	0.0	2.453	2.8397	2.0040	1.1811	6.0247	0.0	6.025	0.0	8.478
1-2	1.960	0.0	1.960	3.7931	2.5831	1.6789	8.0551	0.0	8.055	0.0	10.015
1-3	2.064	0.0	2.064	2.8175	1.9455	1.3339	6.0969	0.0	6.097	0.0	8.161
1-4	1.832	0.0	1.832	3.0128	2.0663	1.1724	6.2515	0.0	6.251	0.0	8.084
2-1	2.515	0.0	2.515	3.6433	2.8940	1.3234	7.8607	0.0	7.861	0.0	10.376
2-2	2.022	0.0	2.022	4.6307	3.4947	1.8399	9.9652	0.0	9.965	0.0	11.988
2-3	2.126	0.0	2.126	3.6273	2.8388	1.4839	7.9501	0.0	7.950	0.0	10.076
2-4	1.895	0.0	1.895	3.8345	2.9673	1.3225	8.1242	0.0	8.124	0.0	10.019
3-1	2.112	0.0	2.112	2.7888	2.1958	1.1757	6.1604	0.0	6.160	0.0	8.273
3-2	1.620	0.0	1.620	3.5561	2.6570	1.5713	7.7844	0.0	7.784	0.0	9.404
3-3	1.723	0.0	1.723	2.7330	2.1192	1.2857	6.1379	0.0	6.138	0.0	7.861
3-4	1.492	0.0	1.492	2.8635	2.1982	1.1242	6.1858	0.0	6.186	0.0	7.678
4-2	0.871	0.0	0.871	1.7031	1.1508	0.8970	3.7509	0.0	3.751	0.0	4.622
4-4	0.744	0.0	0.744	1.2027	0.8194	0.5804	2.6025	0.0	2.603	0.0	3.346
5-5	1.911	0.0	1.911	1.5444	1.0899	1.1049	3.7394	0.0	3.739	0.0	5.650
6-6	1.674	0.0	1.674	1.7729	1.2512	1.0513	4.0754	0.0	4.075	0.0	5.749
7-7	0.714	0.0	0.714	1.0508	0.7416	0.6476	2.4399	0.0	2.440	0.0	3.154
8-8	4.445	0.0	4.445	2.1781	1.5371	1.4894	5.2045	0.0	5.204	0.0	9.650
9-9	2.419	0.0	2.419	1.5479	1.0923	1.1822	3.8224	0.0	3.822	0.0	6.242
10-10	1.837	0.0	1.837	1.5857	1.1190	1.2823	3.9870	0.0	3.987	0.0	5.824
165M											
1-1	2.726	0.0	2.726	3.0351	2.1419	1.3030	6.4800	0.0	6.480	0.0	9.206
1-2	2.087	0.0	2.087	4.0221	2.7348	1.8115	8.5684	0.0	8.568	0.0	10.655
1-3	2.288	0.0	2.288	3.0226	2.0828	1.4905	6.5960	0.0	6.596	0.0	8.884
1-4	1.959	0.0	1.959	3.1769	2.1750	1.2608	6.6127	0.0	6.613	0.0	8.572
2-1	2.788	0.0	2.788	3.8386	3.0319	1.4453	8.3160	0.0	8.316	0.0	11.104

(TABLE B.58A CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
2-2	2.149	0.0	2.149	4.8597	3.6464	1.9724	10.4785	0.0	10.479	0.0	12.628
2-3	2.350	0.0	2.350	3.8325	2.9762	1.6406	8.4493	0.0	8.449	0.0	10.800
2-4	2.021	0.0	2.021	3.9986	3.0760	1.4109	8.4854	0.0	8.485	0.0	10.507
3-1	2.385	0.0	2.385	2.9843	2.3338	1.2976	6.6156	0.0	6.616	0.0	9.001
3-2	1.746	0.0	1.746	3.7851	2.8087	1.7039	8.2977	0.0	8.298	0.0	10.044
3-3	1.948	0.0	1.948	2.9382	2.2566	1.4423	6.6371	0.0	6.637	0.0	8.585
3-4	1.618	0.0	1.618	3.0275	2.3069	1.2126	6.5471	0.0	6.547	0.0	8.166
4-2	0.998	0.0	0.998	1.9321	1.3025	1.0295	4.2641	0.0	4.264	0.0	5.262
4-4	0.870	0.0	0.870	1.3668	0.9281	0.6689	2.9638	0.0	2.964	0.0	3.834
5-5	2.245	0.0	2.245	1.8116	1.2786	1.2963	4.3867	0.0	4.387	0.0	6.631
6-6	1.699	0.0	1.699	1.8891	1.3332	1.0969	4.3192	0.0	4.319	0.0	6.018
7-7	0.824	0.0	0.824	1.2135	0.8564	0.7478	2.8177	0.0	2.818	0.0	3.642
8-8	7.173	0.0	7.173	3.5147	2.4803	2.4034	8.3983	0.0	8.398	0.0	15.572
9-9	3.916	0.0	3.916	2.5051	1.7679	1.9133	6.1863	0.0	6.186	0.0	10.102
10-10	2.954	0.0	2.954	2.5494	1.7991	2.0616	6.4101	0.0	6.410	0.0	9.364
500M											
1-1	2.804	0.0	2.804	3.0912	2.1815	1.3379	6.6106	0.0	6.611	0.0	9.415
1-2	2.124	0.0	2.124	4.0887	2.7790	1.8501	8.7177	0.0	8.718	0.0	10.841
1-3	2.354	0.0	2.354	3.0826	2.1230	1.5363	6.7419	0.0	6.742	0.0	9.096
1-4	1.996	0.0	1.996	3.2244	2.2065	1.2865	6.7174	0.0	6.717	0.0	8.713
2-1	2.866	0.0	2.866	3.8949	3.0715	1.4802	8.4466	0.0	8.447	0.0	11.313
2-2	2.186	0.0	2.186	4.9263	3.6905	2.0110	10.6278	0.0	10.628	0.0	12.814
2-3	2.416	0.0	2.416	3.8924	3.0163	1.6864	8.5952	0.0	8.595	0.0	11.011
2-4	2.058	0.0	2.058	4.0461	3.1074	1.4365	8.5901	0.0	8.590	0.0	10.648
3-1	2.463	0.0	2.463	3.0403	2.3734	1.3326	6.7462	0.0	6.746	0.0	9.209
3-2	1.783	0.0	1.783	3.8518	2.8529	1.7424	8.4470	0.0	8.447	0.0	10.230
3-3	2.013	0.0	2.013	2.9981	2.2968	1.4881	6.7830	0.0	6.783	0.0	8.796
3-4	1.655	0.0	1.655	3.0751	2.3384	1.2383	6.6517	0.0	6.652	0.0	8.307
4-2	1.035	0.0	1.035	1.9987	1.3467	1.0681	4.4135	0.0	4.413	0.0	5.448
4-4	0.907	0.0	0.907	1.4143	0.9596	0.6945	3.0684	0.0	3.068	0.0	3.975
5-5	3.338	0.0	3.338	2.9032	2.0488	2.0877	7.0397	0.0	7.040	0.0	10.378
6-6	2.811	0.0	2.811	3.1259	2.2059	1.8150	7.1467	0.0	7.147	0.0	9.958
7-7	1.405	0.0	1.405	2.0696	1.4605	1.2754	4.8055	0.0	4.806	0.0	6.211
8-8	21.446	0.0	21.446	10.5079	7.4155	7.1854	25.1088	0.0	25.109	0.0	46.555
9-9	11.708	0.0	11.708	7.4904	5.2860	5.7208	18.4972	0.0	18.497	0.0	30.206
10-10	8.812	0.0	8.812	7.6064	5.3679	6.1511	19.1254	0.0	19.125	0.0	27.938
800M											
1-1	3.168	0.0	3.168	3.3516	2.3654	1.5004	7.2176	0.0	7.218	0.0	10.385
1-2	2.295	0.0	2.295	4.3989	2.9845	2.0296	9.4130	0.0	9.413	0.0	11.708
1-3	2.653	0.0	2.653	3.3561	2.3061	1.7452	7.4075	0.0	7.407	0.0	10.061
1-4	2.166	0.0	2.166	3.4450	2.3526	1.4054	7.2030	0.0	7.203	0.0	9.369
2-1	3.230	0.0	3.230	4.1555	3.2554	1.6427	9.0536	0.0	9.054	0.0	12.283
2-2	2.357	0.0	2.357	5.2365	3.8960	2.1906	11.3231	0.0	11.323	0.0	13.680
2-3	2.715	0.0	2.715	4.1659	3.1995	1.8953	9.2607	0.0	9.261	0.0	11.976
2-4	2.228	0.0	2.228	4.2667	3.2535	1.5555	9.0757	0.0	9.076	0.0	11.304
3-1	2.827	0.0	2.827	3.3009	2.5573	1.4950	7.3532	0.0	7.353	0.0	10.180
3-2	1.954	0.0	1.954	4.1620	3.0584	1.9220	9.1423	0.0	9.142	0.0	11.097

(TABLE B.5AA CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
3-3	2.312	0.0	2.312	3.2716	2.4799	1.6970	7.4486	0.0	7.449	0.0	9.761
3-4	1.826	0.0	1.826	3.2956	2.4845	1.3572	7.1373	0.0	7.137	0.0	8.963
4-2	1.206	0.0	1.206	2.3089	1.5522	1.2477	5.1087	0.0	5.109	0.0	6.315
4-4	1.077	0.0	1.077	1.6345	1.1057	0.8134	3.5540	0.0	3.554	0.0	4.631
5-5	4.466	0.0	4.466	3.9559	2.7917	2.8478	9.5955	0.0	9.596	0.0	14.062
6-6	3.571	0.0	3.571	4.0822	2.8808	2.3423	9.3052	0.0	9.305	0.0	12.876
7-7	1.808	0.0	1.808	2.7304	1.9269	1.6628	6.3201	0.0	6.320	0.0	8.128
8-8	34.223	0.0	34.223	16.7675	11.8332	11.4662	40.0673	0.0	40.067	0.0	74.290
9-9	18.684	0.0	18.684	11.9528	8.4352	9.1290	29.5170	0.0	29.517	0.0	48.201
10-10	14.061	0.0	14.061	12.1369	8.5650	9.8148	30.5167	0.0	30.517	0.0	44.578
SPR/COMP ($/100BCM) 98%											
11	1.390	0.0	1.390	0.7160	0.5125	0.4659	1.6944	0.0	1.694	0.0	3.085
12	0.988	0.0	0.988	0.6014	0.4317	0.3928	1.4259	0.0	1.426	0.0	2.413
13	1.021	0.0	1.021	0.4174	0.3342	0.3257	1.0774	0.0	1.077	0.0	2.098
14	0.897	0.0	0.897	0.4309	0.3346	0.2917	1.0573	0.0	1.057	0.0	1.954
21	1.191	0.0	1.191	0.7623	0.5452	0.5391	1.8466	0.0	1.847	0.0	3.038
22	0.788	0.0	0.788	0.6477	0.4644	0.4660	1.5781	0.0	1.578	0.0	2.367
23	0.822	0.0	0.822	0.4638	0.3669	0.3990	1.2297	0.0	1.230	0.0	2.051
24	0.698	0.0	0.698	0.4773	0.3673	0.3650	1.2095	0.0	1.210	0.0	1.907
31	1.046	0.0	1.046	0.5413	0.3835	0.4847	1.4095	0.0	1.410	0.0	2.456
32	0.643	0.0	0.643	0.4268	0.3026	0.4116	1.1410	0.0	1.141	0.0	1.784
33	0.677	0.0	0.677	0.2428	0.2052	0.3446	0.7926	0.0	0.793	0.0	1.469
34	0.552	0.0	0.552	0.2563	0.2056	0.3106	0.7725	0.0	0.772	0.0	1.325
41	0.982	0.0	0.982	0.5439	0.4010	0.3806	1.3255	0.0	1.326	0.0	2.307
42	0.579	0.0	0.579	0.4294	0.3202	0.3075	1.0570	0.0	1.057	0.0	1.636
43	0.612	0.0	0.612	0.2454	0.2227	0.2405	0.7086	0.0	0.709	0.0	1.321
44	0.488	0.0	0.488	0.2589	0.2231	0.2064	0.6885	0.0	0.688	0.0	1.176
SURFACING GRAVEL ($/100CCM)											
11	1.207	0.0	1.207	0.4988	0.4306	0.3342	1.2636	0.0	1.264	536.54	539.012
12	0.889	0.0	0.889	0.4246	0.3388	0.2865	1.0500	0.0	1.050	536.54	538.480
21	1.119	0.0	1.119	0.6044	0.5051	0.4495	1.5590	0.0	1.559	536.54	539.219
22	0.800	0.0	0.800	0.5302	0.4134	0.4018	1.3454	0.0	1.345	536.54	538.687
31	0.945	0.0	0.945	0.3645	0.3304	0.3722	1.0671	0.0	1.067	536.54	538.553
32	0.626	0.0	0.626	0.2904	0.2386	0.3245	0.8535	0.0	0.853	536.54	538.021
41	0.897	0.0	0.897	0.3748	0.3531	0.2821	1.0100	0.0	1.010	536.54	538.448
42	0.578	0.0	0.578	0.3007	0.2613	0.2344	0.7964	0.0	0.796	536.54	537.916
51	1.346	0.1751	1.521	0.9398	0.7219	0.6351	2.2968	0.0	2.297	536.54	540.359
52	1.027	0.1751	1.202	0.8657	0.6301	0.5874	2.0832	0.0	2.083	536.54	539.826
WBR ($/100CCM)											
111	9.563	1.3345	10.897	4.5840	4.0324	4.3430	12.9595	0.0	12.959	640.15	664.005
112	7.400	1.1083	8.508	4.2293	3.5016	3.7509	11.4818	0.0	11.482	640.15	660.138
211	9.374	1.3345	10.709	4.6350	4.0684	4.4193	13.1227	0.0	13.123	640.15	663.979
212	7.211	1.1083	8.320	4.2803	3.5376	3.8272	11.6451	0.0	11.645	640.15	660.113
311	9.227	1.3345	10.561	4.4134	3.9063	4.3626	12.6824	0.0	12.682	640.15	663.392
312	7.064	1.1083	8.172	4.0587	3.3755	3.7705	11.2048	0.0	11.205	640.15	659.525
411	9.162	1.3345	10.497	4.4154	3.9231	4.2594	12.5979	0.0	12.598	640.15	663.243

(TABLE B.5BA CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
412	6.999	1.1083	8.108	4.0607	3.3923	3.6673	11.1203	0.0	11.120	640.15	659.376
511	9.631	1.5096	11.140	5.0104	4.3122	4.6310	13.9536	0.0	13.954	640.15	665.242
512	7.468	1.2834	8.751	4.6557	3.7814	4.0389	12.4760	0.0	12.476	640.15	661.375
DBST/G ($/100SF)											
1111	0.198	0.0662	0.264	0.1434	0.1067	0.2341	0.4842	0.0	0.484	13.69	14.437
1112	0.175	0.0662	0.241	0.1466	0.1086	0.2133	0.4686	0.0	0.469	13.69	14.399
1121	0.201	0.0884	0.290	0.1134	0.0890	0.2068	0.4092	0.0	0.409	13.69	14.388
1122	0.178	0.0884	0.267	0.1166	0.0910	0.1860	0.3936	0.0	0.394	13.69	14.350
2111	0.198	0.0614	0.259	0.1418	0.1062	0.2337	0.4816	0.0	0.482	13.69	14.430
2112	0.175	0.0614	0.236	0.1450	0.1081	0.2129	0.4660	0.0	0.466	13.69	14.391
2121	0.201	0.0842	0.286	0.1118	0.0885	0.2063	0.4067	0.0	0.407	13.69	14.381
2122	0.178	0.0842	0.263	0.1150	0.0905	0.1856	0.3911	0.0	0.391	13.69	14.343
DDST/W ($/100SF)											
1111	0.198	0.0662	0.264	0.1434	0.1067	0.2341	0.4842	0.0	0.484	12.18	12.930
1112	0.175	0.0662	0.241	0.1466	0.1086	0.2133	0.4686	0.0	0.469	12.18	12.892
1121	0.201	0.0884	0.290	0.1134	0.0890	0.2068	0.4092	0.0	0.409	12.18	12.881
1122	0.178	0.0884	0.267	0.1166	0.0910	0.1860	0.3936	0.0	0.394	12.18	12.843
2111	0.198	0.0614	0.259	0.1418	0.1062	0.2337	0.4816	0.0	0.482	12.18	12.923
2112	0.175	0.0614	0.236	0.1450	0.1081	0.2129	0.4660	0.0	0.466	12.18	12.884
2121	0.201	0.0842	0.286	0.1118	0.0885	0.2063	0.4067	0.0	0.407	12.18	12.874
2122	0.178	0.0842	0.263	0.1150	0.0905	0.1856	0.3911	0.0	0.391	12.18	12.836

TABLE B.5BB: UNIT COSTS OF THE 1950'S TECHNICAL PACKAGES FOR ALL STAGES AT THE PRICES OF 1956.

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
SITE PREP ($/HA)											
11	486.532	2897.7073	3384.239	7.2087	3.2781	3.1212	13.6080	0.0	13.608	93.94	3491.789
21	61.707	51.2011	112.908	27.7785	19.8579	11.8701	59.5064	0.0	59.506	0.0	172.415
31	42.125	51.2011	93.327	16.5355	11.7571	7.4920	35.7850	0.0	35.785	0.0	129.112
EXC/HAUL ($/100BCM)											
2M											
11-0	1.343	0.0	1.343	0.2826	0.2250	0.7151	1.2227	0.0	1.223	0.0	2.566
6M											
1-1	7.389	0.0	7.389	7.4596	5.3666	1.6511	14.5176	0.0	14.518	0.0	21.906
1-2	6.385	0.0	6.385	10.1504	7.0280	2.4437	19.6220	0.0	19.622	0.0	26.007
1-3	6.244	0.0	6.244	7.3933	5.1952	1.8186	14.4071	0.0	14.407	0.0	20.651
1-4	5.925	0.0	5.925	8.1407	5.6782	1.7166	15.5355	0.0	15.536	0.0	21.461
2-1	7.613	0.0	7.613	9.8464	8.0190	1.8856	19.7510	0.0	19.751	0.0	27.364
2-2	6.609	0.0	6.609	12.5967	9.7444	2.7090	25.0501	0.0	25.050	0.0	31.659
2-3	6.468	0.0	6.468	9.7579	7.8574	2.0660	19.6813	0.0	19.681	0.0	26.150
2-4	6.149	0.0	6.149	10.5401	8.3631	1.9640	20.8672	0.0	20.867	0.0	27.016
3-1	6.161	0.0	6.161	7.3395	5.9385	1.6422	14.9202	0.0	14.920	0.0	21.082
3-2	5.158	0.0	5.158	9.4431	7.2482	2.2662	18.9575	0.0	18.958	0.0	24.116
3-3	5.017	0.0	5.017	7.1341	5.7130	1.7391	14.5862	0.0	14.586	0.0	19.603
3-4	4.698	0.0	4.698	7.6909	6.0713	1.6372	15.3993	0.0	15.399	0.0	20.097
5-5	5.092	0.0	5.092	3.3507	2.3977	1.3446	7.0930	0.0	7.093	0.0	12.185
6-6	4.760	0.0	4.760	4.1138	2.9437	1.3682	8.4257	0.0	8.426	0.0	13.186
7-7	2.227	0.0	2.227	2.5723	1.8407	0.9101	5.3231	0.0	5.323	0.0	7.550
8-8	1.484	0.0	1.484	0.5934	0.4246	0.2276	1.2456	0.0	1.246	0.0	2.730
9-9	0.809	0.0	0.809	0.4220	0.3020	0.1808	0.9048	0.0	0.905	0.0	1.713
10-10	0.659	0.0	0.659	0.4643	0.3322	0.2106	1.0071	0.0	1.007	0.0	1.666
9M											
1-1	7.434	0.0	7.434	7.5265	5.3857	1.6604	14.5726	0.0	14.573	0.0	22.007
1-2	6.406	0.0	6.406	10.1809	7.0485	2.4536	19.6831	0.0	19.683	0.0	26.089
1-3	6.282	0.0	6.282	7.4211	5.2141	1.8305	14.4657	0.0	14.466	0.0	20.747
1-4	5.946	0.0	5.946	8.1626	5.6929	1.7232	15.5787	0.0	15.579	0.0	21.525
2-1	7.658	0.0	7.658	9.8731	8.0381	1.8949	19.8061	0.0	19.806	0.0	27.464
2-2	6.630	0.0	6.630	12.6273	9.7650	2.7189	25.1112	0.0	25.111	0.0	31.741
2-3	6.506	0.0	6.506	9.7857	7.8763	2.0779	19.7399	0.0	19.740	0.0	26.246
2-4	6.170	0.0	6.170	10.5620	8.3778	1.9706	20.9105	0.0	20.910	0.0	27.080
3-1	6.207	0.0	6.207	7.3662	5.9576	1.6515	14.9752	0.0	14.975	0.0	21.182
3-2	5.179	0.0	5.179	9.4737	7.2687	2.2762	19.0186	0.0	19.019	0.0	24.197
3-3	5.054	0.0	5.054	7.1619	5.7319	1.7511	14.6449	0.0	14.645	0.0	19.699
3-4	4.719	0.0	4.719	7.7128	6.0860	1.6438	15.4425	0.0	15.443	0.0	20.161
5-5	5.150	0.0	5.150	3.3877	2.4241	1.3595	7.1713	0.0	7.171	0.0	12.321
6-6	4.801	0.0	4.801	4.1491	2.9690	1.3798	8.4979	0.0	8.498	0.0	13.299
7-7	2.247	0.0	2.247	2.5764	1.8436	0.9096	5.3296	0.0	5.330	0.0	7.577
8-8	1.953	0.0	1.953	0.7807	0.5586	0.2994	1.6387	0.0	1.639	0.0	3.592
9-9	1.061	0.0	1.061	0.5540	0.3964	0.2373	1.1878	0.0	1.188	0.0	2.249
10-10	0.850	0.0	0.850	0.5986	0.4283	0.2715	1.2984	0.0	1.298	0.0	2.148
60M											

(TABLE B.5BB CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR: SKILLED	LABOR: UNSKILLED	LABOR: TOTAL	EQUIPMENT: INT/DEP	EQUIPMENT: MAINT/MISC	EQUIPMENT: FUEL	EQUIPMENT: TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
1-1	8.226	0.0	8.226	7.9854	5.7170	1.8223	15.5287	0.0	15.529	0.0	23.755
1-2	6.775	0.0	6.775	10.7255	7.4143	2.6304	20.7702	0.0	20.770	0.0	27.545
1-3	6.937	0.0	6.937	7.9096	5.5458	2.0398	15.4951	0.0	15.495	0.0	22.432
1-4	6.315	0.0	6.315	8.5525	5.9547	1.8411	16.3482	0.0	16.348	0.0	22.663
2-1	8.450	0.0	8.450	10.3360	8.3694	2.0568	20.7622	0.0	20.762	0.0	29.212
2-2	6.999	0.0	6.999	13.1719	10.1308	2.8957	26.1983	0.0	26.198	0.0	33.197
2-3	7.161	0.0	7.161	10.2742	8.2080	2.2871	20.7693	0.0	20.769	0.0	27.930
2-4	6.539	0.0	6.539	10.9518	8.6397	2.0885	21.6800	0.0	21.680	0.0	28.219
3-1	6.999	0.0	6.999	7.8291	6.2888	1.8134	15.9313	0.0	15.931	0.0	22.930
3-2	5.548	0.0	5.548	10.0183	7.6345	2.4530	20.1058	0.0	20.106	0.0	25.654
3-3	5.710	0.0	5.710	7.6504	6.0636	1.9603	15.6743	0.0	15.674	0.0	21.384
3-4	5.088	0.0	5.088	8.1026	6.3478	1.7616	16.2120	0.0	16.212	0.0	21.300
4-2	2.853	0.0	2.853	4.5831	3.1460	1.3414	9.0705	0.0	9.070	0.0	11.923
4-4	2.392	0.0	2.392	3.2726	2.2389	0.8653	6.3368	0.0	6.337	0.0	8.729
5-5	6.128	0.0	6.128	4.0317	2.8849	1.6179	8.5345	0.0	8.534	0.0	14.663
6-6	5.494	0.0	5.494	4.7482	3.3977	1.5792	9.7250	0.0	9.725	0.0	15.219
7-7	2.612	0.0	2.612	2.9932	2.1419	1.0566	6.1918	0.0	6.192	0.0	8.804
8-8	9.918	0.0	9.918	3.9647	2.8370	1.5206	8.3224	0.0	8.322	0.0	18.240
9-9	5.399	0.0	5.399	2.8178	2.0163	1.2070	6.0411	0.0	6.041	0.0	11.440
10-10	4.130	0.0	4.130	2.9083	2.0811	1.3190	6.3084	0.0	6.308	0.0	10.438
100M											
1-1	8.836	0.0	8.836	8.3457	5.9719	1.9469	16.2646	0.0	16.265	0.0	25.100
1-2	7.061	0.0	7.061	11.1478	7.6979	2.7675	21.6131	0.0	21.613	0.0	28.674
1-3	7.434	0.0	7.434	8.2806	5.7977	2.1987	16.2770	0.0	16.277	0.0	23.711
1-4	6.601	0.0	6.601	8.8547	6.1577	1.9325	16.9448	0.0	16.945	0.0	23.546
2-1	9.060	0.0	9.060	10.6923	8.6243	2.1814	21.4980	0.0	21.498	0.0	30.558
2-2	7.285	0.0	7.285	13.5941	10.4144	3.0328	27.0412	0.0	27.041	0.0	34.326
2-3	7.658	0.0	7.658	10.6452	8.4599	2.4461	21.5512	0.0	21.551	0.0	29.209
2-4	6.825	0.0	6.825	11.2540	8.8426	2.1799	22.2766	0.0	22.277	0.0	29.101
3-1	7.609	0.0	7.609	8.1854	6.5438	1.9380	16.6671	0.0	16.667	0.0	24.276
3-2	5.834	0.0	5.834	10.4405	7.9181	2.5900	20.9486	0.0	20.949	0.0	26.783
3-3	6.207	0.0	6.207	8.0214	6.3155	2.1192	16.4561	0.0	16.456	0.0	22.663
3-4	5.374	0.0	5.374	8.4048	6.5508	1.8530	16.8086	0.0	16.809	0.0	22.182
4-2	3.139	0.0	3.139	5.0053	3.4296	1.4785	9.9133	0.0	9.913	0.0	13.052
4-4	2.679	0.0	2.679	3.5348	2.4419	0.9567	6.9334	0.0	6.933	0.0	9.612
5-5	6.883	0.0	6.883	4.5391	3.2480	1.8216	9.6087	0.0	9.609	0.0	16.492
6-6	6.029	0.0	6.029	5.2106	3.7285	1.7329	10.6720	0.0	10.672	0.0	16.701
7-7	2.571	0.0	2.571	3.0883	2.2099	1.0674	6.3656	0.0	6.366	0.0	8.936
8-8	16.013	0.0	16.013	6.4013	4.5805	2.4550	13.4368	0.0	13.437	0.0	29.450
9-9	8.716	0.0	8.716	4.5491	3.2552	1.9486	9.7530	0.0	9.753	0.0	18.469
10-10	6.618	0.0	6.618	4.6602	3.3347	2.1137	10.1086	0.0	10.109	0.0	16.726
165M											
1-1	9.819	0.0	9.819	8.9202	6.3830	2.1478	17.4509	0.0	17.451	0.0	27.269
1-2	7.517	0.0	7.517	11.8208	8.1500	2.9860	22.9568	0.0	22.957	0.0	30.474
1-3	8.243	0.0	8.243	8.8835	6.2070	2.4569	17.5474	0.0	17.547	0.0	25.790
1-4	7.058	0.0	7.058	9.3369	6.4816	2.0783	17.8969	0.0	17.897	0.0	24.954
2-1	10.042	0.0	10.042	11.2667	9.0353	2.3823	22.6844	0.0	22.684	0.0	32.727

(TABLE 8.5BB CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR			EQUIPMENT					EQUIPMENT		
	SKILLED	UNSKILLED	TOTAL	INT/DEP	MAINT/MISC	FUEL	TOTAL	HORSE	AND HORSE	MATERIALS	TOTAL
2-2	7.741	0.0	7.741	14.2672	10.8665	3.2513	28.3849	0.0	28.385	0.0	36.126
2-3	8.467	0.0	8.467	11.2481	8.8692	2.7043	22.8216	0.0	22.822	0.0	31.289
2-4	7.281	0.0	7.281	11.7363	9.1665	2.3257	23.2285	0.0	23.229	0.0	30.510
3-1	8.591	0.0	8.591	8.7596	6.9548	2.1389	17.8535	0.0	17.853	0.0	26.445
3-2	6.290	0.0	6.290	11.1136	8.3702	2.8085	22.2923	0.0	22.292	0.0	28.582
3-3	7.016	0.0	7.016	8.6243	6.7248	2.3775	17.7266	0.0	17.727	0.0	24.742
3-4	5.830	0.0	5.830	8.8870	6.8747	1.9988	17.7606	0.0	17.761	0.0	23.591
4-2	3.595	0.0	3.595	5.6784	3.8817	1.6970	11.2570	0.0	11.257	0.0	14.852
4-4	3.135	0.0	3.135	4.0170	2.7658	1.1025	7.8853	0.0	7.885	0.0	11.020
5-5	8.085	0.0	8.085	5.3246	3.8103	2.1368	11.2719	0.0	11.272	0.0	19.357
6-6	6.120	0.0	6.120	5.5521	3.9729	1.8081	11.3331	0.0	11.333	0.0	17.453
7-7	2.969	0.0	2.969	3.5665	2.5520	1.2327	7.3512	0.0	7.351	0.0	10.320
8-8	25.840	0.0	25.840	10.3295	7.3915	3.9616	21.6826	0.0	21.683	0.0	47.523
9-9	14.106	0.0	14.106	7.3626	5.2684	3.1538	15.7848	0.0	15.785	0.0	29.891
10-10	10.640	0.0	10.640	7.4926	5.3615	3.3983	16.2523	0.0	16.252	0.0	26.892
500M											
1-1	10.101	0.0	10.101	9.0850	6.5009	2.2054	17.7913	0.0	17.791	0.0	27.852
1-2	7.650	0.0	7.650	12.0167	8.2815	3.0496	23.3477	0.0	23.348	0.0	30.998
1-3	8.479	0.0	8.479	9.0598	6.3267	2.5324	17.9188	0.0	17.919	0.0	26.398
1-4	7.190	0.0	7.190	9.4766	6.5754	2.1205	18.1726	0.0	18.173	0.0	25.362
2-1	10.324	0.0	10.324	11.4315	9.1533	2.4399	23.0247	0.0	23.025	0.0	33.349
2-2	7.874	0.0	7.874	14.4630	10.9980	3.3148	28.7758	0.0	28.776	0.0	36.650
2-3	8.703	0.0	8.703	11.4244	8.9889	2.7798	23.1930	0.0	23.193	0.0	31.896
2-4	7.414	0.0	7.414	11.8760	9.2604	2.3679	23.5043	0.0	23.504	0.0	30.918
3-1	8.873	0.0	8.873	8.9246	7.0728	2.1965	18.1939	0.0	18.194	0.0	27.067
3-2	6.423	0.0	6.423	11.3094	8.5017	2.8721	22.6832	0.0	22.683	0.0	29.106
3-3	7.252	0.0	7.252	8.8005	6.8445	2.4530	18.0980	0.0	18.098	0.0	25.350
3-4	5.962	0.0	5.962	9.0267	6.9685	2.0411	18.0364	0.0	18.036	0.0	23.999
4-2	3.728	0.0	3.728	5.8742	4.0132	1.7606	11.6479	0.0	11.648	0.0	15.376
4-4	3.267	0.0	3.267	4.1567	2.8596	1.1448	8.1611	0.0	8.161	0.0	11.428
5-5	12.024	0.0	12.024	8.5326	6.1057	3.4412	18.0794	0.0	18.079	0.0	30.104
6-6	10.125	0.0	10.125	9.1869	6.5738	2.9917	18.7523	0.0	18.752	0.0	28.878
7-7	5.063	0.0	5.063	6.0826	4.3525	2.1023	12.5374	0.0	12.537	0.0	17.600
8-8	77.255	0.0	77.255	30.8826	22.0986	11.8441	64.8253	0.0	64.825	0.0	142.080
9-9	42.177	0.0	42.177	22.0142	15.7527	9.4299	47.1968	0.0	47.197	0.0	89.374
10-10	31.745	0.0	31.745	22.3551	15.9966	10.1392	48.4910	0.0	48.491	0.0	80.236
800M											
1-1	11.411	0.0	11.411	9.8509	7.0490	2.4732	19.3731	0.0	19.373	0.0	30.784
1-2	8.268	0.0	8.268	12.9284	8.8939	3.3456	25.1678	0.0	25.168	0.0	33.436
1-3	9.557	0.0	9.557	9.8636	6.8725	2.8767	19.6128	0.0	19.613	0.0	29.170
1-4	7.803	0.0	7.803	10.1248	7.0108	2.3165	19.4522	0.0	19.452	0.0	27.256
2-1	11.635	0.0	11.635	12.1974	9.7013	2.7078	24.6065	0.0	24.607	0.0	36.241
2-2	8.492	0.0	8.492	15.3747	11.6104	3.6108	30.5959	0.0	30.596	0.0	39.088
2-3	9.781	0.0	9.781	12.2282	9.5347	3.1241	24.8870	0.0	24.887	0.0	34.668
2-4	8.027	0.0	8.027	12.5242	9.6958	2.5639	24.7839	0.0	24.784	0.0	32.811
3-1	10.183	0.0	10.183	9.6905	7.6208	2.4643	19.7757	0.0	19.776	0.0	29.959
3-2	7.041	0.0	7.041	12.2211	9.1141	3.1681	24.5033	0.0	24.503	0.0	31.544

(TABLE B.5BB CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
3-3	8.330	0.0	8.330	9.6044	7.3903	2.7973	19.7919	0.0	19.792	0.0	28.122
3-4	6.576	0.0	6.576	9.6750	7.4039	2.2371	19.3160	0.0	19.316	0.0	25.892
4-2	4.345	0.0	4.345	6.7859	4.6256	2.0566	13.4681	0.0	13.468	0.0	17.813
4-4	3.881	0.0	3.881	4.8049	3.2950	1.3408	9.4407	0.0	9.441	0.0	13.322
5-5	16.088	0.0	16.088	11.6265	8.3195	4.6942	24.6402	0.0	24.640	0.0	40.728
6-6	12.862	0.0	12.862	11.9975	8.5850	3.8609	24.4433	0.0	24.443	0.0	37.305
7-7	6.514	0.0	6.514	8.0247	5.7422	2.7409	16.5078	0.0	16.508	0.0	23.022
8-8	123.280	0.0	123.280	49.2808	35.2638	18.9002	103.4449	0.0	103.445	0.0	226.724
9-9	67.304	0.0	67.304	35.1293	25.1374	15.0478	75.3144	0.0	75.314	0.0	142.618
10-10	50.652	0.0	50.652	35.6701	25.5244	16.1782	77.3727	0.0	77.373	0.0	128.025
SPR/COMP ($/100BCM) 98%											
11	5.009	0.0	5.009	2.1048	1.5274	0.7679	4.4001	0.0	4.400	0.0	9.409
12	3.558	0.0	3.558	1.7681	1.2865	0.6474	3.7020	0.0	3.702	0.0	7.260
13	3.678	0.0	3.678	1.2251	0.9960	0.4902	2.7114	0.0	2.711	0.0	6.389
14	3.230	0.0	3.230	1.2685	0.9972	0.4808	2.7465	0.0	2.746	0.0	5.976
21	4.291	0.0	4.291	2.2409	1.6248	0.8886	4.7544	0.0	4.754	0.0	9.046
22	2.840	0.0	2.840	1.9043	1.3839	0.7681	4.0564	0.0	4.056	0.0	6.897
23	2.961	0.0	2.961	1.3613	1.0934	0.6110	3.0657	0.0	3.066	0.0	6.026
24	2.513	0.0	2.513	1.4046	1.0946	0.6016	3.1008	0.0	3.101	0.0	5.614
31	3.769	0.0	3.769	1.5922	1.1428	0.7218	3.4568	0.0	3.457	0.0	7.226
32	2.318	0.0	2.318	1.2556	0.9019	0.6013	2.7587	0.0	2.759	0.0	5.077
33	2.438	0.0	2.438	0.7126	0.6114	0.4441	1.7681	0.0	1.768	0.0	4.206
34	1.990	0.0	1.990	0.7559	0.6126	0.4347	1.8032	0.0	1.803	0.0	3.793
41	3.537	0.0	3.537	1.5991	1.1951	0.6273	3.4216	0.0	3.422	0.0	6.958
42	2.086	0.0	2.086	1.2625	0.9542	0.5068	2.7235	0.0	2.724	0.0	4.809
43	2.206	0.0	2.206	0.7195	0.6637	0.3497	1.7329	0.0	1.733	0.0	3.939
44	1.758	0.0	1.758	0.7628	0.6649	0.3403	1.7680	0.0	1.768	0.0	3.526
SURFACING GRAVEL ($/100CCM)											
11	4.350	0.0	4.350	1.4625	1.2832	0.5510	3.2967	0.0	3.297	673.88	681.527
12	3.201	0.0	3.201	1.2504	1.0097	0.4723	2.7324	0.0	2.732	673.88	679.815
21	4.030	0.0	4.030	1.7730	1.5053	0.7410	4.0193	0.0	4.019	673.88	681.931
22	2.882	0.0	2.882	1.5608	1.2318	0.6623	3.4550	0.0	3.455	673.88	680.218
31	3.404	0.0	3.404	1.0687	0.9847	0.5410	2.5944	0.0	2.594	673.88	679.880
32	2.256	0.0	2.256	0.8566	0.7112	0.4624	2.0301	0.0	2.030	673.88	678.167
41	3.230	0.0	3.230	1.0983	1.0523	0.4650	2.6156	0.0	2.616	673.88	679.727
42	2.081	0.0	2.081	0.8862	0.7788	0.3863	2.0513	0.0	2.051	673.88	678.014
51	4.847	0.8983	5.745	2.7598	2.1512	0.9896	5.9006	0.0	5.901	673.88	685.527
52	3.699	0.8983	4.597	2.5477	1.8777	0.9109	5.3363	0.0	5.336	673.88	683.814
WBM ($/100CCM)											
111	34.448	6.8467	41.295	13.4392	12.0169	6.5042	31.9603	0.0	31.960	773.51	846.767
112	26.657	5.6860	32.343	12.4685	10.4351	5.7043	28.6079	0.0	28.608	773.51	834.462
211	33.768	6.8467	40.615	13.5890	12.1241	6.6300	32.3431	0.0	32.343	773.51	846.469
212	25.977	5.6860	31.663	12.6184	10.5423	5.8300	28.9907	0.0	28.991	773.51	834.165
311	33.237	6.8467	40.084	12.9385	11.6411	6.4604	31.0399	0.0	31.040	773.51	844.635
312	25.446	5.6860	31.132	11.9678	10.0592	5.6605	27.6876	0.0	27.688	773.51	832.332
411	33.005	6.8467	39.852	12.9435	11.6912	6.3664	31.0011	0.0	31.001	773.51	844.365

(TABLE B.5BB CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
412	25.214	5.6860	30.900	11.9729	10.1094	5.5665	27.6487	0.0	27.649	773.51	832.060
511	34.693	7.7450	42.438	14.6934	12.8506	6.9216	34.4655	0.0	34.466	773.51	850.415
512	26.902	6.5843	33.486	13.7227	11.2688	6.1216	31.1131	0.0	31.113	773.51	836.111
DBST/G ($/100SM)											
1111	0.713	0.3396	1.053	0.4214	0.3179	0.3177	1.0570	0.0	1.057	19.67	21.779
1112	0.630	0.3396	0.970	0.4311	0.3237	0.2943	1.0492	0.0	1.049	19.67	21.688
1121	0.726	0.4538	1.179	0.3332	0.2653	0.2799	0.8785	0.0	0.878	19.67	21.727
1122	0.643	0.4538	1.096	0.3429	0.2711	0.2565	0.8706	0.0	0.871	19.67	21.636
2111	0.713	0.3149	1.028	0.4167	0.3164	0.3171	1.0503	0.0	1.050	19.67	21.748
2112	0.630	0.3149	0.945	0.4264	0.3222	0.2937	1.0424	0.0	1.042	19.67	21.657
2121	0.726	0.4322	1.158	0.3285	0.2638	0.2794	0.8717	0.0	0.872	19.67	21.699
2122	0.643	0.4322	1.075	0.3382	0.2696	0.2559	0.8638	0.0	0.864	19.67	21.608
DBST/W ($/100SM)											
1111	0.713	0.3396	1.053	0.4214	0.3179	0.3177	1.0570	0.0	1.057	17.16	19.267
1112	0.630	0.3396	0.970	0.4311	0.3237	0.2943	1.0492	0.0	1.049	17.16	19.177
1121	0.726	0.4538	1.179	0.3332	0.2653	0.2799	0.8785	0.0	0.878	17.16	19.215
1122	0.643	0.4538	1.096	0.3429	0.2711	0.2565	0.8706	0.0	0.871	17.16	19.125
2111	0.713	0.3149	1.028	0.4167	0.3164	0.3171	1.0503	0.0	1.050	17.16	19.236
2112	0.630	0.3149	0.945	0.4264	0.3222	0.2937	1.0424	0.0	1.042	17.16	19.145
2121	0.726	0.4322	1.158	0.3285	0.2638	0.2794	0.8717	0.0	0.872	17.16	19.187
2122	0.643	0.4322	1.075	0.3382	0.2696	0.2559	0.8638	0.0	0.864	17.16	19.096

TABLE B.5BC: UNIT COSTS OF THE 1950'S TECHNICAL PACKAGES FOR ALL STAGES AT THE PRICES OF 1974.

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
SITE PREP ($/HA)											
11	1513.314	9675.3984	11188.703	15.2656	6.4428	5.3186	27.0270	0.0	27.027	137.77	11353.500
21	191.935	170.9595	362.895	65.6476	39.0295	28.0925	132.7696	0.0	132.770	0.0	495.664
31	131.027	170.9595	301.987	39.0334	23.1080	17.7310	79.8724	0.0	79.872	0.0	381.859
EXC/HAUL ($/100BCM)											
2M											
11-0	4.179	0.0	4.179	0.6492	0.4421	1.2186	2.3099	0.0	2.310	0.0	6.489
6M											
1-1	22.982	0.0	22.982	17.7295	10.5478	3.9076	32.1849	0.0	32.185	0.0	55.167
1-2	19.861	0.0	19.861	23.9953	13.8130	5.7834	43.5917	0.0	43.592	0.0	63.453
1-3	19.423	0.0	19.423	17.4777	10.2108	4.3040	31.9925	0.0	31.992	0.0	51.415
1-4	18.430	0.0	18.430	19.2446	11.1601	4.0627	34.4673	0.0	34.467	0.0	52.897
2-1	23.679	0.0	23.679	23.7498	15.7609	4.4626	43.9733	0.0	43.973	0.0	67.652
2-2	20.558	0.0	20.558	30.2514	19.1521	6.4112	55.8148	0.0	55.815	0.0	76.372
2-3	20.119	0.0	20.119	23.5406	15.4432	4.8895	43.8734	0.0	43.873	0.0	63.992
2-4	19.126	0.0	19.126	25.3898	16.4372	4.6482	46.4751	0.0	46.475	0.0	65.601
3-1	19.165	0.0	19.165	17.6842	11.6717	3.8865	33.2424	0.0	33.242	0.0	52.407
3-2	16.044	0.0	16.044	22.6571	14.2459	5.3634	42.2664	0.0	42.266	0.0	58.310
3-3	15.605	0.0	15.605	17.1987	11.2286	4.1160	32.5432	0.0	32.543	0.0	48.148
3-4	14.612	0.0	14.612	18.5148	11.9327	3.8746	34.3222	0.0	34.322	0.0	48.934
5-5	15.837	0.0	15.837	7.9210	4.7125	3.1823	15.8158	0.0	15.816	0.0	31.653
6-6	14.806	0.0	14.806	9.7250	5.7857	3.2380	18.7488	0.0	18.749	0.0	33.554
7-7	6.926	0.0	6.926	6.0809	3.6177	2.1539	11.8525	0.0	11.852	0.0	18.778
8-8	4.617	0.0	4.617	1.4028	0.8345	0.5386	2.7759	0.0	2.776	0.0	7.393
9-9	2.515	0.0	2.515	0.9976	0.5935	0.4278	2.0190	0.0	2.019	0.0	4.534
10-10	2.051	0.0	2.051	1.0975	0.6530	0.4984	2.2488	0.0	2.249	0.0	4.299
9M											
1-1	23.124	0.0	23.124	17.7925	10.5853	3.9296	32.3075	0.0	32.308	0.0	55.432
1-2	19.926	0.0	19.926	24.0676	13.8534	5.8069	43.7279	0.0	43.728	0.0	63.654
1-3	19.539	0.0	19.539	17.5434	10.2480	4.3322	32.1236	0.0	32.124	0.0	51.662
1-4	18.494	0.0	18.494	19.2963	11.1890	4.0783	34.5637	0.0	34.564	0.0	53.058
2-1	23.821	0.0	23.821	23.8129	15.7984	4.4847	44.0959	0.0	44.096	0.0	67.916
2-2	20.622	0.0	20.622	30.3236	19.1925	6.4347	55.9510	0.0	55.951	0.0	76.573
2-3	20.235	0.0	20.235	23.6064	15.4804	4.9177	44.0045	0.0	44.004	0.0	64.240
2-4	19.191	0.0	19.191	25.4415	16.4661	4.6638	46.5715	0.0	46.571	0.0	65.762
3-1	19.307	0.0	19.307	17.7472	11.7092	3.9086	33.3650	0.0	33.365	0.0	52.672
3-2	16.108	0.0	16.108	22.7294	14.2863	5.3869	42.4026	0.0	42.403	0.0	58.511
3-3	15.721	0.0	15.721	17.2644	11.2657	4.1442	32.6743	0.0	32.674	0.0	48.396
3-4	14.677	0.0	14.677	18.5666	11.9617	3.8903	34.4185	0.0	34.419	0.0	49.095
5-5	16.018	0.0	16.018	8.0085	4.7645	3.2174	15.9904	0.0	15.990	0.0	32.008
6-6	14.935	0.0	14.935	9.8084	5.8353	3.2656	18.9093	0.0	18.909	0.0	33.844
7-7	6.990	0.0	6.990	6.0906	3.6235	2.1527	11.8668	0.0	11.867	0.0	18.857
8-8	6.074	0.0	6.074	1.8455	1.0980	0.7086	3.6521	0.0	3.652	0.0	9.727
9-9	3.302	0.0	3.302	1.3097	0.7792	0.5617	2.6506	0.0	2.651	0.0	5.952
10-10	2.644	0.0	2.644	1.4151	0.8419	0.6425	2.8994	0.0	2.899	0.0	5.543
60M											

(TABLE 8.5BC CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
1-1	25.587	0.0	25.587	18.8865	11.2364	4.3128	34.4361	0.0	34.436	0.0	60.023
1-2	21.073	0.0	21.073	25.3550	14.5723	6.2253	46.1526	0.0	46.153	0.0	67.226
1-3	21.576	0.0	21.576	18.6982	10.8999	4.8274	34.4255	0.0	34.426	0.0	56.002
1-4	19.642	0.0	19.642	20.2178	11.7036	4.3573	36.2787	0.0	36.279	0.0	55.921
2-1	26.284	0.0	26.284	24.9072	16.4494	4.8678	46.2245	0.0	46.225	0.0	72.508
2-2	21.770	0.0	21.770	31.6112	19.9114	6.8531	58.3757	0.0	58.376	0.0	80.146
2-3	22.273	0.0	22.273	24.7612	16.1323	5.4129	46.3064	0.0	46.306	0.0	68.579
2-4	20.338	0.0	20.338	26.3630	16.9807	4.9428	48.2865	0.0	48.287	0.0	68.625
3-1	21.770	0.0	21.770	18.8416	12.3603	4.2917	35.4936	0.0	35.494	0.0	57.264
3-2	17.256	0.0	17.256	24.0168	15.0052	5.8053	44.8273	0.0	44.827	0.0	62.083
3-3	17.759	0.0	17.759	18.4192	11.9176	4.6394	34.9762	0.0	34.976	0.0	52.735
3-4	15.824	0.0	15.824	19.4881	12.4763	4.1692	36.1336	0.0	36.134	0.0	51.958
4-2	8.873	0.0	8.873	10.8343	6.1832	3.1747	20.1922	0.0	20.192	0.0	29.065
4-4	7.441	0.0	7.441	7.6417	4.4004	2.0479	14.0901	0.0	14.090	0.0	21.532
5-5	19.062	0.0	19.062	9.5308	5.6702	3.8290	19.0299	0.0	19.030	0.0	38.092
6-6	17.088	0.0	17.088	11.2247	6.6779	3.7373	21.6400	0.0	21.640	0.0	38.728
7-7	8.125	0.0	8.125	7.0760	4.2097	2.5007	13.7864	0.0	13.786	0.0	21.911
8-8	30.849	0.0	30.849	9.3726	5.5760	3.5987	18.5473	0.0	18.547	0.0	49.397
9-9	16.792	0.0	16.792	6.6612	3.9630	2.8566	13.4807	0.0	13.481	0.0	30.272
10-10	12.845	0.0	12.845	6.8751	4.0902	3.1218	14.0871	0.0	14.087	0.0	26.932
100M											
1-1	27.483	0.0	27.483	19.7292	11.7375	4.6077	36.0743	0.0	36.074	0.0	63.558
1-2	21.963	0.0	21.963	26.3531	15.1297	6.5497	48.0325	0.0	48.033	0.0	69.996
1-3	23.124	0.0	23.124	19.5753	11.3950	5.2035	36.1738	0.0	36.174	0.0	59.298
1-4	20.532	0.0	20.532	20.9323	12.1026	4.5736	37.6084	0.0	37.608	0.0	58.140
2-1	28.180	0.0	28.180	25.7495	16.9505	5.1627	47.8627	0.0	47.863	0.0	76.042
2-2	22.660	0.0	22.660	32.6093	20.4688	7.1775	60.2556	0.0	60.256	0.0	82.915
2-3	23.821	0.0	23.821	25.6382	16.6274	5.7890	48.0547	0.0	48.055	0.0	71.875
2-4	21.228	0.0	21.228	27.0775	17.3797	5.1590	49.6162	0.0	49.616	0.0	70.844
3-1	23.666	0.0	23.666	19.6835	12.8614	4.5866	37.1319	0.0	37.132	0.0	60.798
3-2	18.146	0.0	18.146	25.0149	15.5626	6.1297	46.7072	0.0	46.707	0.0	64.853
3-3	19.307	0.0	19.307	19.2963	12.4127	5.0155	36.7245	0.0	36.724	0.0	56.031
3-4	16.714	0.0	16.714	20.2025	12.8752	4.3855	37.4633	0.0	37.463	0.0	54.178
4-2	9.763	0.0	9.763	11.8324	6.7406	3.4991	22.0721	0.0	22.072	0.0	31.835
4-4	8.331	0.0	8.331	8.3561	4.7994	2.2642	15.4197	0.0	15.420	0.0	23.751
5-5	21.409	0.0	21.409	10.7303	6.3839	4.3110	21.4250	0.0	21.425	0.0	42.834
6-6	18.752	0.0	18.752	12.3177	7.3282	4.1012	23.7471	0.0	23.747	0.0	42.499
7-7	7.996	0.0	7.996	7.3006	4.3434	2.5262	14.1703	0.0	14.170	0.0	22.166
8-8	49.808	0.0	49.808	15.1325	9.0028	5.8102	29.9455	0.0	29.945	0.0	79.753
9-9	27.109	0.0	27.109	10.7541	6.3979	4.6118	21.7638	0.0	21.764	0.0	48.873
10-10	20.583	0.0	20.583	11.0167	6.5542	5.0023	22.5733	0.0	22.573	0.0	43.157
165M											
1-1	30.540	0.0	30.540	21.0871	12.5454	5.0831	38.7156	0.0	38.716	0.0	69.255
1-2	23.382	0.0	23.382	27.9443	16.0183	7.0669	51.0294	0.0	51.029	0.0	74.411
1-3	25.639	0.0	25.639	21.0005	12.1995	5.8147	39.0147	0.0	39.015	0.0	64.654
1-4	21.952	0.0	21.952	22.0723	12.7392	4.9186	39.7301	0.0	39.730	0.0	61.682
2-1	31.236	0.0	31.236	27.1075	17.7584	5.6381	50.5040	0.0	50.504	0.0	81.740

(TABLE B.58C CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
2-2	24.078	0.0	24.078	34.2005	21.3574	7.6947	63.2525	0.0	63.253	0.0	87.331
2-3	26.335	0.0	26.335	27.0634	17.4319	6.4002	50.8956	0.0	50.896	0.0	77.231
2-4	22.648	0.0	22.648	28.2175	18.0163	5.5041	51.7379	0.0	51.738	0.0	74.386
3-1	26.722	0.0	26.722	21.0418	13.6693	5.0620	39.7731	0.0	39.773	0.0	66.495
3-2	19.565	0.0	19.565	26.6061	16.4512	6.6469	49.7041	0.0	49.704	0.0	69.269
3-3	21.822	0.0	21.822	20.7215	13.2173	5.6267	39.5654	0.0	39.565	0.0	61.387
3-4	18.134	0.0	18.134	21.3425	13.5118	4.7306	39.5849	0.0	39.585	0.0	57.719
4-2	11.182	0.0	11.182	13.4236	7.6292	4.0161	25.0690	0.0	25.069	0.0	36.251
4-4	9.751	0.0	9.751	9.4961	5.4360	2.6093	17.5414	0.0	17.541	0.0	27.293
5-5	25.149	0.0	25.149	12.5878	7.4889	5.0571	25.1337	0.0	25.134	0.0	50.283
6-6	19.036	0.0	19.036	13.1251	7.8085	4.2792	25.2128	0.0	25.213	0.0	44.249
7-7	9.234	0.0	9.234	8.4311	5.0159	2.9174	16.3643	0.0	16.364	0.0	25.599
8-8	80.373	0.0	80.373	24.4189	14.5275	9.3758	48.3222	0.0	48.322	0.0	128.696
9-9	43.875	0.0	43.875	17.4051	10.3548	7.4640	35.2239	0.0	35.224	0.0	79.099
10-10	33.093	0.0	33.093	17.7124	10.5376	8.0426	36.2926	0.0	36.293	0.0	69.386
500M											
1-1	31.417	0.0	31.417	21.4767	12.7772	5.2195	39.4734	0.0	39.473	0.0	70.890
1-2	23.795	0.0	23.795	28.4072	16.2768	7.2173	51.9012	0.0	51.901	0.0	75.696
1-3	26.374	0.0	26.374	21.4171	12.4347	5.9934	39.8452	0.0	39.845	0.0	66.219
1-4	22.363	0.0	22.363	22.4026	12.9236	5.0186	40.3448	0.0	40.345	0.0	62.708
2-1	32.113	0.0	32.113	27.4971	17.9902	5.7745	51.2618	0.0	51.262	0.0	83.375
2-2	24.491	0.0	24.491	34.6633	21.6159	7.8451	64.1243	0.0	64.124	0.0	88.616
2-3	27.071	0.0	27.071	27.4800	17.6671	6.5789	51.7260	0.0	51.726	0.0	78.797
2-4	23.060	0.0	23.060	28.5477	18.2007	5.6041	52.3526	0.0	52.353	0.0	75.412
3-1	27.599	0.0	27.599	21.4314	13.9011	5.1984	40.5309	0.0	40.531	0.0	68.130
3-2	19.977	0.0	19.977	27.0690	16.7097	6.7973	50.5759	0.0	50.576	0.0	70.553
3-3	22.557	0.0	22.557	21.1381	13.4525	5.8053	40.3958	0.0	40.396	0.0	62.952
3-4	18.546	0.0	18.546	21.6728	13.6963	4.8306	40.1997	0.0	40.200	0.0	58.745
4-2	11.594	0.0	11.594	13.8864	7.8877	4.1667	25.9408	0.0	25.941	0.0	37.535
4-4	10.163	0.0	10.163	9.8264	5.6204	2.7093	18.1561	0.0	18.156	0.0	28.319
5-5	37.401	0.0	37.401	20.1710	12.0003	8.1441	40.3154	0.0	40.315	0.0	77.716
6-6	31.494	0.0	31.494	21.7176	12.9205	7.0804	41.7184	0.0	41.718	0.0	73.213
7-7	15.747	0.0	15.747	14.3792	8.5546	4.9754	27.9091	0.0	27.909	0.0	43.656
8-8	240.295	0.0	240.295	73.0059	43.4334	28.0311	144.4704	0.0	144.470	0.0	384.765
9-9	131.187	0.0	131.187	52.0413	30.9610	22.3174	105.3197	0.0	105.320	0.0	236.507
10-10	98.739	0.0	98.739	52.8472	31.4404	23.9961	108.2838	0.0	108.284	0.0	207.022
800M											
1-1	35.492	0.0	35.492	23.2873	13.8543	5.8534	42.9950	0.0	42.995	0.0	78.487
1-2	25.716	0.0	25.716	30.5625	17.4804	7.9178	55.9607	0.0	55.961	0.0	81.677
1-3	29.727	0.0	29.727	23.3174	13.5074	6.8083	43.6331	0.0	43.633	0.0	73.360
1-4	24.272	0.0	24.272	23.9350	13.7793	5.4825	43.1968	0.0	43.197	0.0	67.469
2-1	36.189	0.0	36.189	29.3077	19.0674	6.4084	54.7834	0.0	54.783	0.0	90.972
2-2	26.413	0.0	26.413	36.8187	22.8195	8.5456	68.1838	0.0	68.184	0.0	94.597
2-3	30.424	0.0	30.424	29.3803	18.7398	7.3938	55.5139	0.0	55.514	0.0	85.938
2-4	24.968	0.0	24.968	30.0801	19.0565	6.0680	55.2046	0.0	55.205	0.0	80.173
3-1	31.675	0.0	31.675	23.2420	14.9783	5.8323	44.0526	0.0	44.053	0.0	75.727
3-2	21.899	0.0	21.899	29.2243	17.9133	7.4979	54.6354	0.0	54.635	0.0	76.534

(TABLE B.5BC CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
3-3	25.910	0.0	25.910	23.0384	14.5252	6.6203	44.1838	0.0	44.184	0.0	70.094
3-4	20.454	0.0	20.454	23.2052	14.5520	5.2944	43.0517	0.0	43.052	0.0	63.506
4-2	13.516	0.0	13.516	16.0418	9.0913	4.8672	30.0002	0.0	30.000	0.0	43.516
4-4	12.071	0.0	12.071	11.3588	6.4762	3.1732	21.0081	0.0	21.008	0.0	33.080
5-5	50.040	0.0	50.040	27.4848	16.3515	11.1097	54.9461	0.0	54.946	0.0	104.986
6-6	40.006	0.0	40.006	28.3618	16.8733	9.1374	54.3725	0.0	54.372	0.0	94.379
7-7	20.261	0.0	20.261	18.5703	11.2860	6.4867	36.7430	0.0	36.743	0.0	57.004
8-8	383.449	0.0	383.449	116.4992	69.3089	44.7306	230.5386	0.0	230.539	0.0	613.988
9-9	209.342	0.0	209.342	83.0451	49.4060	35.6131	168.0641	0.0	168.064	0.0	377.406
10-10	157.548	0.0	157.548	84.3236	50.1667	38.2885	172.7789	0.0	172.779	0.0	330.327
SPR/COMP ($/100BCM) 98%											
11	15.579	0.0	15.579	4.9579	3.0020	1.8174	9.7773	0.0	9.777	0.0	25.357
12	11.066	0.0	11.066	4.1621	2.5286	1.5322	8.2228	0.0	8.223	0.0	19.288
13	11.440	0.0	11.440	2.9474	1.9576	1.0494	5.9543	0.0	5.954	0.0	17.394
14	10.047	0.0	10.047	2.9416	1.9599	1.1380	6.0395	0.0	6.039	0.0	16.086
21	13.348	0.0	13.348	5.2798	3.1935	2.1031	10.5765	0.0	10.576	0.0	23.925
22	8.834	0.0	8.834	4.4840	2.7201	1.8179	9.0220	0.0	9.022	0.0	17.856
23	9.208	0.0	9.208	3.2693	2.1491	1.3351	6.7535	0.0	6.753	0.0	15.962
24	7.816	0.0	7.816	3.2635	2.1514	1.4237	6.8386	0.0	6.839	0.0	14.654
31	11.723	0.0	11.723	3.7242	2.2461	1.5248	7.4951	0.0	7.495	0.0	19.218
32	7.209	0.0	7.209	2.9284	1.7727	1.2395	5.9406	0.0	5.941	0.0	13.150
33	7.583	0.0	7.583	1.7137	1.2017	0.7567	3.6721	0.0	3.672	0.0	11.255
34	6.191	0.0	6.191	1.7078	1.2040	0.8454	3.7572	0.0	3.757	0.0	9.948
41	11.001	0.0	11.001	3.7626	2.3489	1.4847	7.5963	0.0	7.596	0.0	18.597
42	6.487	0.0	6.487	2.9668	1.8755	1.1995	6.0418	0.0	6.042	0.0	12.529
43	6.861	0.0	6.861	1.7521	1.3045	0.7167	3.7733	0.0	3.773	0.0	10.634
44	5.468	0.0	5.468	1.7462	1.3068	0.8053	3.8584	0.0	3.858	0.0	9.327
SURFACING GRAVEL ($/100CCM)											
11	13.529	0.0	13.529	3.5590	2.5220	1.3039	7.3849	0.0	7.385	1023.64	1044.554
12	9.956	0.0	9.956	2.8826	1.9845	1.1178	5.9849	0.0	5.985	1023.64	1039.582
21	12.536	0.0	12.536	4.2929	2.9586	1.7536	9.0051	0.0	9.005	1023.64	1045.181
22	8.963	0.0	8.963	3.6165	2.4211	1.5675	7.6051	0.0	7.605	1023.64	1040.209
31	10.588	0.0	10.588	2.6073	1.9353	1.1083	5.6510	0.0	5.651	1023.64	1039.880
32	7.016	0.0	7.016	1.9310	1.3978	0.9222	4.2510	0.0	4.251	1023.64	1034.907
41	10.047	0.0	10.047	2.6980	2.0682	1.1004	5.8667	0.0	5.867	1023.64	1039.554
42	6.474	0.0	6.474	2.0217	1.5307	0.9143	4.4667	0.0	4.467	1023.64	1034.581
51	15.076	2.9993	18.076	6.5953	4.2281	2.2057	13.0291	0.0	13.029	1023.64	1054.745
52	11.504	2.9993	14.503	5.9189	3.6906	2.0196	11.6291	0.0	11.629	1023.64	1049.773
WDM ($/100CCM)											
111	107.147	22.8610	130.008	32.7977	23.6185	13.8392	70.2554	0.0	70.255	1110.92	1311.187
112	82.914	18.9856	101.900	28.3201	20.5096	12.3640	61.1936	0.0	61.194	1110.92	1274.017
211	105.032	22.8610	127.893	33.1519	23.8293	14.1368	71.1180	0.0	71.118	1110.92	1309.934
212	80.799	18.9856	99.785	28.6742	20.7203	12.6616	62.0562	0.0	62.056	1110.92	1272.764
311	103.381	22.8610	126.242	31.5923	22.8798	13.5549	68.0270	0.0	68.027	1110.92	1305.193
312	79.148	18.9856	98.134	27.1147	19.7709	12.0796	58.9652	0.0	58.965	1110.92	1268.022
411	102.659	22.8610	125.520	31.6259	22.9784	13.5131	68.1175	0.0	68.117	1110.92	1304.561

(TABLE B.5DC CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
412	78.426	18.9856	97.411	27.1483	19.8694	12.0379	59.0556	0.0	59.056	1110.92	1267.390
511	107.908	25.0604	133.769	35.7321	25.2571	14.6908	75.6800	0.0	75.680	1110.92	1320.372
512	83.675	21.9849	105.660	31.2544	22.1482	13.2156	66.6182	0.0	66.618	1110.92	1283.201
DBST/G ($/100SM)											
1111	2.218	1.1338	3.352	0.9952	0.6249	0.5901	2.2101	0.0	2.210	45.64	51.203
1112	1.960	1.1338	3.094	1.0085	0.6363	0.5602	2.2050	0.0	2.205	45.64	50.940
1121	2.257	1.5151	3.772	0.7904	0.5215	0.5180	1.8299	0.0	1.830	45.64	51.243
1122	1.999	1.5151	3.514	0.8038	0.5329	0.4881	1.8248	0.0	1.825	45.64	50.980
2111	2.218	1.0513	3.270	0.9854	0.6219	0.5891	2.1964	0.0	2.196	45.64	51.106
2112	1.960	1.0513	3.012	0.9987	0.6333	0.5592	2.1913	0.0	2.191	45.64	50.843
2121	2.257	1.4430	3.700	0.7806	0.5185	0.5171	1.8162	0.0	1.816	45.64	51.157
2122	1.999	1.4430	3.442	0.7940	0.5299	0.4872	1.8111	0.0	1.811	45.64	50.894
DBST/W ($/100SM)											
1111	2.218	1.1338	3.352	0.9952	0.6249	0.5901	2.2101	0.0	2.210	38.11	43.667
1112	1.960	1.1338	3.094	1.0085	0.6363	0.5602	2.2050	0.0	2.205	38.11	43.404
1121	2.257	1.5151	3.772	0.7904	0.5215	0.5180	1.8299	0.0	1.830	38.11	43.707
1122	1.999	1.5151	3.514	0.8038	0.5329	0.4881	1.8248	0.0	1.825	38.11	43.444
2111	2.218	1.0513	3.270	0.9854	0.6219	0.5891	2.1964	0.0	2.196	38.11	43.571
2112	1.960	1.0513	3.012	0.9987	0.6333	0.5592	2.1913	0.0	2.191	38.11	43.308
2121	2.257	1.4430	3.700	0.7806	0.5185	0.5171	1.8162	0.0	1.816	38.11	43.621
2122	1.999	1.4430	3.442	0.7940	0.5299	0.4872	1.8111	0.0	1.811	38.11	43.358

TABLE D.50D: UNIT COSTS OF THE 1950'S TECHNICAL PACKAGES FOR ALL STAGES AT THE PRICES OF A TYPICAL DEVELOPING COUNTRY.

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
SITE PREP ($/HA)											
11	30.696	61.3921	92.088	12.7550	5.0075	24.9698	42.7323	0.0	42.732	202.62	337.442
21	3.893	1.0848	4.978	158.7319	77.3757	118.7010	354.8083	0.0	354.808	0.0	359.786
31	2.658	1.0848	3.743	94.1625	45.7675	74.9197	214.8496	0.0	214.850	0.0	218.592
EXC/HAUL ($/100BCM)											
2M											
11-0	0.085	0.0	0.085	1.5282	0.8777	5.7212	8.1271	0.0	8.127	0.0	8.212
6M											
1-1	0.466	0.0	0.466	42.9567	20.9401	16.5109	80.4077	0.0	80.408	0.0	80.874
1-2	0.403	0.0	0.403	58.1379	27.4223	24.4369	109.9972	0.0	109.997	0.0	110.400
1-3	0.394	0.0	0.394	42.3465	20.2711	18.1859	80.8036	0.0	80.804	0.0	81.198
1-4	0.374	0.0	0.374	46.6275	22.1556	17.1662	85.9493	0.0	85.949	0.0	86.323
2-1	0.480	0.0	0.480	58.6895	31.2833	18.8561	108.8349	0.0	108.835	0.0	109.315
2-2	0.417	0.0	0.417	74.4422	38.0218	27.0896	139.5535	0.0	139.554	0.0	139.971
2-3	0.408	0.0	0.408	58.1826	30.6587	20.6598	109.5012	0.0	109.501	0.0	109.909
2-4	0.388	0.0	0.388	62.6628	32.6320	19.6401	114.9349	0.0	114.935	0.0	115.323
3-1	0.389	0.0	0.389	43.6555	23.1713	16.4219	83.2487	0.0	83.249	0.0	83.637
3-2	0.325	0.0	0.325	55.7042	28.2817	22.6622	106.6482	0.0	106.648	0.0	106.974
3-3	0.317	0.0	0.317	42.4791	22.2916	17.3913	82.1620	0.0	82.162	0.0	82.479
3-4	0.296	0.0	0.296	45.6680	23.6895	16.3716	85.7292	0.0	85.729	0.0	86.026
5-5	0.321	0.0	0.321	19.1917	9.3554	13.4464	41.9935	0.0	41.994	0.0	42.315
6-6	0.300	0.0	0.300	23.5627	11.4861	13.6818	48.7307	0.0	48.731	0.0	49.031
7-7	0.140	0.0	0.140	14.7333	7.1821	9.1009	31.0163	0.0	31.016	0.0	31.157
8-8	0.094	0.0	0.094	3.3987	1.6568	2.2758	7.3313	0.0	7.331	0.0	7.425
9-9	0.051	0.0	0.051	2.4172	1.1783	1.8077	5.4032	0.0	5.403	0.0	5.454
10-10	0.042	0.0	0.042	2.6592	1.2963	2.1057	6.0612	0.0	6.061	0.0	6.103
9M											
1-1	0.469	0.0	0.469	43.1094	21.0145	16.6041	80.7281	0.0	80.728	0.0	81.197
1-2	0.404	0.0	0.404	58.3132	27.5025	24.5362	110.3519	0.0	110.352	0.0	110.756
1-3	0.396	0.0	0.396	42.5059	20.3448	18.3051	81.1559	0.0	81.156	0.0	81.552
1-4	0.375	0.0	0.375	46.7529	22.2130	17.2324	86.1983	0.0	86.198	0.0	86.574
2-1	0.483	0.0	0.483	58.8422	31.3638	18.9493	109.1553	0.0	109.155	0.0	109.638
2-2	0.418	0.0	0.418	74.6174	38.1020	27.1889	139.9083	0.0	139.908	0.0	140.327
2-3	0.410	0.0	0.410	58.3419	30.7324	20.7790	109.8535	0.0	109.853	0.0	110.264
2-4	0.389	0.0	0.389	62.7882	32.6894	19.7063	115.1839	0.0	115.184	0.0	115.573
3-1	0.392	0.0	0.392	43.8082	23.2458	16.5152	83.5691	0.0	83.569	0.0	83.961
3-2	0.327	0.0	0.327	55.8795	28.3619	22.7616	107.0030	0.0	107.003	0.0	107.330
3-3	0.319	0.0	0.319	42.6384	22.3653	17.5105	82.5143	0.0	82.514	0.0	82.833
3-4	0.298	0.0	0.298	45.7935	23.7469	16.4378	85.9782	0.0	85.978	0.0	86.276
5-5	0.325	0.0	0.325	19.4037	9.4587	13.5947	42.4571	0.0	42.457	0.0	42.782
6-6	0.303	0.0	0.303	23.7647	11.5846	13.7984	49.1476	0.0	49.148	0.0	49.451
7-7	0.142	0.0	0.142	14.7569	7.1935	9.0959	31.0462	0.0	31.046	0.0	31.188
8-8	0.123	0.0	0.123	4.4715	2.1797	2.9941	9.6453	0.0	9.645	0.0	9.769
9-9	0.067	0.0	0.067	3.1733	1.5469	2.3732	7.0935	0.0	7.093	0.0	7.160
10-10	0.054	0.0	0.054	3.4285	1.6713	2.7149	7.8147	0.0	7.815	0.0	7.868
60M											

(TABLE B.5BD CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
1-1	0.519	0.0	0.519	45.7610	22.3071	18.2230	86.2911	0.0	86.291	0.0	86.810
1-2	0.427	0.0	0.427	61.4324	28.9299	26.3042	116.6664	0.0	116.666	0.0	117.094
1-3	0.438	0.0	0.438	45.3038	21.6390	20.3976	87.3404	0.0	87.340	0.0	87.778
1-4	0.398	0.0	0.398	48.9857	23.2346	18.4111	90.6314	0.0	90.631	0.0	91.030
2-1	0.533	0.0	0.533	61.4937	32.6563	20.5682	114.7182	0.0	114.718	0.0	115.251
2-2	0.442	0.0	0.442	77.7367	39.5293	28.9569	146.2228	0.0	146.223	0.0	146.664
2-3	0.452	0.0	0.452	61.1399	32.0266	22.8715	116.0380	0.0	116.038	0.0	116.490
2-4	0.413	0.0	0.413	65.0210	33.7110	20.8850	119.6170	0.0	119.617	0.0	120.029
3-1	0.442	0.0	0.442	46.4597	24.5383	18.1340	89.1321	0.0	89.132	0.0	89.574
3-2	0.350	0.0	0.350	58.9987	29.7892	24.5296	113.3175	0.0	113.317	0.0	113.667
3-3	0.360	0.0	0.360	45.4364	23.6595	19.6030	88.6989	0.0	88.699	0.0	89.059
3-4	0.321	0.0	0.321	48.0262	24.7685	17.6165	90.4112	0.0	90.411	0.0	90.732
4-2	0.180	0.0	0.180	26.2503	12.2753	13.4143	51.9399	0.0	51.940	0.0	52.120
4-4	0.151	0.0	0.151	18.5150	8.7359	8.6533	35.9043	0.0	35.904	0.0	36.055
5-5	0.387	0.0	0.387	23.0921	11.2567	16.1788	50.5276	0.0	50.528	0.0	50.914
6-6	0.347	0.0	0.347	27.1963	13.2574	15.7915	56.2451	0.0	56.245	0.0	56.592
7-7	0.165	0.0	0.165	17.1443	8.3573	10.5665	36.0681	0.0	36.068	0.0	36.233
8-8	0.626	0.0	0.626	22.7088	11.0698	15.2056	48.9843	0.0	48.984	0.0	49.610
9-9	0.341	0.0	0.341	16.1394	7.8675	12.0701	36.0769	0.0	36.077	0.0	36.418
10-10	0.261	0.0	0.261	16.6576	8.1201	13.1905	37.9682	0.0	37.968	0.0	38.229
100M											
1-1	0.557	0.0	0.557	47.8017	23.3019	19.4690	90.5726	0.0	90.573	0.0	91.130
1-2	0.446	0.0	0.446	63.8507	30.0363	27.6749	121.5619	0.0	121.562	0.0	122.007
1-3	0.469	0.0	0.469	47.4288	22.6219	21.9868	92.0375	0.0	92.038	0.0	92.507
1-4	0.416	0.0	0.416	50.7167	24.0266	19.3249	94.0682	0.0	94.068	0.0	94.485
2-1	0.572	0.0	0.572	63.5345	33.6511	21.8141	118.9997	0.0	119.000	0.0	119.571
2-2	0.460	0.0	0.460	80.1550	40.6358	30.3276	151.1183	0.0	151.118	0.0	151.578
2-3	0.483	0.0	0.483	63.2649	33.0095	24.4607	120.7351	0.0	120.735	0.0	121.218
2-4	0.431	0.0	0.431	66.7519	34.5030	21.7988	123.0538	0.0	123.054	0.0	123.484
3-1	0.480	0.0	0.480	48.5005	25.5331	19.3800	93.4136	0.0	93.414	0.0	93.894
3-2	0.368	0.0	0.368	61.4170	30.8957	25.9003	118.2130	0.0	118.213	0.0	118.581
3-3	0.392	0.0	0.392	47.5614	24.6424	21.1922	93.3960	0.0	93.396	0.0	93.788
3-4	0.339	0.0	0.339	49.7572	25.5605	18.5303	93.8480	0.0	93.848	0.0	94.187
4-2	0.198	0.0	0.198	28.6686	13.3818	14.7850	56.8354	0.0	56.835	0.0	57.033
4-4	0.169	0.0	0.169	20.2460	9.5280	9.5671	39.3411	0.0	39.341	0.0	39.510
5-5	0.433	0.0	0.433	25.9983	12.6734	18.2156	56.8873	0.0	56.887	0.0	57.320
6-6	0.380	0.0	0.380	29.8445	14.5483	17.3291	61.7218	0.0	61.722	0.0	62.102
7-7	0.162	0.0	0.162	17.6887	8.6227	10.6743	36.9856	0.0	36.986	0.0	37.148
8-8	1.010	0.0	1.010	36.6644	17.8728	24.5502	79.0875	0.0	79.088	0.0	80.098
9-9	0.550	0.0	0.550	26.0560	12.7015	19.4865	58.2440	0.0	58.244	0.0	58.794
10-10	0.418	0.0	0.418	26.6924	13.0117	21.1366	60.8407	0.0	60.841	0.0	61.258
165M											
1-1	0.619	0.0	0.619	51.0918	24.9057	21.4778	97.4753	0.0	97.475	0.0	98.095
1-2	0.474	0.0	0.474	67.7060	31.8003	29.8601	129.3664	0.0	129.366	0.0	129.841
1-3	0.520	0.0	0.520	50.8819	24.2191	24.5693	99.6704	0.0	99.670	0.0	100.190
1-4	0.445	0.0	0.445	53.4787	25.2904	20.7830	99.5522	0.0	99.552	0.0	99.997
2-1	0.634	0.0	0.634	66.8246	35.2550	23.8229	125.9025	0.0	125.902	0.0	126.536

(TABLE B.5BD CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
2-2	0.488	0.0	0.488	84.0102	42.3998	32.5128	158.9228	0.0	158.923	0.0	159.411
2-3	0.534	0.0	0.534	66.7180	34.6068	27.0432	128.3680	0.0	128.368	0.0	128.902
2-4	0.459	0.0	0.459	69.5140	35.7669	23.2569	128.5378	0.0	128.538	0.0	128.997
3-1	0.542	0.0	0.542	51.7906	27.1370	21.3888	100.3163	0.0	100.316	0.0	100.858
3-2	0.397	0.0	0.397	65.2723	32.6597	28.0854	126.0175	0.0	126.017	0.0	126.414
3-3	0.443	0.0	0.443	51.0145	26.2396	23.7747	101.0288	0.0	101.029	0.0	101.471
3-4	0.368	0.0	0.368	52.5192	26.8244	19.9884	99.3320	0.0	99.332	0.0	99.700
4-2	0.227	0.0	0.227	32.5239	15.1459	16.9702	64.6399	0.0	64.640	0.0	64.867
4-4	0.198	0.0	0.198	23.0081	10.7918	11.0252	44.8251	0.0	44.825	0.0	45.023
5-5	0.510	0.0	0.510	30.4998	14.8673	21.3681	66.7342	0.0	66.734	0.0	67.244
6-6	0.386	0.0	0.386	31.9006	15.5019	18.0813	65.3838	0.0	65.384	0.0	65.770
7-7	0.187	0.0	0.187	20.4276	9.9578	12.3270	42.7124	0.0	42.712	0.0	42.900
8-8	1.630	0.0	1.630	59.1644	28.8409	39.6160	127.6213	0.0	127.621	0.0	129.252
9-9	0.890	0.0	0.890	42.1706	20.5569	31.5380	94.2656	0.0	94.266	0.0	95.156
10-10	0.671	0.0	0.671	42.9152	20.9198	33.9828	97.8178	0.0	97.818	0.0	98.489
500M											
1-1	0.637	0.0	0.637	52.0358	25.3659	22.0541	99.4559	0.0	99.456	0.0	100.093
1-2	0.483	0.0	0.483	68.8275	32.3135	30.4958	131.6368	0.0	131.637	0.0	132.119
1-3	0.535	0.0	0.535	51.8913	24.6860	25.3242	101.9015	0.0	101.902	0.0	102.436
1-4	0.454	0.0	0.454	54.2790	25.6566	21.2055	101.1411	0.0	101.141	0.0	101.595
2-1	0.651	0.0	0.651	67.7686	35.7151	24.3993	127.8830	0.0	127.883	0.0	128.534
2-2	0.497	0.0	0.497	85.1317	42.9130	33.1484	161.1931	0.0	161.193	0.0	161.690
2-3	0.549	0.0	0.549	67.7274	35.0736	27.7981	130.5991	0.0	130.599	0.0	131.148
2-4	0.468	0.0	0.468	70.3143	36.1330	23.6793	130.1267	0.0	130.127	0.0	130.594
3-1	0.560	0.0	0.560	52.7346	27.5972	21.9651	102.2969	0.0	102.297	0.0	102.857
3-2	0.405	0.0	0.405	66.3938	33.1729	28.7211	128.2878	0.0	128.288	0.0	128.693
3-3	0.458	0.0	0.458	52.0238	26.7065	24.5296	103.2600	0.0	103.260	0.0	103.718
3-4	0.376	0.0	0.376	53.3195	27.1905	20.4109	100.9209	0.0	100.921	0.0	101.297
4-2	0.235	0.0	0.235	33.6453	15.6590	17.6059	66.9102	0.0	66.910	0.0	67.145
4-4	0.206	0.0	0.206	23.8084	11.1580	11.4477	46.4140	0.0	46.414	0.0	46.620
5-5	0.759	0.0	0.759	48.8721	23.8237	34.4119	107.1076	0.0	107.108	0.0	107.866
6-6	0.639	0.0	0.639	52.6193	25.6504	29.9170	108.1867	0.0	108.187	0.0	108.826
7-7	0.319	0.0	0.319	34.8392	16.9831	21.0227	72.8449	0.0	72.845	0.0	73.164
8-8	4.874	0.0	4.874	176.8854	86.2264	118.4413	381.5530	0.0	381.553	0.0	386.427
9-9	2.661	0.0	2.661	126.0905	61.4654	94.2990	281.8542	0.0	281.854	0.0	284.515
10-10	2.003	0.0	2.003	128.0432	62.4172	101.3922	291.8521	0.0	291.852	0.0	293.855
800M											
1-1	0.720	0.0	0.720	56.4227	27.5044	24.7325	108.6596	0.0	108.660	0.0	109.379
1-2	0.522	0.0	0.522	74.0496	34.7029	33.4557	142.2083	0.0	142.208	0.0	142.730
1-3	0.603	0.0	0.603	56.4955	26.8156	28.7675	112.0786	0.0	112.079	0.0	112.682
1-4	0.492	0.0	0.492	57.9918	27.3555	23.1655	108.5128	0.0	108.513	0.0	109.005
2-1	0.734	0.0	0.734	72.1555	37.8536	27.0776	137.0867	0.0	137.087	0.0	137.821
2-2	0.536	0.0	0.536	90.3539	45.3024	36.1084	171.7646	0.0	171.765	0.0	172.300
2-3	0.617	0.0	0.617	72.3315	37.2033	31.2414	140.7762	0.0	140.776	0.0	141.393
2-4	0.506	0.0	0.506	74.0271	37.8319	25.6394	137.4984	0.0	137.498	0.0	138.005
3-1	0.642	0.0	0.642	57.1215	29.7356	24.6435	111.5006	0.0	111.501	0.0	112.143
3-2	0.444	0.0	0.444	71.6159	35.5623	31.6811	138.8593	0.0	138.859	0.0	139.303

(TABLE B.5DD CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
3-3	0.526	0.0	0.526	56.6280	28.8362	27.9729	113.4371	0.0	113.437	0.0	113.963
3-4	0.415	0.0	0.415	57.0324	28.8894	22.3709	108.2927	0.0	108.293	0.0	108.708
4-2	0.274	0.0	0.274	38.8675	18.0485	20.5658	77.4817	0.0	77.482	0.0	77.756
4-4	0.245	0.0	0.245	27.5212	12.8568	13.4077	53.7857	0.0	53.786	0.0	54.031
5-5	1.015	0.0	1.015	66.5928	32.4620	46.9423	145.9971	0.0	145.997	0.0	147.012
6-6	0.811	0.0	0.811	68.7176	33.4978	38.6087	140.8241	0.0	140.824	0.0	141.636
7-7	0.411	0.0	0.411	45.9630	22.4056	27.4087	95.7773	0.0	95.777	0.0	96.188
8-8	7.778	0.0	7.778	282.2646	137.5956	189.0025	608.8630	0.0	608.863	0.0	616.641
9-9	4.246	0.0	4.246	201.2092	98.0835	150.4778	449.7700	0.0	449.770	0.0	454.016
10-10	3.196	0.0	3.196	204.3070	99.5936	161.7825	465.6826	0.0	465.683	0.0	468.878
SPR/COMP ($/100BCM) 98%											
11	0.316	0.0	0.316	11.9706	5.9598	7.6791	25.6095	0.0	25.610	0.0	25.926
12	0.224	0.0	0.224	10.0424	5.0198	6.4739	21.5361	0.0	21.536	0.0	21.761
13	0.232	0.0	0.232	7.2666	3.8863	4.5678	15.7206	0.0	15.721	0.0	15.953
14	0.204	0.0	0.204	6.9942	3.8909	4.8084	15.6936	0.0	15.694	0.0	15.897
21	0.271	0.0	0.271	12.7506	6.3400	8.8864	27.9769	0.0	27.977	0.0	28.248
22	0.179	0.0	0.179	10.8224	5.4000	7.6812	23.9036	0.0	23.904	0.0	24.083
23	0.187	0.0	0.187	8.0466	4.2665	5.7750	18.0881	0.0	18.088	0.0	18.275
24	0.159	0.0	0.159	7.7742	4.2711	6.0157	18.0610	0.0	18.061	0.0	18.219
31	0.238	0.0	0.238	8.9294	4.4591	6.6641	20.0526	0.0	20.053	0.0	20.290
32	0.146	0.0	0.146	7.0011	3.5192	5.4590	15.9793	0.0	15.979	0.0	16.125
33	0.154	0.0	0.154	4.2254	2.3856	3.5528	10.1637	0.0	10.164	0.0	10.318
34	0.126	0.0	0.126	3.9529	2.3903	3.7935	10.1367	0.0	10.137	0.0	10.262
41	0.223	0.0	0.223	9.0745	4.6633	6.2734	20.0112	0.0	20.011	0.0	20.234
42	0.132	0.0	0.132	7.1463	3.7233	5.0683	15.9379	0.0	15.938	0.0	16.069
43	0.139	0.0	0.139	4.3705	2.5897	3.1621	10.1224	0.0	10.122	0.0	10.262
44	0.111	0.0	0.111	4.0981	2.5944	3.4028	10.0953	0.0	10.095	0.0	10.206
SURFACING GRAVEL ($/100CCM)											
11	0.274	0.0	0.274	8.8716	5.0068	5.5096	19.3880	0.0	19.388	274.68	294.342
12	0.202	0.0	0.202	6.8137	3.9397	4.7232	15.4766	0.0	15.477	274.68	290.358
21	0.254	0.0	0.254	10.6498	5.8736	7.4097	23.9331	0.0	23.933	274.68	298.867
22	0.182	0.0	0.182	8.5918	4.8065	6.6233	20.0216	0.0	20.022	274.68	294.883
31	0.215	0.0	0.215	6.5170	3.8420	4.8908	15.2499	0.0	15.250	274.68	290.144
32	0.142	0.0	0.142	4.4591	2.7749	4.1044	11.3384	0.0	11.338	274.68	286.160
41	0.204	0.0	0.204	6.7856	4.1059	4.6498	15.5413	0.0	15.541	274.68	290.425
42	0.131	0.0	0.131	4.7277	3.0388	3.8634	11.6299	0.0	11.630	274.68	286.441
51	0.306	0.0190	0.325	16.1527	8.3924	9.4845	34.0295	0.0	34.030	274.68	309.034
52	0.233	0.0190	0.252	14.0948	7.3253	8.6981	30.1181	0.0	30.118	274.68	305.050
WBM ($/100CCM)											
111	2.173	0.1451	2.318	81.9797	46.8849	60.3516	189.2160	0.0	189.216	417.30	608.839
112	1.682	0.1205	1.802	65.9135	40.7128	53.6137	160.2398	0.0	160.240	417.30	579.346
211	2.130	0.1451	2.276	82.8379	47.3032	61.6092	191.7501	0.0	191.750	417.30	611.330
212	1.639	0.1205	1.759	66.7717	41.1311	54.8713	162.7739	0.0	162.774	417.30	581.837
311	2.097	0.1451	2.242	79.0078	45.4183	59.3684	183.7944	0.0	183.794	417.30	603.341
312	1.605	0.1205	1.726	62.9416	39.2462	52.6305	154.8183	0.0	154.818	417.30	573.848
411	2.082	0.1451	2.227	79.1408	45.6139	58.9738	183.7284	0.0	183.728	417.30	603.260

(TABLE B.5BD CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
412	1.591	0.1205	1.711	63.0745	39.4419	52.2358	154.7522	0.0	154.752	417.30	573.768
511	2.189	0.1641	2.353	89.0139	50.1364	64.1143	203.2647	0.0	203.265	417.30	622.922
512	1.697	0.1395	1.837	72.9476	43.9644	57.3764	174.2884	0.0	174.288	417.30	593.429
DBST/G ($/100SM)											
1111	0.045	0.0072	0.052	2.4087	1.2403	2.6887	6.3377	0.0	6.338	107.54	113.925
1112	0.040	0.0072	0.047	2.4180	1.2630	2.5315	6.2126	0.0	6.213	107.54	113.795
1121	0.046	0.0096	0.055	1.9212	1.0349	2.3633	5.3194	0.0	5.319	107.54	112.910
1122	0.041	0.0096	0.050	1.9305	1.0576	2.2062	5.1943	0.0	5.194	107.54	112.780
2111	0.045	0.0067	0.052	2.3881	1.2344	2.6841	6.3066	0.0	6.307	107.54	113.894
2112	0.040	0.0067	0.046	2.3974	1.2572	2.5269	6.1815	0.0	6.182	107.54	113.764
2121	0.046	0.0092	0.055	1.9005	1.0290	2.3588	5.2883	0.0	5.288	107.54	112.879
2122	0.041	0.0092	0.050	1.9099	1.0517	2.2016	5.1632	0.0	5.163	107.54	112.748
DBST/W ($/100SM)											
1111	0.045	0.0072	0.052	2.4087	1.2403	2.6887	6.3377	0.0	6.338	84.93	91.320
1112	0.040	0.0072	0.047	2.4180	1.2630	2.5315	6.2126	0.0	6.213	84.93	91.189
1121	0.046	0.0096	0.055	1.9212	1.0349	2.3633	5.3194	0.0	5.319	84.93	90.305
1122	0.041	0.0096	0.050	1.9305	1.0576	2.2062	5.1943	0.0	5.194	84.93	90.174
2111	0.045	0.0067	0.052	2.3881	1.2344	2.6841	6.3066	0.0	6.307	84.93	91.288
2112	0.040	0.0067	0.046	2.3974	1.2572	2.5269	6.1815	0.0	6.182	84.93	91.158
2121	0.046	0.0092	0.055	1.9005	1.0290	2.3588	5.2883	0.0	5.288	84.93	90.273
2122	0.041	0.0092	0.050	1.9099	1.0517	2.2016	5.1632	0.0	5.163	84.93	90.143

TABLE D.5CA: UNIT COSTS OF THE 1970'S TECHNICAL PACKAGES FOR ALL STAGES AT THE PRICES OF 1930.

STAGE/TECHNICAL	LABOR			EQUIPMENT					EQUIPMENT		
PACKAGE NUMBER	SKILLED	UNSKILLED	TOTAL	INT/DEP	MAINT/MISC	FUEL	TOTAL	HORSE	AND HORSE	MATERIALS	TOTAL
SITE PREP ($/HA)											
11	53.210	161.8944	215.104	19.6050	12.4247	22.5491	54.5788	0.0	54.579	4.69	274.373
21	9.046	26.8024	35.848	4.6138	2.9835	5.0040	12.6012	0.0	12.601	4.69	53.140
31	5.893	11.9349	17.828	3.7601	2.9710	2.5499	9.2811	0.0	9.281	4.69	31.799
EXC/HAUL ($/100BCM)											
2M											
14-0	0.167	0.0	0.167	0.1103	0.0721	0.0489	0.2313	0.0	0.231	0.0	0.398
6M											
1-1	1.578	0.0	1.578	1.9331	1.5316	0.9229	4.3876	0.0	4.388	0.0	5.966
1-2	1.526	0.0	1.526	2.1761	1.6223	1.1608	4.9591	0.0	4.959	0.0	6.485
2-3	1.233	0.0	1.233	2.1832	2.0144	1.6295	5.8271	0.0	5.827	0.0	7.060
2-5	1.142	0.0	1.142	1.9144	1.9474	1.0912	4.9530	0.0	4.953	0.0	6.095
3-4	0.864	0.0	0.864	2.0206	1.9739	1.3904	5.3849	0.0	5.385	0.0	6.249
3-6	0.773	0.0	0.773	1.6365	1.8276	1.0928	4.5569	0.0	4.557	0.0	5.330
4-1	1.550	0.0	1.550	1.0486	0.8979	0.9066	2.8529	0.0	2.853	0.0	4.403
4-2	1.499	0.0	1.499	1.2869	0.9866	1.1400	3.4134	0.0	3.413	0.0	4.912
4-7	1.004	0.0	1.004	0.7528	0.6942	0.6726	2.1196	0.0	2.120	0.0	3.123
5-3	1.138	0.0	1.138	1.5142	1.0995	1.2336	3.8473	0.0	3.847	0.0	4.986
5-5	1.047	0.0	1.047	1.2550	1.0305	0.7263	3.0117	0.0	3.012	0.0	4.059
5-8	0.534	0.0	0.534	0.5336	0.4644	0.3576	1.3556	0.0	1.356	0.0	1.889
6-4	0.786	0.0	0.786	1.6902	1.2965	1.0164	4.0031	0.0	4.003	0.0	4.789
6-6	0.695	0.0	0.695	1.3218	1.1504	0.7340	3.2063	0.0	3.206	0.0	3.901
6-9	0.353	0.0	0.353	0.6381	0.6216	0.3651	1.6247	0.0	1.625	0.0	1.978
7-10	0.548	0.0	0.548	0.5385	0.4976	0.3443	1.3804	0.0	1.380	0.0	1.927
8-11	0.284	0.0	0.284	0.4841	0.4474	0.3087	1.2401	0.0	1.240	0.0	1.524
9-12	0.387	0.0	0.387	0.6452	0.5112	0.4571	1.6135	0.0	1.614	0.0	2.000
10-13	0.283	0.0	0.283	0.7094	0.5621	0.4539	1.7254	0.0	1.725	0.0	2.008
11-14	0.326	0.0	0.326	0.2033	0.1370	0.1410	0.4813	0.0	0.481	0.0	0.807
12-15	0.126	0.0	0.126	0.1575	0.1248	0.1052	0.3875	0.0	0.387	0.0	0.513
13-16	0.065	0.0	0.065	0.1686	0.1336	0.1167	0.4190	0.0	0.419	0.0	0.484
9M											
1-1	1.583	0.0	1.583	1.9359	1.5338	0.9253	4.3951	0.0	4.395	0.0	5.978
1-2	1.529	0.0	1.529	2.1782	1.6237	1.1627	4.9647	0.0	4.965	0.0	6.493
2-3	1.235	0.0	1.235	2.1868	2.0168	1.6326	5.8362	0.0	5.836	0.0	7.071
2-5	1.146	0.0	1.146	1.9206	1.9524	1.0945	4.9675	0.0	4.957	0.0	6.114
3-4	0.866	0.0	0.866	2.0233	1.9757	1.3921	5.3912	0.0	5.391	0.0	6.257
3-6	0.776	0.0	0.776	1.6411	1.8312	1.0953	4.5676	0.0	4.568	0.0	5.343
4-1	1.555	0.0	1.555	1.0514	0.9001	0.9089	2.8604	0.0	2.860	0.0	4.415
4-2	1.501	0.0	1.501	1.2891	0.9880	1.1419	3.4190	0.0	3.419	0.0	4.920
4-7	1.161	0.0	1.161	0.8711	0.8033	0.7782	2.4526	0.0	2.453	0.0	3.614
5-3	1.141	0.0	1.141	1.5178	1.1018	1.2368	3.8564	0.0	3.856	0.0	4.997
5-5	1.052	0.0	1.052	1.2612	1.0354	0.7296	3.0262	0.0	3.026	0.0	4.078
5-8	0.568	0.0	0.568	0.5685	0.4947	0.3809	1.4442	0.0	1.444	0.0	2.013
6-4	0.787	0.0	0.787	1.6930	1.2983	1.0181	4.0093	0.0	4.009	0.0	4.797
6-6	0.697	0.0	0.697	1.3264	1.1540	0.7365	3.2169	0.0	3.217	0.0	3.914
6-9	0.373	0.0	0.373	0.6734	0.6560	0.3853	1.7146	0.0	1.715	0.0	2.088

(TABLE B.5CA CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
7-10	0.572	0.0	0.572	0.5617	0.5192	0.3592	1.4401	0.0	1.440	0.0	2.012
8-11	0.291	0.0	0.291	0.4972	0.4595	0.3171	1.2739	0.0	1.274	0.0	1.565
9-12	0.397	0.0	0.397	0.6615	0.5241	0.4687	1.6544	0.0	1.654	0.0	2.051
10-13	0.288	0.0	0.288	0.7218	0.5718	0.4618	1.7554	0.0	1.755	0.0	2.043
11-14	0.427	0.0	0.427	0.2666	0.1796	0.1848	0.6310	0.0	0.631	0.0	1.058
12-15	0.164	0.0	0.164	0.2060	0.1632	0.1376	0.5068	0.0	0.507	0.0	0.671
13-16	0.090	0.0	0.090	0.2343	0.1856	0.1621	0.5819	0.0	0.582	0.0	0.672
60M											
1-1	1.660	0.0	1.660	1.9836	1.5716	0.9652	4.5203	0.0	4.520	0.0	6.180
1-2	1.583	0.0	1.583	2.2297	1.6578	1.2080	5.0956	0.0	5.096	0.0	6.678
2-3	1.281	0.0	1.281	2.2585	2.0643	1.6956	6.0184	0.0	6.018	0.0	7.299
2-5	1.215	0.0	1.215	2.0143	2.0265	1.1436	5.1844	0.0	5.184	0.0	6.400
3-4	0.900	0.0	0.900	2.1055	2.0302	1.4427	5.5784	0.0	5.578	0.0	6.478
3-6	0.814	0.0	0.814	1.7170	1.8914	1.1365	4.7449	0.0	4.745	0.0	5.559
4-1	1.632	0.0	1.632	1.0990	0.9378	0.9488	2.9856	0.0	2.986	0.0	4.618
4-2	1.555	0.0	1.555	1.3405	1.0221	1.1872	3.5499	0.0	3.550	0.0	5.105
4-7	3.842	0.0	3.842	2.8818	2.6575	2.5746	8.1139	0.0	8.114	0.0	11.956
5-3	1.187	0.0	1.187	1.5895	1.1493	1.2998	4.0386	0.0	4.039	0.0	5.225
5-5	1.121	0.0	1.121	1.3548	1.1096	0.7788	3.2432	0.0	3.243	0.0	4.364
5-8	1.161	0.0	1.161	1.1615	1.0107	0.7782	2.9504	0.0	2.950	0.0	4.112
6-4	0.822	0.0	0.822	1.7751	1.3527	1.0687	4.1965	0.0	4.197	0.0	5.018
6-6	0.736	0.0	0.736	1.4023	1.2142	0.7777	3.3942	0.0	3.394	0.0	4.130
6-9	0.706	0.0	0.706	1.2740	1.2411	0.7289	3.2440	0.0	3.244	0.0	3.950
7-10	0.736	0.0	0.736	0.7225	0.6678	0.4621	1.8524	0.0	1.852	0.0	2.588
8-11	0.384	0.0	0.384	0.6564	0.6067	0.4186	1.6817	0.0	1.682	0.0	2.066
9-12	0.550	0.0	0.550	0.9179	0.7272	0.6503	2.2954	0.0	2.295	0.0	2.846
10-13	0.372	0.0	0.372	0.9340	0.7400	0.5977	2.2717	0.0	2.272	0.0	2.644
11-14	1.931	0.0	1.931	1.2056	0.8125	0.8359	2.8540	0.0	2.854	0.0	4.785
12-15	0.741	0.0	0.741	0.9293	0.7362	0.6206	2.2861	0.0	2.286	0.0	3.027
13-16	0.464	0.0	0.464	1.2087	0.9576	0.8364	3.0027	0.0	3.003	0.0	3.467
100M											
1-1	1.720	0.0	1.720	2.0205	1.6008	0.9961	4.6174	0.0	4.617	0.0	6.337
1-2	1.624	0.0	1.624	2.2691	1.6839	1.2428	5.1959	0.0	5.196	0.0	6.820
2-3	1.316	0.0	1.316	2.3123	2.0999	1.7428	6.1550	0.0	6.155	0.0	7.471
2-5	1.268	0.0	1.268	2.0860	2.0834	1.1813	5.3508	0.0	5.351	0.0	6.619
3-4	0.927	0.0	0.927	2.1684	2.0719	1.4815	5.7219	0.0	5.722	0.0	6.648
3-6	0.844	0.0	0.844	1.7758	1.9390	1.1684	4.8822	0.0	4.882	0.0	5.726
4-1	1.692	0.0	1.692	1.1360	0.9671	0.9797	3.0827	0.0	3.083	0.0	4.775
4-2	1.596	0.0	1.596	1.3799	1.0482	1.2219	3.6501	0.0	3.650	0.0	5.247
4-7	5.891	0.0	5.891	4.4185	4.0746	3.9475	12.4406	0.0	12.441	0.0	18.332
5-3	1.221	0.0	1.221	1.6433	1.1849	1.3470	4.1751	0.0	4.175	0.0	5.397
5-5	1.174	0.0	1.174	1.4266	1.1664	0.8165	3.4095	0.0	3.410	0.0	4.584
5-8	1.615	0.0	1.615	1.6150	1.4054	1.0821	4.1025	0.0	4.103	0.0	5.717
6-4	0.848	0.0	0.848	1.8381	1.3944	1.1075	4.3400	0.0	4.340	0.0	5.188
6-6	0.765	0.0	0.765	1.4611	1.2608	0.8096	3.5315	0.0	3.532	0.0	4.297
6-9	0.998	0.0	0.998	1.8019	1.7553	1.0309	4.5882	0.0	4.588	0.0	5.586
7-10	0.779	0.0	0.779	0.7655	0.7075	0.4895	1.9625	0.0	1.963	0.0	2.742

(TABLE B.5CA CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
8-11	0.402	0.0	0.402	0.6859	0.6339	0.4374	1.7572	0.0	1.757	0.0	2.159
9-12	0.577	0.0	0.577	0.9621	0.7622	0.6816	2.4059	0.0	2.406	0.0	2.983
10-13	0.414	0.0	0.414	1.0383	0.8226	0.6644	2.5253	0.0	2.525	0.0	2.940
11-14	2.772	0.0	2.772	1.7301	1.1660	1.1995	4.0956	0.0	4.096	0.0	6.867
12-15	1.067	0.0	1.067	1.3378	1.0599	0.8935	3.2912	0.0	3.291	0.0	4.359
13-16	0.676	0.0	0.676	1.7599	1.3943	1.2178	4.3720	0.0	4.372	0.0	5.048
165M											
1-1	1.781	0.0	1.781	2.0582	1.6307	1.0276	4.7164	0.0	4.716	0.0	6.497
1-2	1.668	0.0	1.668	2.3107	1.7115	1.2794	5.3016	0.0	5.302	0.0	6.969
2-3	1.351	0.0	1.351	2.3678	2.1367	1.7917	6.2962	0.0	6.296	0.0	7.649
2-5	1.320	0.0	1.320	2.1563	2.1390	1.2182	5.5135	0.0	5.514	0.0	6.834
3-4	0.953	0.0	0.953	2.2314	2.1136	1.5203	5.8654	0.0	5.865	0.0	6.818
3-6	0.872	0.0	0.872	1.8328	1.9831	1.1993	5.0153	0.0	5.015	0.0	5.888
4-1	1.753	0.0	1.753	1.1736	0.9969	1.0112	3.1817	0.0	3.182	0.0	4.935
4-2	1.640	0.0	1.640	1.4215	1.0758	1.2586	3.7559	0.0	3.756	0.0	5.396
4-7	8.043	0.0	8.043	6.0329	5.5634	5.3899	16.9861	0.0	16.986	0.0	25.030
5-3	1.257	0.0	1.257	1.6989	1.2218	1.3958	4.3165	0.0	4.316	0.0	5.573
5-5	1.226	0.0	1.226	1.4960	1.2221	0.8533	3.5722	0.0	3.572	0.0	4.798
5-8	2.110	0.0	2.110	2.1100	1.8361	1.4138	5.3599	0.0	5.360	0.0	7.470
6-4	0.875	0.0	0.875	1.9011	1.4362	1.1463	4.4836	0.0	4.484	0.0	5.359
6-6	0.794	0.0	0.794	1.5181	1.3060	0.8406	3.6646	0.0	3.665	0.0	4.459
6-9	1.259	0.0	1.259	2.2737	2.2149	1.3009	5.7895	0.0	5.790	0.0	7.049
7-10	0.849	0.0	0.849	0.8345	0.7712	0.5336	2.1393	0.0	2.139	0.0	2.989
8-11	0.429	0.0	0.429	0.7331	0.6775	0.4675	1.8781	0.0	1.878	0.0	2.307
9-12	0.624	0.0	0.624	1.0408	0.8246	0.7371	2.6025	0.0	2.603	0.0	3.226
10-13	0.442	0.0	0.442	1.1099	0.8793	0.7101	2.6993	0.0	2.699	0.0	3.141
11-14	4.187	0.0	4.187	2.6139	1.7615	1.8122	6.1876	0.0	6.188	0.0	10.375
12-15	1.613	0.0	1.613	2.0235	1.6032	1.3514	4.9781	0.0	4.978	0.0	6.592
13-16	1.027	0.0	1.027	2.6735	2.1182	1.8500	6.6418	0.0	6.642	0.0	7.669
500M											
1-1	2.075	0.0	2.075	2.2401	1.7748	1.1798	5.1947	0.0	5.195	0.0	7.270
1-2	1.874	0.0	1.874	2.5066	1.8413	1.4520	5.7999	0.0	5.800	0.0	7.674
2-3	1.522	0.0	1.522	2.6331	2.3124	2.0247	6.9703	0.0	6.970	0.0	8.492
2-5	1.570	0.0	1.570	2.4948	2.4073	1.3961	6.2982	0.0	6.298	0.0	7.868
3-4	1.081	0.0	1.081	2.5354	2.3150	1.7076	6.5580	0.0	6.558	0.0	7.639
3-6	1.011	0.0	1.011	2.1064	2.1999	1.3478	5.6541	0.0	5.654	0.0	6.665
4-1	2.048	0.0	2.048	1.3556	1.1411	1.1634	3.6600	0.0	3.660	0.0	5.708
4-2	1.846	0.0	1.846	1.6175	1.2056	1.4311	4.2542	0.0	4.254	0.0	6.100
4-7	19.796	0.0	19.796	14.8474	13.6920	13.2648	41.8042	0.0	41.804	0.0	61.600
5-3	1.427	0.0	1.427	1.9641	1.3975	1.6289	4.9905	0.0	4.991	0.0	6.418
5-5	1.476	0.0	1.476	1.8354	1.4903	1.0312	4.3569	0.0	4.357	0.0	5.833
5-8	4.308	0.0	4.308	4.3085	3.7494	2.8870	10.9449	0.0	10.945	0.0	15.253
6-4	1.003	0.0	1.003	2.2051	1.6375	1.3336	5.1762	0.0	5.176	0.0	6.179
6-6	0.932	0.0	0.932	1.7917	1.5227	0.9890	4.3034	0.0	4.303	0.0	5.236
6-9	2.524	0.0	2.524	4.5579	4.4400	2.6077	11.6055	0.0	11.605	0.0	14.130
7-10	1.182	0.0	1.182	1.1613	1.0732	0.7426	2.9771	0.0	2.977	0.0	4.159
8-11	0.574	0.0	0.574	0.9807	0.9064	0.6254	2.5125	0.0	2.513	0.0	3.087

(TABLE B.5CA CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
9-12	0.832	0.0	0.832	1.3884	1.1009	0.9836	3.4720	0.0	3.472	0.0	4.304
10-13	0.587	0.0	0.587	1.4729	1.1670	0.9424	3.5823	0.0	3.582	0.0	4.169
11-14	11.750	0.0	11.750	7.3343	4.9427	5.0849	17.3620	0.0	17.362	0.0	29.112
12-15	4.503	0.0	4.503	5.6470	4.4741	3.7714	13.8924	0.0	13.892	0.0	18.395
13-16	2.903	0.0	2.903	7.5562	5.9868	5.2288	18.7718	0.0	18.772	0.0	21.675
800B											
1-1	2.236	0.0	2.236	2.3396	1.8537	1.2630	5.4563	0.0	5.456	0.0	7.693
1-2	1.998	0.0	1.988	2.6150	1.9130	1.5474	6.0755	0.0	6.075	0.0	8.063
2-3	1.614	0.0	1.614	2.7765	2.4074	2.1507	7.3346	0.0	7.335	0.0	8.948
2-5	1.709	0.0	1.709	2.6836	2.5569	1.4952	6.7357	0.0	6.736	0.0	8.445
3-4	1.149	0.0	1.149	2.6970	2.4220	1.8072	6.9262	0.0	6.926	0.0	8.075
3-6	1.083	0.0	1.083	2.2500	2.3137	1.4257	5.9895	0.0	5.989	0.0	7.073
4-1	2.209	0.0	2.209	1.4551	1.2199	1.2466	3.9216	0.0	3.922	0.0	6.130
4-2	1.960	0.0	1.960	1.7259	1.2773	1.5266	4.5298	0.0	4.530	0.0	6.490
4-7	25.896	0.0	25.896	19.4229	17.9115	17.3527	54.6872	0.0	54.687	0.0	80.583
5-3	1.519	0.0	1.519	2.1075	1.4925	1.7549	5.3549	0.0	5.355	0.0	6.874
5-5	1.615	0.0	1.615	2.0242	1.6399	1.1303	4.7945	0.0	4.794	0.0	6.409
5-8	5.540	0.0	5.540	5.5402	4.8212	3.7123	14.0737	0.0	14.074	0.0	19.614
6-4	1.070	0.0	1.070	2.3667	1.7446	1.4331	5.5443	0.0	5.544	0.0	6.615
6-6	1.005	0.0	1.005	1.9353	1.6365	1.0670	4.6388	0.0	4.639	0.0	5.644
6-9	3.215	0.0	3.215	5.8049	5.6547	3.3211	14.7807	0.0	14.781	0.0	17.996
7-10	1.447	0.0	1.447	1.4213	1.3136	0.9089	3.6438	0.0	3.644	0.0	5.091
8-11	0.683	0.0	0.683	1.1655	1.0771	0.7432	2.9858	0.0	2.986	0.0	3.668
9-12	0.892	0.0	0.892	1.4882	1.1791	1.0430	3.7103	0.0	3.710	0.0	4.602
10-13	0.620	0.0	0.620	1.5495	1.2276	0.9809	3.7581	0.0	3.758	0.0	4.378
11-14	18.426	0.0	18.426	11.5015	7.7511	7.9741	27.2267	0.0	27.227	0.0	45.653
12-15	7.092	0.0	7.092	8.8951	7.0475	5.9407	21.8933	0.0	21.883	0.0	28.976
13-16	4.607	0.0	4.607	11.9896	9.4993	8.2967	29.7856	0.0	29.786	0.0	34.393
SPR/COMP ($/100BCM)											
98%											
11	0.387	0.0	0.387	0.4386	0.3373	0.3225	1.0984	0.0	1.098	0.0	1.485
12	0.500	0.0	0.500	0.7327	0.5868	0.5115	1.8310	0.0	1.831	0.0	2.331
13	0.477	0.0	0.477	0.5298	0.4402	0.3371	1.3071	0.0	1.307	0.0	1.784
14	0.700	0.0	0.700	0.6482	0.4744	0.4094	1.5319	0.0	1.532	0.0	2.232
21	0.250	0.0	0.250	0.4749	0.3660	0.3564	1.1971	0.0	1.197	0.0	1.447
22	0.363	0.0	0.363	0.7689	0.6155	0.5453	1.9297	0.0	1.930	0.0	2.292
23	0.340	0.0	0.340	0.5660	0.4689	0.3709	1.4058	0.0	1.406	0.0	1.745
24	0.563	0.0	0.563	0.6844	0.5030	0.4432	1.6306	0.0	1.631	0.0	2.193
31	0.209	0.0	0.209	0.1599	0.1045	0.1359	0.4002	0.0	0.400	0.0	0.610
32	0.322	0.0	0.322	0.4540	0.3540	0.3248	1.1128	0.0	1.133	0.0	1.455
33	0.299	0.0	0.299	0.2511	0.2074	0.1504	0.6089	0.0	0.609	0.0	0.908
34	0.523	0.0	0.523	0.3695	0.2416	0.2227	0.8337	0.0	0.834	0.0	1.356
41	0.182	0.0	0.182	0.1600	0.1046	0.1355	0.4001	0.0	0.400	0.0	0.582
42	0.295	0.0	0.295	0.4541	0.3541	0.3244	1.1327	0.0	1.133	0.0	1.427
43	0.272	0.0	0.272	0.2512	0.2075	0.1500	0.6088	0.0	0.609	0.0	0.880

(TABLE D.5CA CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
44	0.495	0.0	0.495	0.3696	0.2417	0.2223	0.8336	0.0	0.834	0.0	1.329
SURFACING											
GRAVEL ($/100CCM)											
11	0.628	0.0	0.628	0.3789	0.3237	0.2957	0.9982	0.0	0.998	536.54	538.168
12	0.554	0.0	0.554	0.5705	0.4894	0.3504	1.4102	0.0	1.410	536.54	538.505
13	0.916	0.0	0.916	0.7554	0.5312	0.4641	1.7507	0.0	1.751	536.54	539.208
21	0.567	0.0	0.567	0.5103	0.4279	0.3931	1.3313	0.0	1.331	536.54	538.440
22	0.493	0.0	0.493	0.7019	0.5935	0.4478	1.7433	0.0	1.743	536.54	538.777
23	0.855	0.0	0.855	0.8868	0.6354	0.5616	2.0838	0.0	2.084	536.54	539.480
31	0.523	0.0	0.523	0.1923	0.1643	0.1706	0.5271	0.0	0.527	536.54	537.591
32	0.448	0.0	0.448	0.3839	0.3300	0.2253	0.9391	0.0	0.939	536.54	537.928
33	0.810	0.0	0.810	0.5688	0.3719	0.3390	1.2796	0.0	1.280	536.54	538.631
41	0.512	0.0	0.512	0.2076	0.1744	0.1802	0.5622	0.0	0.562	536.54	537.616
42	0.437	0.0	0.437	0.3993	0.3401	0.2349	0.9742	0.0	0.974	536.54	537.953
43	0.800	0.0	0.800	0.5842	0.3819	0.3486	1.3147	0.0	1.315	536.54	538.656
51	0.929	0.1456	1.074	0.6008	0.4345	0.6553	1.6906	0.0	1.691	536.54	539.307
52	0.854	0.1456	1.000	0.7924	0.6002	0.7100	2.1026	0.0	2.103	536.54	539.644
53	1.220	0.1456	1.366	0.9773	0.6421	0.8237	2.4431	0.0	2.443	536.54	540.350
WBM ($/100CCM)											
111	6.020	0.6498	6.670	2.3876	2.0811	3.3278	7.7965	0.0	7.797	640.15	654.614
112	5.847	0.6318	6.479	5.6834	4.9733	4.4426	15.0993	0.0	15.099	640.15	661.726
113	7.781	0.8363	8.617	6.1022	3.9807	5.1611	15.2440	0.0	15.244	640.15	664.009
121	6.653	1.0409	7.694	2.7163	2.3782	3.5103	8.6048	0.0	8.605	640.15	656.447
122	6.492	1.0289	7.521	6.0121	5.2704	4.6250	15.9075	0.0	15.907	640.15	663.576
123	8.414	1.2334	9.648	6.4308	4.2778	5.3436	16.0522	0.0	16.052	640.15	665.849
211	5.951	0.6498	6.601	2.5273	2.1917	3.4314	8.1504	0.0	8.150	640.15	654.899
212	5.790	0.6318	6.421	5.8230	5.0839	4.5461	15.4531	0.0	15.453	640.15	662.022
213	7.712	0.8363	8.548	6.2418	4.0914	5.2647	15.5979	0.0	15.598	640.15	664.294
221	6.584	1.0409	7.625	2.8560	2.4888	3.6139	8.9586	0.0	8.959	640.15	656.731
222	6.423	1.0289	7.452	6.1517	5.3810	4.7286	16.2613	0.0	16.261	640.15	663.861
223	8.345	1.2334	9.578	6.5705	4.3885	5.4472	16.4061	0.0	16.406	640.15	666.132
311	5.893	0.6498	6.541	2.1798	1.9051	3.1885	7.2734	0.0	7.273	640.15	653.964
312	5.744	0.6318	6.375	5.4755	4.7974	4.3032	14.5761	0.0	14.576	640.15	661.100
313	7.666	0.8363	8.502	5.8943	3.8048	5.0218	14.7209	0.0	14.721	640.15	663.371
321	6.526	1.0409	7.567	2.5084	2.2022	3.3710	8.0816	0.0	8.082	640.15	655.797
322	6.365	1.0289	7.394	5.8042	5.0945	4.4857	15.3844	0.0	15.384	640.15	662.926
323	8.287	1.2334	9.521	6.2229	4.1019	5.2043	15.5291	0.0	15.529	640.15	665.198
411	5.892	0.6498	6.532	2.1946	1.9148	3.1978	7.3072	0.0	7.307	640.15	653.987
412	5.721	0.6318	6.352	5.4903	4.8071	4.3125	14.6099	0.0	14.610	640.15	661.110
413	7.643	0.8363	8.479	5.9091	3.8145	5.0311	14.7546	0.0	14.755	640.15	663.382
421	6.515	1.0409	7.556	2.5232	2.2119	3.3802	9.1154	0.0	9.115	640.15	655.819
422	6.354	1.0289	7.383	5.8190	5.1042	4.4949	15.4181	0.0	15.418	640.15	662.949
423	8.276	1.2334	9.509	6.2378	4.1116	5.2135	15.5629	0.0	15.563	640.15	665.220
511	6.308	0.7942	7.102	2.6000	2.1831	3.6848	8.4679	0.0	8.468	640.15	655.720
512	6.147	0.7822	6.929	5.8958	5.0753	4.7995	15.7706	0.0	15.771	640.15	662.847
513	8.069	0.9807	9.050	6.3145	4.0828	5.5181	15.9154	0.0	15.915	640.15	665.113
521	6.941	1.1913	8.132	2.9287	2.4802	3.8673	9.2761	0.0	9.276	640.15	657.556
[illegible]	[illegible]	1.1733	7.951	[illegible]	[illegible]	[illegible]	16.5788	0.0	16.579	640.15	[illegible]

(TABLE B.5CA CONTINUED)

STAGE/TECHNICAL	LABOR			EQUIPMENT					EQUIPMENT		
PACKAGE NUMBER	SKILLED	UNSKILLED	TOTAL	INT/DEP	MAINT/MISC	FUEL	TOTAL	HORSE	AND HORSE	MATERIALS	TOTAL
523	8.702	1.3778	10.080	6.6432	4.3799	5.7005	16.7236	0.0	16.724	640.15	666.951
DBST/G ($/100SM)											
1111	0.125	0.0291	0.155	0.0900	0.0651	0.1136	0.2687	0.0	0.269	13.70	14.121
1112	0.111	0.0291	0.140	0.0920	0.0658	0.1108	0.2687	0.0	0.269	13.70	14.107
1121	0.138	0.0537	0.192	0.0739	0.0619	0.0809	0.2167	0.0	0.217	13.70	14.107
1122	0.123	0.0537	0.177	0.0759	0.0626	0.0781	0.2166	0.0	0.217	13.70	14.092
1211	0.125	0.0289	0.154	0.0905	0.0655	0.1181	0.2741	0.0	0.274	13.70	14.127
1212	0.111	0.0289	0.140	0.0925	0.0663	0.1154	0.2741	0.0	0.274	13.70	14.112
1221	0.138	0.0536	0.192	0.0744	0.0623	0.0855	0.2221	0.0	0.222	13.70	14.112
1222	0.123	0.0536	0.177	0.0764	0.0630	0.0827	0.2221	0.0	0.222	13.70	14.097
DBST/W ($/100SM)											
1111	0.123	0.0280	0.151	0.0890	0.0643	0.1092	0.2625	0.0	0.262	12.19	12.605
1112	0.109	0.0280	0.137	0.0910	0.0650	0.1065	0.2625	0.0	0.262	12.19	12.590
1121	0.136	0.0525	0.188	0.0729	0.0610	0.0765	0.2104	0.0	0.210	12.19	12.590
1122	0.121	0.0525	0.173	0.0749	0.0617	0.0738	0.2104	0.0	0.210	12.19	12.575
1211	0.123	0.0278	0.151	0.0894	0.0646	0.1128	0.2667	0.0	0.267	12.19	12.609
1212	0.108	0.0278	0.136	0.0914	0.0653	0.1100	0.2667	0.0	0.267	12.19	12.594
1221	0.136	0.0524	0.188	0.0733	0.0613	0.0801	0.2147	0.0	0.215	12.19	12.594
1222	0.121	0.0524	0.173	0.0753	0.0621	0.0773	0.2147	0.0	0.215	12.19	12.579

TABLE 8.5CB: UNIT COSTS OF THE 1970'S TECHNICAL PACKAGES FOR ALL STAGES AT THE PRICES OF 1956.

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
SITE PREP ($/HA)											
11	191.675	830.5881	1022.263	57.5809	37.0260	32.6996	127.3065	0.0	127.306	8.48	1158.045
21	32.586	137.5081	170.094	13.5918	8.8908	7.4131	29.8958	0.0	29.896	8.48	208.465
31	21.228	61.2313	82.459	11.0516	8.8537	4.2032	24.1084	0.0	24.108	8.48	115.043
EXC/HAUL ($/100BCM)											
2M											
14-0	0.601	0.0	0.601	0.3248	0.2148	0.0807	0.6203	0.0	0.620	0.0	1.222
6M											
1-1	5.685	0.0	5.685	5.6814	4.5642	1.5213	11.7669	0.0	11.767	0.0	17.452
1-2	5.498	0.0	5.498	6.3954	4.8345	1.9134	13.1433	0.0	13.143	0.0	18.641
2-3	4.441	0.0	4.441	6.3837	6.0031	2.6859	15.0727	0.0	15.073	0.0	19.513
2-5	4.113	0.0	4.113	5.5937	5.8034	1.7987	13.1959	0.0	13.196	0.0	17.309
3-4	3.114	0.0	3.114	5.9232	5.8824	2.2919	14.0976	0.0	14.098	0.0	17.211
3-6	2.786	0.0	2.786	4.7946	5.4464	1.8013	12.0423	0.0	12.042	0.0	14.828
4-1	5.585	0.0	5.585	3.0817	2.6756	1.4943	7.2516	0.0	7.252	0.0	12.837
4-2	5.399	0.0	5.399	3.7822	2.9400	1.8791	8.6013	0.0	8.601	0.0	14.000
4-7	3.616	0.0	3.616	2.2125	2.0689	1.1086	5.3900	0.0	5.390	0.0	9.006
5-3	4.101	0.0	4.101	4.4504	3.2765	2.0335	9.7603	0.0	9.760	0.0	13.861
5-5	3.773	0.0	3.773	3.6883	3.0708	1.1972	7.9564	0.0	7.956	0.0	11.730
5-8	1.922	0.0	1.922	1.5684	1.3839	0.5894	3.5417	0.0	3.542	0.0	5.464
6-4	2.832	0.0	2.832	4.9675	3.8636	1.6754	10.5065	0.0	10.507	0.0	13.338
6-6	2.504	0.0	2.504	3.8848	3.4284	1.2100	8.5231	0.0	8.523	0.0	11.027
6-9	1.273	0.0	1.273	1.8752	1.8523	0.6017	4.3292	0.0	4.329	0.0	5.602
7-10	1.974	0.0	1.974	1.5791	1.4830	0.5676	3.6296	0.0	3.630	0.0	5.604
8-11	1.021	0.0	1.021	1.4196	1.3332	0.5089	3.2616	0.0	3.262	0.0	4.283
9-12	1.393	0.0	1.393	1.8963	1.5234	0.7535	4.1732	0.0	4.173	0.0	5.566
10-13	1.018	0.0	1.018	2.0850	1.6750	0.7482	4.5083	0.0	4.508	0.0	5.527
11-14	1.173	0.0	1.173	0.5987	0.4084	0.2324	1.2395	0.0	1.239	0.0	2.413
12-15	0.452	0.0	0.452	0.4629	0.3719	0.1734	1.0081	0.0	1.008	0.0	1.461
13-16	0.233	0.0	0.233	0.4957	0.3982	0.1924	1.0862	0.0	1.086	0.0	1.320
9M											
1-1	5.701	0.0	5.701	5.6097	4.5709	1.5253	11.7859	0.0	11.786	0.0	17.487
1-2	5.506	0.0	5.506	6.4019	4.8388	1.9166	13.1573	0.0	13.157	0.0	18.664
2-3	4.449	0.0	4.449	6.3943	6.0101	2.6911	15.0955	0.0	15.096	0.0	19.545
2-5	4.130	0.0	4.130	5.6121	5.8182	1.8041	13.2343	0.0	13.234	0.0	17.364
3-4	3.118	0.0	3.118	5.9313	5.8878	2.2947	14.1138	0.0	14.114	0.0	17.232
3-6	2.794	0.0	2.794	4.8080	5.4571	1.8054	12.0705	0.0	12.071	0.0	14.865
4-1	5.602	0.0	5.602	3.0900	2.6823	1.4982	7.2705	0.0	7.271	0.0	12.872
4-2	5.407	0.0	5.407	3.7886	2.9444	1.8823	8.6153	0.0	8.615	0.0	14.022
4-7	4.184	0.0	4.184	2.5601	2.3939	1.2828	6.2368	0.0	6.237	0.0	10.421
5-3	4.109	0.0	4.109	4.4609	3.2835	2.0386	9.7831	0.0	9.783	0.0	13.892
5-5	3.790	0.0	3.790	3.7067	3.0856	1.2026	7.9949	0.0	7.995	0.0	11.785
5-8	2.048	0.0	2.048	1.6709	1.4744	0.6279	3.7732	0.0	3.773	0.0	5.821
6-4	2.836	0.0	2.836	4.9756	3.8690	1.6781	10.5228	0.0	10.523	0.0	13.359
6-6	2.512	0.0	2.512	3.8982	3.4391	1.2140	8.5513	0.0	8.551	0.0	11.064
6-9	1.343	0.0	1.343	1.9791	1.9548	0.6351	4.5690	0.0	4.569	0.0	5.912

(TABLE B.5CB CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
7-10	2.060	0.0	2.060	1.6474	1.5471	0.5921	3.7867	0.0	3.787	0.0	5.847
8-11	1.049	0.0	1.049	1.4582	1.3695	0.5227	3.3504	0.0	3.350	0.0	4.399
9-12	1.428	0.0	1.428	1.9443	1.5620	0.7726	4.2788	0.0	4.279	0.0	5.707
10-13	1.036	0.0	1.036	2.1212	1.7041	0.7612	4.5866	0.0	4.587	0.0	5.623
11-14	1.538	0.0	1.538	0.7849	0.5353	0.3046	1.6249	0.0	1.625	0.0	3.163
12-15	0.592	0.0	0.592	0.6054	0.4864	0.2268	1.3186	0.0	1.319	0.0	1.910
13-16	0.324	0.0	0.324	0.6885	0.5531	0.2672	1.5087	0.0	1.509	0.0	1.833
60M											
1-1	5.979	0.0	5.979	5.8297	4.6834	1.5909	12.1039	0.0	12.104	0.0	18.083
1-2	5.701	0.0	5.701	6.5531	4.9404	1.9913	13.4847	0.0	13.485	0.0	19.186
2-3	4.615	0.0	4.615	6.6050	6.1517	2.7950	15.5516	0.0	15.552	0.0	20.166
2-5	4.379	0.0	4.379	5.8872	6.0392	1.8851	13.8115	0.0	13.812	0.0	18.190
3-4	3.242	0.0	3.242	6.1727	6.0500	2.3781	14.6009	0.0	14.601	0.0	17.843
3-6	2.932	0.0	2.932	5.0311	5.6364	1.8733	12.5408	0.0	12.541	0.0	15.473
4-1	5.880	0.0	5.880	3.2300	2.7947	1.5639	7.5886	0.0	7.589	0.0	13.468
4-2	5.602	0.0	5.602	3.9398	3.0459	1.9570	8.9427	0.0	8.943	0.0	14.544
4-7	13.841	0.0	13.841	8.4695	7.9195	4.2438	20.6328	0.0	20.633	0.0	34.473
5-3	4.275	0.0	4.275	4.6716	3.4251	2.1425	10.2392	0.0	10.239	0.0	14.514
5-5	4.039	0.0	4.039	3.9818	3.3066	1.2837	8.5721	0.0	8.572	0.0	12.611
5-8	4.184	0.0	4.184	3.4135	3.0120	1.2828	7.7084	0.0	7.708	0.0	11.892
6-4	2.960	0.0	2.960	5.2171	4.0312	1.7616	11.0098	0.0	11.010	0.0	13.970
6-6	2.650	0.0	2.650	4.1213	3.6184	1.2820	9.0216	0.0	9.022	0.0	11.672
6-9	2.542	0.0	2.542	3.7444	3.6985	1.2015	8.6444	0.0	8.644	0.0	11.186
7-10	2.650	0.0	2.650	2.1189	1.9900	0.7616	4.8705	0.0	4.871	0.0	7.520
8-11	1.385	0.0	1.385	1.9250	1.8079	0.6900	4.4230	0.0	4.423	0.0	5.808
9-12	1.982	0.0	1.982	2.6977	2.1673	1.0718	5.9368	0.0	5.937	0.0	7.919
10-13	1.339	0.0	1.339	2.7451	2.2053	0.9852	5.9357	0.0	5.936	0.0	7.275
11-14	6.958	0.0	6.958	3.5500	2.4213	1.3778	7.3491	0.0	7.349	0.0	14.307
12-15	2.669	0.0	2.669	2.7311	2.1940	1.0230	5.9481	0.0	5.948	0.0	8.617
13-16	1.673	0.0	1.673	3.5524	2.8539	1.3787	7.7849	0.0	7.785	0.0	9.458
100M											
1-1	6.195	0.0	6.195	5.9383	4.7706	1.6419	12.3508	0.0	12.351	0.0	18.545
1-2	5.851	0.0	5.851	6.6689	5.0182	2.0485	13.7356	0.0	13.736	0.0	19.586
2-3	4.739	0.0	4.739	6.7630	6.2578	2.8728	15.8937	0.0	15.894	0.0	20.633
2-5	4.569	0.0	4.569	6.0982	6.2087	1.9473	14.2541	0.0	14.254	0.0	18.823
3-4	3.338	0.0	3.338	6.3579	6.1744	2.4421	14.9743	0.0	14.974	0.0	18.312
3-6	3.039	0.0	3.039	5.2040	5.7753	1.9259	12.9052	0.0	12.905	0.0	15.944
4-1	6.095	0.0	6.095	3.3386	2.8819	1.6149	7.8354	0.0	7.835	0.0	13.931
4-2	5.751	0.0	5.751	4.0557	3.1237	2.0142	9.1935	0.0	9.194	0.0	14.945
4-7	21.221	0.0	21.221	12.9859	12.1426	6.5069	31.6354	0.0	31.635	0.0	52.856
5-3	4.399	0.0	4.399	4.8297	3.5312	2.2203	10.5812	0.0	10.581	0.0	14.981
5-5	4.229	0.0	4.229	4.1928	3.4761	1.3458	9.0147	0.0	9.015	0.0	13.244
5-8	5.817	0.0	5.817	4.7464	4.1882	1.7837	10.7184	0.0	10.718	0.0	16.536
6-4	3.056	0.0	3.056	5.4022	4.1556	1.8255	11.3833	0.0	11.383	0.0	14.439
6-6	2.757	0.0	2.757	4.2942	3.7573	1.3346	9.3860	0.0	9.386	0.0	12.143
6-9	3.595	0.0	3.595	5.2959	5.2310	1.6993	12.2263	0.0	12.226	0.0	15.821
7-10	2.807	0.0	2.807	2.2449	2.1083	0.8069	5.1602	0.0	5.160	0.0	7.967

(TABLE B.5CB CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
8-11	1.447	0.0	1.447	2.0115	1.8891	0.7210	4.6216	0.0	4.622	0.0	6.069
9-12	2.077	0.0	2.077	2.8275	2.2715	1.1235	6.2226	0.0	6.223	0.0	8.300
10-13	1.493	0.0	1.493	3.0515	2.4515	1.0951	6.5982	0.0	6.598	0.0	8.091
11-14	9.984	0.0	9.984	5.0944	3.4746	1.9772	10.5463	0.0	10.546	0.0	20.531
12-15	3.842	0.0	3.842	3.9318	3.1587	1.4727	8.5631	0.0	8.563	0.0	12.406
13-16	2.436	0.0	2.436	5.1723	4.1552	2.0074	11.3349	0.0	11.335	0.0	13.771
165M											
1-1	6.414	0.0	6.414	6.0490	4.0596	1.6938	12.6023	0.0	12.602	0.0	19.017
1-2	6.008	0.0	6.008	6.7911	5.1003	2.1089	14.0003	0.0	14.000	0.0	20.008
2-3	4.868	0.0	4.868	6.9263	6.3675	2.9533	16.2471	0.0	16.247	0.0	21.115
2-5	4.756	0.0	4.756	6.3045	6.3744	2.0081	14.6870	0.0	14.687	0.0	19.443
3-4	3.433	0.0	3.433	6.5430	6.2987	2.5061	15.3477	0.0	15.348	0.0	18.781
3-6	3.143	0.0	3.143	5.3715	5.9098	1.9769	13.2583	0.0	13.258	0.0	16.401
4-1	6.315	0.0	6.315	3.4493	2.9709	1.6668	8.0870	0.0	8.087	0.0	14.402
4-2	5.909	0.0	5.909	4.1779	3.2058	2.0746	9.4583	0.0	9.458	0.0	15.367
4-7	28.975	0.0	28.975	17.7306	16.5793	8.8844	43.1943	0.0	43.194	0.0	72.169
5-3	4.528	0.0	4.528	4.9930	3.6409	2.3008	10.9347	0.0	10.935	0.0	15.463
5-5	4.416	0.0	4.416	4.3991	3.6419	1.4066	9.4476	0.0	9.448	0.0	13.863
5-8	7.600	0.0	7.600	6.2011	5.4718	2.3304	14.0034	0.0	14.003	0.0	21.604
6-4	3.151	0.0	3.151	5.5873	4.2799	1.8895	11.7567	0.0	11.757	0.0	14.908
6-6	2.861	0.0	2.861	4.4617	3.8918	1.3856	9.7391	0.0	9.739	0.0	12.600
6-9	4.536	0.0	4.536	6.6825	6.6006	2.1443	15.4274	0.0	15.427	0.0	19.963
7-10	3.060	0.0	3.060	2.4472	2.2983	0.8796	5.6251	0.0	5.625	0.0	8.685
8-11	1.547	0.0	1.547	2.1498	2.0190	0.7706	4.9395	0.0	4.939	0.0	6.486
9-12	2.247	0.0	2.247	3.0589	2.4574	1.2150	6.7313	0.0	6.731	0.0	8.979
10-13	1.592	0.0	1.592	3.2619	2.6205	1.1705	7.0529	0.0	7.053	0.0	8.645
11-14	15.084	0.0	15.084	7.6967	5.2495	2.9871	15.9333	0.0	15.933	0.0	31.018
12-15	5.812	0.0	5.812	5.9471	4.7777	2.2276	12.9524	0.0	12.952	0.0	18.764
13-16	3.701	0.0	3.701	7.8575	6.3124	3.0495	17.2194	0.0	17.219	0.0	20.920
500M											
1-1	7.476	0.0	7.476	6.5837	5.2891	1.9447	13.8175	0.0	13.817	0.0	21.293
1-2	6.750	0.0	6.750	7.3670	5.4871	2.3934	15.2475	0.0	15.247	0.0	21.998
2-3	5.481	0.0	5.481	7.7060	6.8912	3.3375	17.9346	0.0	17.935	0.0	23.416
2-5	5.656	0.0	5.656	7.2996	7.1739	2.3012	16.7747	0.0	16.775	0.0	22.430
3-4	3.893	0.0	3.893	7.4364	6.8988	2.8148	17.1499	0.0	17.150	0.0	21.043
3-6	3.641	0.0	3.641	6.1756	6.5558	2.2216	14.9530	0.0	14.953	0.0	18.594
4-1	7.376	0.0	7.376	3.9840	3.4004	1.9177	9.3021	0.0	9.302	0.0	16.678
4-2	6.651	0.0	6.651	4.7538	3.5926	2.3590	10.7054	0.0	10.705	0.0	17.356
4-7	71.309	0.0	71.309	43.6364	40.8029	21.8651	106.3044	0.0	106.304	0.0	177.613
5-3	5.141	0.0	5.141	5.7726	4.1646	2.6850	12.6222	0.0	12.622	0.0	17.764
5-5	5.316	0.0	5.316	5.3942	4.4413	1.6997	11.5353	0.0	11.535	0.0	16.851
5-8	15.520	0.0	15.520	12.6628	11.1735	4.7588	28.5950	0.0	28.595	0.0	44.115
6-4	3.611	0.0	3.611	6.4807	4.8800	2.1982	13.5589	0.0	13.559	0.0	17.170
6-6	3.359	0.0	3.359	5.2657	4.5378	1.6303	11.4338	0.0	11.434	0.0	14.792
6-9	9.093	0.0	9.093	13.3955	13.2314	4.2984	30.9252	0.0	30.925	0.0	40.018
7-10	4.258	0.0	4.258	3.4055	3.1983	1.2241	7.8279	0.0	7.828	0.0	12.086
8-11	2.069	0.0	2.069	2.8760	2.7011	1.0309	6.6080	0.0	6.608	0.0	8.677

(TABLE B.5CB CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
9-12	2.998	0.0	2.998	4.0804	3.2781	1.6214	8.9799	0.0	8.980	0.0	11.978
10-13	2.115	0.0	2.115	4.3289	3.4777	1.5535	9.3601	0.0	9.360	0.0	11.475
11-14	42.326	0.0	42.326	21.5964	14.7297	8.3818	44.7078	0.0	44.708	0.0	87.034
12-15	16.219	0.0	16.219	16.5964	13.3330	6.2165	36.1459	0.0	36.146	0.0	52.365
13-16	10.459	0.0	10.459	22.2077	17.8410	8.6189	48.6677	0.0	48.668	0.0	59.127
BOOM											
1-1	8.056	0.0	8.056	6.8761	5.5240	2.0819	14.4820	0.0	14.482	0.0	22.538
1-2	7.161	0.0	7.161	7.6855	5.7010	2.5507	15.9372	0.0	15.937	0.0	23.098
2-3	5.813	0.0	5.813	8.1274	7.1742	3.5451	18.8468	0.0	18.847	0.0	24.660
2-5	6.157	0.0	6.157	7.8545	7.6196	2.4646	17.9388	0.0	17.939	0.0	24.096
3-4	4.138	0.0	4.138	7.9113	7.2177	2.9789	18.1078	0.0	18.108	0.0	22.246
3-6	3.902	0.0	3.902	6.5977	6.8949	2.3501	15.8428	0.0	15.843	0.0	19.744
4-1	7.957	0.0	7.957	4.2764	3.6353	2.0549	9.9666	0.0	9.967	0.0	17.923
4-2	7.061	0.0	7.061	5.0723	3.8065	2.5164	11.3952	0.0	11.395	0.0	18.456
4-7	93.285	0.0	93.285	57.0840	53.3774	28.6034	139.0647	0.0	139.065	0.0	232.349
5-3	5.473	0.0	5.473	6.1941	4.4476	2.8926	13.5343	0.0	13.534	0.0	19.008
5-5	5.817	0.0	5.817	5.9491	4.8871	1.8632	12.6994	0.0	12.699	0.0	18.517
5-8	19.956	0.0	19.956	16.2826	14.3676	6.1191	36.7694	0.0	36.769	0.0	56.726
6-4	3.856	0.0	3.856	6.9556	5.1989	2.3623	14.5168	0.0	14.517	0.0	18.373
6-6	3.620	0.0	3.620	5.6879	4.8769	1.7588	12.3236	0.0	12.324	0.0	15.943
6-9	11.581	0.0	11.581	17.0605	16.8514	5.4744	39.3863	0.0	39.386	0.0	50.967
7-10	5.212	0.0	5.212	4.1681	3.9146	1.4982	9.5810	0.0	9.581	0.0	14.793
8-11	2.459	0.0	2.459	3.4178	3.2099	1.2251	7.8528	0.0	7.853	0.0	10.312
9-12	3.213	0.0	3.213	4.3738	3.5138	1.7192	9.6068	0.0	9.607	0.0	12.820
10-13	2.235	0.0	2.235	4.5539	3.6585	1.6169	9.8293	0.0	9.829	0.0	12.064
11-14	66.375	0.0	66.375	33.8671	23.0988	13.1441	70.1100	0.0	70.110	0.0	136.485
12-15	25.549	0.0	25.549	26.1426	21.0021	9.7923	56.9370	0.0	56.937	0.0	82.486
13-16	16.596	0.0	16.596	35.2375	28.3086	13.6758	77.2219	0.0	77.222	0.0	93.818
SPR/COMP ($/100BCM)											
98%											
11	1.393	0.0	1.393	1.2895	1.0053	0.5316	2.8264	0.0	2.826	0.0	4.220
12	1.800	0.0	1.800	2.1531	1.7487	0.8431	4.7450	0.0	4.745	0.0	6.545
13	1.717	0.0	1.717	1.5592	1.3120	0.5556	3.4268	0.0	3.427	0.0	5.143
14	2.521	0.0	2.521	1.9069	1.4136	0.6748	3.9953	0.0	3.995	0.0	6.516
21	0.900	0.0	0.900	1.3958	1.0907	0.5874	3.0738	0.0	3.074	0.0	3.974
22	1.306	0.0	1.306	2.2594	1.8341	0.8989	4.9925	0.0	4.992	0.0	6.299
23	1.223	0.0	1.223	1.6655	1.3974	0.6114	3.6743	0.0	3.674	0.0	4.897
24	2.028	0.0	2.028	2.0132	1.4990	0.7305	4.2428	0.0	4.243	0.0	6.270
31	0.755	0.0	0.755	0.4709	0.3115	0.2240	1.0063	0.0	1.006	0.0	1.761
32	1.161	0.0	1.161	1.3345	1.0549	0.5355	2.9249	0.0	2.925	0.0	4.086
33	1.078	0.0	1.078	0.7406	0.6182	0.2479	1.6067	0.0	1.607	0.0	2.685
34	1.882	0.0	1.882	1.0883	0.7198	0.3671	2.1752	0.0	2.175	0.0	4.058
41	0.655	0.0	0.655	0.4713	0.3118	0.2233	1.0064	0.0	1.006	0.0	1.662
42	1.061	0.0	1.061	1.3350	1.0552	0.5348	2.9250	0.0	2.925	0.0	3.986
43	0.979	0.0	0.979	0.7411	0.6185	0.2473	1.6068	0.0	1.607	0.0	2.585
44	1.783	0.0	1.783	1.0887	0.7201	0.3664	2.1753	0.0	2.175	0.0	3.958
SURFACING											

(TABLE B.5CB CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
11	2.264	0.0	2.264	1.1121	0.9647	0.4874	2.5641	0.0	2.564	673.88	678.709
12	1.994	0.0	1.994	1.6805	1.4584	0.5775	3.7165	0.0	3.716	673.88	679.592
13	3.301	0.0	3.301	2.2232	1.5831	0.7650	4.5713	0.0	4.571	673.88	681.753
21	2.044	0.0	2.044	1.4984	1.2750	0.6480	3.4215	0.0	3.421	673.88	679.347
22	1.775	0.0	1.775	2.0669	1.7688	0.7382	4.5738	0.0	4.574	673.88	680.230
23	3.081	0.0	3.081	2.6095	1.8935	0.9256	5.4286	0.0	5.429	673.88	682.391
31	1.882	0.0	1.892	0.5642	0.4897	0.2811	1.3351	0.0	1.335	673.88	677.097
32	1.613	0.0	1.613	1.1327	0.9835	0.3713	2.4874	0.0	2.487	673.88	677.982
33	2.919	0.0	2.919	1.6753	1.1082	0.5588	3.3422	0.0	3.342	673.88	680.143
41	1.845	0.0	1.845	0.6095	0.5197	0.2970	1.4262	0.0	1.426	673.88	677.153
42	1.576	0.0	1.576	1.1780	1.0134	0.3871	2.5786	0.0	2.579	673.88	678.035
43	2.802	0.0	2.882	1.7207	1.1381	0.5746	3.4334	0.0	3.433	673.88	680.196
51	3.346	0.7470	4.093	1.7644	1.2947	1.0027	4.0619	0.0	4.062	673.88	682.036
52	3.077	0.7470	3.824	2.3329	1.7884	1.0928	5.2141	0.0	5.214	673.88	682.919
53	4.395	0.7470	5.142	2.8756	1.9131	1.2803	6.0689	0.0	6.069	673.88	685.092
WBM ($/100CCM)											
111	21.685	3.3338	25.019	7.0011	6.2015	4.9750	18.1776	0.0	18.178	773.51	816.708
112	21.063	3.2412	24.305	16.7686	14.8206	6.8262	38.4155	0.0	38.415	773.51	836.232
113	28.029	4.2908	32.320	17.9702	11.8627	7.8436	37.6765	0.0	37.677	773.51	843.508
121	23.966	5.3403	29.306	7.9646	7.0861	5.3135	20.3642	0.0	20.364	773.51	823.182
122	23.385	5.2786	28.664	17.7321	15.7052	7.1648	40.6021	0.0	40.602	773.51	842.778
123	30.310	6.3281	36.638	18.9337	12.7473	8.1821	39.8631	0.0	39.863	773.51	850.013
211	21.437	3.3338	24.770	7.4115	6.5312	5.1457	19.0884	0.0	19.088	773.51	817.371
212	20.856	3.2412	24.097	17.1790	15.1503	6.9970	39.3263	0.0	39.326	773.51	836.935
213	27.781	4.2908	32.071	18.3806	12.1924	8.0143	38.5874	0.0	38.587	773.51	844.170
221	23.717	5.3403	29.057	8.3750	7.4158	5.4843	21.2751	0.0	21.275	773.51	823.844
222	23.137	5.2786	28.415	18.1425	16.0349	7.3355	41.5129	0.0	41.513	773.51	843.440
223	30.061	6.3281	36.389	19.3441	13.0770	8.3529	40.7740	0.0	40.774	773.51	850.675
311	21.229	3.3338	24.563	6.3906	5.6773	4.7453	16.8133	0.0	16.813	773.51	814.888
312	20.690	3.2412	23.932	16.1581	14.2964	6.5966	37.0511	0.0	37.051	773.51	834.494
313	27.615	4.2908	31.906	17.3598	11.3385	7.6139	36.3122	0.0	36.312	773.51	841.729
321	23.510	5.3403	28.850	7.3541	6.5619	5.0839	18.9999	0.0	19.000	773.51	821.362
322	22.929	5.2786	28.208	17.1216	15.1810	6.9351	39.2377	0.0	39.238	773.51	840.957
323	29.854	6.3281	36.182	18.3233	12.2231	7.9525	38.4988	0.0	38.499	773.51	848.192
411	21.188	3.3338	24.522	6.4343	5.7062	4.7606	16.9010	0.0	16.901	773.51	814.934
412	20.607	3.2412	23.849	16.2018	14.3253	6.6118	37.1389	0.0	37.139	773.51	834.499
413	27.532	4.2908	31.823	17.4034	11.3673	7.6292	36.3999	0.0	36.400	773.51	841.734
421	23.468	5.3403	28.809	7.3978	6.5907	5.0991	19.0876	0.0	19.088	773.51	821.408
422	22.888	5.2786	20.166	17.1653	15.2098	6.9504	39.3255	0.0	39.325	773.51	841.003
423	29.812	6.3281	36.140	18.3669	12.2519	7.9677	38.5865	0.0	38.587	773.51	848.239
511	22.722	4.0747	26.797	7.6253	6.5053	5.4846	19.6152	0.0	19.615	773.51	819.924
512	22.142	4.0129	26.154	17.3928	15.1244	7.3358	39.8531	0.0	39.853	773.51	839.519
513	29.066	5.0316	34.098	18.5945	12.1665	8.3532	39.1142	0.0	39.114	773.51	846.723
521	25.003	6.1120	31.115	8.5889	7.3899	5.8231	21.8018	0.0	21.802	773.51	826.428
522	24.422	6.0194	30.441	18.3563	16.0090	7.6744	42.0397	0.0	42.040	773.51	845.993
523	31.346	7.0690	38.415	19.5580	13.0510	8.6917	41.3008	0.0	41.301	773.51	853.228
DBST/G ($/100SM)											

(TABLE 8.5CB CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
1111	0.452	0.1491	0.601	0.2643	0.1940	0.1682	0.6265	0.0	0.627	19.68	20.906
1112	0.400	0.1491	0.549	0.2705	0.1962	0.1637	0.6304	0.0	0.630	19.68	20.858
1121	0.498	0.2757	0.773	0.2168	0.1843	0.1241	0.5252	0.0	0.525	19.68	20.977
1122	0.444	0.2757	0.719	0.2230	0.1865	0.1196	0.5290	0.0	0.529	19.68	20.927
1211	0.452	0.1485	0.600	0.2657	0.1953	0.1741	0.6351	0.0	0.635	19.68	20.914
1212	0.399	0.1485	0.547	0.2719	0.1974	0.1695	0.6389	0.0	0.639	19.68	20.865
1221	0.498	0.2750	0.773	0.2182	0.1855	0.1300	0.5337	0.0	0.534	19.68	20.985
1222	0.444	0.2750	0.719	0.2244	0.1877	0.1254	0.5375	0.0	0.538	19.68	20.935
DBST/W ($/100SM)											
1111	0.444	0.1438	0.588	0.2614	0.1914	0.1626	0.6154	0.0	0.615	17.17	18.370
1112	0.391	0.1438	0.535	0.2677	0.1936	0.1581	0.6194	0.0	0.619	17.17	18.322
1121	0.489	0.2695	0.759	0.2139	0.1817	0.1185	0.5140	0.0	0.514	17.17	18.440
1122	0.435	0.2695	0.705	0.2201	0.1839	0.1139	0.5179	0.0	0.518	17.17	18.390
1211	0.444	0.1426	0.586	0.2625	0.1924	0.1672	0.6221	0.0	0.622	17.17	18.376
1212	0.391	0.1426	0.533	0.2687	0.1946	0.1626	0.6260	0.0	0.626	17.17	18.327
1221	0.489	0.2689	0.759	0.2150	0.1827	0.1231	0.5207	0.0	0.521	17.17	18.446
1222	0.435	0.2689	0.704	0.2212	0.1849	0.1185	0.5246	0.0	0.525	17.17	18.396

TABLE B.5CC: UNIT COSTS OF THE 1970'S TECHNICAL PACKAGES FOR ALL STAGES AT THE PRICES OF 1974.

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
SITE PREP ($/HA)											
11	596.188	2773.3216	3369.510	137.3270	72.7731	66.7784	276.8787	0.0	276.879	19.09	3665.474
21	101.354	459.1375	560.492	31.1703	17.4746	15.5614	64.2063	0.0	64.206	19.09	643.783
31	66.027	204.4505	270.477	26.1063	17.4015	9.9475	53.4553	0.0	53.455	19.09	343.017
EXC/HAUL ($/100BCM)											
2M											
14-0	1.870	0.0	1.870	0.7461	0.4222	0.1909	1.3592	0.0	1.359	0.0	3.229
6M											
1-1	17.682	0.0	17.692	13.4307	8.9707	3.6005	26.0018	0.0	26.002	0.0	43.683
1-2	17.101	0.0	17.101	15.1187	9.5019	4.5284	29.1490	0.0	29.149	0.0	46.250
2-3	13.813	0.0	13.813	16.1150	11.7987	6.3567	34.2704	0.0	34.270	0.0	48.083
2-5	12.794	0.0	12.794	14.2475	11.4063	4.2569	29.9106	0.0	29.911	0.0	42.704
3-4	9.686	0.0	9.686	14.4729	11.5616	5.4242	31.4587	0.0	31.459	0.0	41.144
3-6	8.665	0.0	8.665	11.8049	10.7045	4.2631	26.7724	0.0	26.772	0.0	35.438
4-1	17.372	0.0	17.372	7.2851	5.2587	3.5365	16.0803	0.0	16.080	0.0	33.452
4-2	16.792	0.0	16.792	8.9410	5.7785	4.4472	19.1667	0.0	19.167	0.0	35.958
4-7	11.246	0.0	11.246	5.2304	4.0662	2.6238	11.9204	0.0	11.920	0.0	23.166
5-3	12.755	0.0	12.755	10.5206	6.4397	4.8125	21.7728	0.0	21.773	0.0	34.528
5-5	11.736	0.0	11.736	8.7192	6.0355	2.8335	17.5882	0.0	17.588	0.0	29.324
5-8	5.979	0.0	5.979	3.7076	2.7200	1.3949	7.8226	0.0	7.823	0.0	13.802
6-4	8.809	0.0	8.809	11.7432	7.5937	3.9650	23.3019	0.0	23.302	0.0	32.110
6-6	7.788	0.0	7.788	9.1635	6.7382	2.8836	18.7853	0.0	18.785	0.0	26.574
6-9	3.959	0.0	3.959	4.4331	3.6405	1.4241	9.4977	0.0	9.498	0.0	13.457
7-10	6.141	0.0	6.141	3.8365	2.9147	1.3433	8.0965	0.0	8.097	0.0	14.238
8-11	3.177	0.0	3.177	3.4508	2.6203	1.2043	7.2754	0.0	7.275	0.0	10.452
9-12	4.333	0.0	4.333	4.4828	2.9942	1.7833	9.2603	0.0	9.260	0.0	13.594
10-13	3.167	0.0	3.167	4.9289	3.2922	1.7708	9.9919	0.0	9.992	0.0	13.159
11-14	3.650	0.0	3.650	1.3811	0.8026	0.5500	2.7337	0.0	2.734	0.0	6.384
12-15	1.407	0.0	1.407	1.0943	0.7309	0.4103	2.2355	0.0	2.235	0.0	3.643
13-16	0.726	0.0	0.726	1.1717	0.7826	0.4553	2.4096	0.0	2.410	0.0	3.136
9M											
1-1	17.733	0.0	17.733	13.4504	8.9839	3.6098	26.0441	0.0	26.044	0.0	43.777
1-2	17.127	0.0	17.127	15.1339	9.5104	4.5359	29.1802	0.0	29.180	0.0	46.307
2-3	13.838	0.0	13.838	16.1399	11.8126	6.3690	34.3215	0.0	34.322	0.0	48.160
2-5	12.845	0.0	12.845	14.2905	11.4352	4.2697	29.9957	0.0	29.996	0.0	42.841
3-4	9.698	0.0	9.698	14.4920	11.5722	5.4308	31.4949	0.0	31.495	0.0	41.193
3-6	8.691	0.0	8.691	11.8365	10.7257	4.2727	26.8349	0.0	26.835	0.0	35.526
4-1	17.424	0.0	17.424	7.3048	5.2718	3.5458	16.1225	0.0	16.122	0.0	33.546
4-2	16.818	0.0	16.818	8.9563	5.7870	4.4547	19.1979	0.0	19.198	0.0	36.015
4-7	13.013	0.0	13.013	6.0521	4.7051	3.0360	13.7932	0.0	13.793	0.0	26.806
5-3	12.781	0.0	12.781	10.5455	6.4536	4.8248	21.8239	0.0	21.824	0.0	34.605
5-5	11.788	0.0	11.788	8.7625	6.0645	2.8462	17.6733	0.0	17.673	0.0	29.461
5-8	6.370	0.0	6.370	3.9500	2.8978	1.4861	8.3339	0.0	8.334	0.0	14.704
6-4	8.821	0.0	8.821	11.7622	7.6044	3.9716	23.3381	0.0	23.338	0.0	32.160
6-6	7.814	0.0	7.814	9.2152	6.7594	2.8732	18.8478	0.0	18.848	0.0	26.662
6-9	4.179	0.0	4.179	4.6785	3.8421	1.5030	10.0236	0.0	10.024	0.0	14.202

(TABLE B.5CC CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
7-10	6.407	0.0	6.407	4.0046	3.0408	1.4014	8.4468	0.0	8.447	0.0	14.854
8-11	3.263	0.0	3.263	3.5447	2.6916	1.2370	7.4733	0.0	7.473	0.0	10.736
9-12	4.443	0.0	4.443	4.5962	3.0699	1.8285	9.4947	0.0	9.495	0.0	13.938
10-13	3.223	0.0	3.223	5.0146	3.3494	1.8016	10.1655	0.0	10.166	0.0	13.388
11-14	4.785	0.0	4.785	1.8106	1.0522	0.7209	3.5837	0.0	3.584	0.0	8.368
12-15	1.840	0.0	1.840	1.4313	0.9560	0.5367	2.9239	0.0	2.924	0.0	4.764
13-16	1.009	0.0	1.009	1.6275	1.0871	0.6324	3.3469	0.0	3.347	0.0	4.355
60M											
1-1	18.597	0.0	18.597	13.7612	9.2049	3.7852	26.7512	0.0	26.751	0.0	45.349
1-2	17.733	0.0	17.733	15.4913	9.7100	4.7127	29.9140	0.0	29.914	0.0	47.647
2-3	14.354	0.0	14.354	16.6381	12.0908	6.6147	35.3435	0.0	35.344	0.0	49.698
2-5	13.619	0.0	13.619	14.9413	11.8697	4.4615	31.2724	0.0	31.272	0.0	44.892
3-4	10.085	0.0	10.085	15.0628	11.8910	5.6282	32.5819	0.0	32.582	0.0	42.667
3-6	9.121	0.0	9.121	12.3640	11.0780	4.4335	27.8755	0.0	27.875	0.0	36.996
4-1	18.288	0.0	18.286	7.6356	5.4928	3.7012	16.8297	0.0	16.830	0.0	35.117
4-2	17.424	0.0	17.424	9.3137	5.9866	4.6315	19.9317	0.0	19.932	0.0	37.355
4-7	43.050	0.0	43.050	20.0217	15.5654	10.0438	45.6309	0.0	45.631	0.0	88.681
5-3	13.297	0.0	13.297	11.0436	6.7318	5.0705	22.8459	0.0	22.846	0.0	36.143
5-5	12.562	0.0	12.562	9.4130	6.4989	3.0381	18.9500	0.0	18.950	0.0	31.512
5-8	13.013	0.0	13.013	8.0695	5.9200	3.0360	17.0254	0.0	17.025	0.0	30.038
6-4	9.208	0.0	9.208	12.3330	7.9231	4.1690	24.4252	0.0	24.425	0.0	33.634
6-6	8.244	0.0	8.244	9.7426	7.1117	3.0340	19.8883	0.0	19.888	0.0	28.132
6-9	7.906	0.0	7.906	8.8517	7.2692	2.8436	18.9644	0.0	18.964	0.0	26.870
7-10	8.241	0.0	8.241	5.1508	3.9112	1.8025	10.8645	0.0	10.865	0.0	19.106
8-11	4.308	0.0	4.308	4.6795	3.5534	1.6331	9.8660	0.0	9.866	0.0	14.174
9-12	6.165	0.0	6.165	6.3773	4.2596	2.5367	13.1736	0.0	13.174	0.0	19.338
10-13	4.166	0.0	4.166	6.4894	4.3345	2.3316	13.1555	0.0	13.156	0.0	17.321
11-14	21.641	0.0	21.641	8.1891	4.7589	3.2608	16.2088	0.0	16.209	0.0	37.850
12-15	8.302	0.0	8.302	6.4562	4.3123	2.4211	13.1895	0.0	13.190	0.0	21.491
13-16	5.204	0.0	5.204	8.3977	5.6091	3.2629	17.2697	0.0	17.270	0.0	22.474
100M											
1-1	19.268	0.0	19.268	14.0380	9.3764	3.8858	27.3001	0.0	27.300	0.0	46.568
1-2	18.197	0.0	18.197	15.7651	9.8629	4.8481	30.4762	0.0	30.476	0.0	48.674
2-3	14.741	0.0	14.741	17.0117	12.2994	6.7990	36.1101	0.0	36.110	0.0	50.851
2-5	14.212	0.0	14.212	15.4400	12.2028	4.6085	32.2512	0.0	32.251	0.0	46.464
3-4	10.382	0.0	10.382	15.5004	12.1353	5.7796	33.4153	0.0	33.415	0.0	43.797
3-6	9.453	0.0	9.453	12.7727	11.3509	4.5580	28.6816	0.0	28.682	0.0	38.135
4-1	18.958	0.0	18.958	7.8924	5.6643	3.8218	17.3785	0.0	17.379	0.0	36.337
4-2	17.888	0.0	17.888	9.5875	6.1395	4.7669	20.4938	0.0	20.494	0.0	38.382
4-7	66.006	0.0	66.006	30.6984	23.8657	15.3997	69.9637	0.0	69.964	0.0	135.970
5-3	13.684	0.0	13.684	11.4172	6.9404	5.2548	23.6125	0.0	23.612	0.0	37.296
5-5	13.155	0.0	13.155	9.9117	6.8320	3.1851	19.9286	0.0	19.929	0.0	33.084
5-8	18.094	0.0	18.094	11.2205	8.2316	4.2215	23.6736	0.0	23.674	0.0	41.768
6-4	9.505	0.0	9.505	12.7707	8.1675	4.3204	25.2586	0.0	25.259	0.0	34.764
6-6	8.576	0.0	8.576	10.1513	7.3847	3.1585	20.6944	0.0	20.694	0.0	29.271
6-9	11.182	0.0	11.182	12.5194	10.2812	4.0218	26.8224	0.0	26.822	0.0	38.004
7-10	8.731	0.0	8.731	5.4571	4.1436	1.9097	11.5106	0.0	11.511	0.0	20.242

(TABLE B.5CC CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
8-11	4.501	0.0	4.501	4.8897	3.7129	1.7064	10.3091	0.0	10.309	0.0	14.810
9-12	6.461	0.0	6.461	6.6842	4.4646	2.6590	13.8078	0.0	13.808	0.0	20.269
10-13	4.643	0.0	4.643	7.2138	4.8163	2.5918	14.6238	0.0	14.624	0.0	19.267
11-14	31.056	0.0	31.056	11.7517	6.8292	4.6794	23.2603	0.0	23.260	0.0	54.316
12-15	11.952	0.0	11.952	9.2946	6.2081	3.4855	18.9882	0.0	18.988	0.0	30.940
13-16	7.577	0.0	7.577	12.2272	8.1669	4.7508	25.1448	0.0	25.145	0.0	32.722
165M											
1-1	19.951	0.0	19.951	14.2997	9.5512	4.0087	27.8595	0.0	27.859	0.0	47.811
1-2	18.686	0.0	18.686	16.0541	10.0243	4.9910	31.0695	0.0	31.069	0.0	49.757
2-3	15.141	0.0	15.141	17.3977	12.5150	6.9895	36.9021	0.0	36.902	0.0	52.043
2-5	14.793	0.0	14.793	15.9278	12.5286	4.7524	33.2087	0.0	33.209	0.0	48.001
3-4	10.679	0.0	10.679	15.9360	12.3797	5.9310	34.2467	0.0	34.249	0.0	44.927
3-6	9.776	0.0	9.776	13.1687	11.6154	4.6787	29.4628	0.0	29.463	0.0	39.239
4-1	19.642	0.0	19.642	8.1541	5.8391	3.9448	17.9379	0.0	17.938	0.0	37.580
4-2	18.378	0.0	18.378	9.8765	6.3009	4.9098	21.0871	0.0	21.087	0.0	39.465
4-7	90.123	0.0	90.123	41.9149	32.5856	21.0263	95.5269	0.0	95.527	0.0	185.650
5-3	14.083	0.0	14.083	11.8033	7.1560	5.4453	24.4045	0.0	24.405	0.0	38.488
5-5	13.735	0.0	13.735	10.3995	7.1579	3.3290	20.8863	0.0	20.886	0.0	34.621
5-8	23.640	0.0	23.640	14.6594	10.7545	5.5153	30.9293	0.0	30.929	0.0	54.569
6-4	9.802	0.0	9.802	13.2083	8.4119	4.4718	26.0919	0.0	26.092	0.0	35.894
6-6	8.899	0.0	8.899	10.5473	7.6492	3.2792	21.4756	0.0	21.476	0.0	30.374
6-9	14.109	0.0	14.109	15.7973	12.9731	5.0748	33.8451	0.0	33.845	0.0	47.954
7-10	9.518	0.0	9.518	5.9488	4.5172	2.0818	12.5478	0.0	12.548	0.0	22.066
8-11	4.811	0.0	4.811	5.2259	3.9683	1.8238	11.0180	0.0	11.018	0.0	15.829
9-12	6.990	0.0	6.990	7.2312	4.8299	2.8755	14.9366	0.0	14.937	0.0	21.927
10-13	4.952	0.0	4.952	7.7111	5.1505	2.7702	15.6318	0.0	15.632	0.0	20.584
11-14	46.919	0.0	46.919	17.7545	10.3175	7.0696	35.1416	0.0	35.142	0.0	82.060
12-15	18.078	0.0	18.078	14.0506	9.3903	5.2720	28.7210	0.0	28.721	0.0	46.799
13-16	11.510	0.0	11.510	18.5749	12.4067	7.2172	38.1987	0.0	38.199	0.0	49.709
500M											
1-1	23.253	0.0	23.253	15.5637	10.3954	4.6025	30.5615	0.0	30.562	0.0	53.815
1-2	20.996	0.0	20.996	17.4155	10.7845	5.6643	33.8643	0.0	33.864	0.0	54.860
2-3	17.050	0.0	17.050	19.2408	13.5442	7.8987	40.6837	0.0	40.684	0.0	57.733
2-5	17.591	0.0	17.591	18.2802	14.0998	5.4461	37.8261	0.0	37.826	0.0	55.417
3-4	12.110	0.0	12.110	18.0500	13.5591	6.6616	38.2707	0.0	38.271	0.0	50.381
3-6	11.323	0.0	11.323	15.0695	12.8850	5.2579	33.2124	0.0	33.212	0.0	44.536
4-1	22.944	0.0	22.944	9.4181	6.6833	4.5385	20.6399	0.0	20.640	0.0	43.583
4-2	20.687	0.0	20.687	11.2379	7.0611	5.5831	23.8820	0.0	23.882	0.0	44.569
4-7	221.801	0.0	221.801	103.1557	80.1958	51.7474	235.0990	0.0	235.099	0.0	456.899
5-3	15.992	0.0	15.992	13.6464	8.1852	6.3545	28.1861	0.0	28.186	0.0	44.178
5-5	16.534	0.0	16.534	12.7519	8.7291	4.0227	25.5037	0.0	25.504	0.0	42.038
5-8	48.273	0.0	48.273	29.9346	21.9606	11.2624	63.1576	0.0	63.158	0.0	111.431
6-4	11.233	0.0	11.233	15.3203	9.5913	5.2024	30.1140	0.0	30.114	0.0	41.347
6-6	10.446	0.0	10.446	12.4481	8.9187	3.8584	25.2252	0.0	25.225	0.0	35.672
6-9	28.283	0.0	28.283	31.6667	26.0054	10.1720	67.8450	0.0	67.845	0.0	96.128
7-10	13.245	0.0	13.245	8.2783	6.2861	2.8970	17.4615	0.0	17.461	0.0	30.707
8-11	6.436	0.0	6.436	6.9913	5.3088	2.4399	14.7399	0.0	14.740	0.0	21.175

(TABLE B.5CC CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
9-12	9.324	0.0	9.324	9.6461	6.4429	3.8373	19.9262	0.0	19.926	0.0	29.251
10-13	6.577	0.0	6.577	10.2335	6.8352	3.6765	20.7452	0.0	20.745	0.0	27.323
11-14	131.651	0.0	131.651	49.8179	28.9503	19.8368	98.6051	0.0	98.605	0.0	230.256
12-15	50.449	0.0	50.449	39.2338	26.2052	14.7125	80.1513	0.0	80.151	0.0	130.600
13-16	32.532	0.0	32.532	52.4988	35.0654	20.3981	107.9623	0.0	107.962	0.0	140.495
800M											
1-1	25.059	0.0	25.059	16.2549	10.8571	4.9272	32.0392	0.0	32.039	0.0	57.098
1-2	22.273	0.0	22.273	18.1684	11.2050	6.0366	35.4100	0.0	35.410	0.0	57.693
2-3	18.081	0.0	18.081	20.2371	14.1006	8.3901	42.7277	0.0	42.728	0.0	60.809
2-5	19.152	0.0	19.152	19.5919	14.9760	5.8339	40.4008	0.0	40.401	0.0	59.553
3-4	12.871	0.0	12.871	19.1726	14.1866	7.0503	40.4086	0.0	40.409	0.0	53.280
3-6	12.136	0.0	12.136	16.0674	13.5516	5.5620	35.1809	0.0	35.181	0.0	47.317
4-1	24.749	0.0	24.749	10.1093	7.1451	4.8632	22.1176	0.0	22.118	0.0	46.867
4-2	21.963	0.0	21.963	11.9908	7.4815	5.9554	25.4277	0.0	25.428	0.0	47.391
4-7	290.154	0.0	290.154	134.9457	104.9102	67.6947	307.5503	0.0	307.550	0.0	597.704
5-3	17.024	0.0	17.024	14.6426	8.7416	6.8459	30.2301	0.0	30.230	0.0	47.254
5-5	18.094	0.0	18.094	14.0636	9.6052	4.4096	28.0784	0.0	28.078	0.0	46.173
5-8	62.073	0.0	62.073	38.4919	28.2387	14.4819	81.2126	0.0	81.213	0.0	143.285
6-4	11.994	0.0	11.994	16.4429	10.2182	5.5908	32.2518	0.0	32.252	0.0	44.246
6-6	11.259	0.0	11.259	13.4460	9.5853	4.1625	27.1937	0.0	27.194	0.0	38.453
6-9	36.021	0.0	36.021	40.3307	33.1205	12.9560	86.4072	0.0	86.407	0.0	122.428
7-10	16,211	0.0	16.211	10.1323	7.6939	3.5458	21.3720	0.0	21.372	0.0	37.583
8-11	7.646	0.0	7.648	8.3083	6.3068	2.8995	17.5165	0.0	17.517	0.0	25.164
9-12	9.995	0.0	9.995	10.3395	6.9061	4.0689	21.3145	0.0	21.314	0.0	31.310
10-13	6.951	0.0	6.951	10.7653	7.1905	3.8268	21.7826	0.0	21.783	0.0	28.734
11-14	206.453	0.0	206.453	78.1236	45.3994	31.1077	154.6305	0.0	154.630	0.0	361.083
12-15	79.467	0.0	79.467	61.8007	41.2784	23.1751	126.2542	0.0	126.254	0.0	205.721
13-16	51.620	0.0	51.620	83.3008	55.6389	32.3661	171.3057	0.0	171.306	0.0	222.925
SPR/COMP ($/100BCM)											
98%											
11	4.333	0.0	4.333	3.0339	1.9758	1.2582	6.2678	0.0	6.268	0.0	10.601
12	5.597	0.0	5.597	5.0993	3.4371	1.9954	10.5318	0.0	10.532	0.0	16.129
13	5.339	0.0	5.339	3.6210	2.5786	1.3149	7.5145	0.0	7.514	0.0	12.854
14	7.841	0.0	7.841	4.4520	2.7784	1.5969	8.8274	0.0	8.827	0.0	16.669
21	2.799	0.0	2.799	3.2851	2.1436	1.3902	6.8190	0.0	6.819	0.0	9.618
22	4.063	0.0	4.063	5.3506	3.6049	2.1274	11.0829	0.0	11.083	0.0	15.145
23	3.805	0.0	3.805	3.8723	2.7464	1.4469	8.0656	0.0	8.066	0.0	11.870
24	6.307	0.0	6.307	4.7033	2.9463	1.7289	9.3785	0.0	9.379	0.0	15.685
31	2.347	0.0	2.347	1.0816	0.6122	0.5300	2.2238	0.0	2.224	0.0	4.571
32	3.611	0.0	3.611	3.1471	2.0734	1.2673	6.4877	0.0	6.488	0.0	10.099
33	3.353	0.0	3.353	1.6688	1.2150	0.5867	3.4705	0.0	3.470	0.0	6.824
34	5.855	0.0	5.855	2.4998	1.4148	0.8688	4.7834	0.0	4.783	0.0	10.639
41	2.038	0.0	2.038	1.0827	0.6128	0.5285	2.2239	0.0	2.224	0.0	4.262
42	3.302	0.0	3.302	3.1481	2.0740	1.2657	6.4878	0.0	6.488	0.0	9.789
43	3.044	0.0	3.044	1.6698	1.2156	0.5852	3.4706	0.0	3.471	0.0	6.514

(TABLE B.5CC CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
44	5.546	0.0	5.546	2.5009	1.4154	0.8672	4.7835	0.0	4.783	0.0	10.329
SURFACING											
GRAVEL ($/100CCM)											
11	7.042	0.0	7.042	2.6715	1.8960	1.1534	5.7209	0.0	5.721	1023.64	1036.403
12	6.203	0.0	6.203	3.8541	2.8664	1.3668	8.0873	0.0	8.087	1023.64	1037.931
13	10.266	0.0	10.266	5.1599	3.1115	1.8104	10.0819	0.0	10.082	1023.64	1043.988
21	6.358	0.0	6.358	3.5948	2.5060	1.5337	7.6245	0.0	7.624	1023.64	1037.623
22	5.520	0.0	5.520	4.7673	3.4764	1.7471	9.9908	0.0	9.991	1023.64	1039.151
23	9.582	0.0	9.582	6.0732	3.7215	2.1907	11.9854	0.0	11.985	1023.64	1045.208
31	5.855	0.0	5.855	1.3600	0.9625	0.6654	2.9878	0.0	2.988	1023.64	1032.483
32	5.017	0.0	5.017	2.5425	1.9329	0.8788	5.3542	0.0	5.354	1023.64	1034.011
33	9.079	0.0	9.079	3.8484	2.1780	1.3224	7.3488	0.0	7.349	1023.64	1040.068
41	5.739	0.0	5.739	1.4641	1.0214	0.7029	3.1884	0.0	3.188	1023.64	1032.568
42	4.901	0.0	4.901	2.6466	1.9918	0.9163	5.5547	0.0	5.555	1023.64	1034.096
43	8.963	0.0	8.963	3.9525	2.2369	1.3599	7.5493	0.0	7.549	1023.64	1040.153
51	10.408	2.4943	12.902	4.1910	2.5452	2.1889	8.9250	0.0	8.925	1023.64	1045.468
52	9.569	2.4943	12.064	5.3735	3.5156	2.4023	11.2914	0.0	11.291	1023.64	1046.996
53	13.671	2.4943	16.165	6.6794	3.7607	2.8459	13.2860	0.0	13.286	1023.64	1053.091
WBM ($/100CCM)											
111	67.451	11.1316	78.582	17.0408	12.1890	10.5622	39.7919	0.0	39.792	1110.92	1229.298
112	65.516	10.8224	76.339	37.6821	29.1294	14.9762	81.7877	0.0	81.788	1110.92	1269.050
113	87.183	14.3268	101.510	41.3852	23.3157	16.9873	81.6883	0.0	81.688	1110.92	1294.121
121	74.544	17.8312	92.375	19.3408	13.9292	11.4531	44.7231	0.0	44.723	1110.92	1248.021
122	72.738	17.6250	90.363	39.9821	30.8695	15.8672	86.7188	0.0	86.719	1110.92	1288.006
123	94.276	21.1294	115.406	43.6852	25.0559	17.8783	86.6194	0.0	86.619	1110.92	1312.948
211	66.677	11.1316	77.808	18.0109	12.8370	10.9663	41.8143	0.0	41.814	1110.92	1230.546
212	64.871	10.8224	75.694	38.6523	29.7774	15.3804	83.8100	0.0	83.810	1110.92	1270.427
213	86.409	14.3268	100.736	42.3554	23.9637	17.3914	83.7106	0.0	83.711	1110.92	1295.370
221	73.770	17.8312	91.601	20.3110	14.5772	11.8573	46.7454	0.0	46.745	1110.92	1249.270
222	71.965	17.6250	89.590	40.9523	31.5175	16.2713	88.7412	0.0	88.741	1110.92	1289.254
223	93.502	21.1294	114.632	44.6554	25.7039	18.2824	88.6417	0.0	88.642	1110.92	1314.197
311	66.032	11.1316	77.164	15.5817	11.1587	10.0187	36.7591	0.0	36.759	1110.92	1224.846
312	64.355	10.8224	75.178	36.2230	28.0991	14.4328	78.7548	0.0	78.755	1110.92	1264.856
313	85.893	14.3268	100.220	39.9261	22.2854	16.4438	78.6554	0.0	78.655	1110.92	1289.799
321	73.125	17.8312	90.956	17.8817	12.8966	10.9097	41.6902	0.0	41.690	1110.92	1243.570
322	71.320	17.6250	88.945	38.5230	29.8392	15.3237	83.6860	0.0	83.686	1110.92	1283.554
323	92.858	21.1294	113.987	42.2262	24.0256	17.3348	83.5865	0.0	83.587	1110.92	1308.497
411	65.903	11.1316	77.035	15.6819	11.2154	10.0548	36.9521	0.0	36.952	1110.92	1224.910
412	64.097	10.8224	74.920	36.3232	28.1558	14.4688	78.9479	0.0	78.948	1110.92	1264.791
413	85.635	14.3268	99.962	40.0263	22.3421	16.4799	78.8484	0.0	78.848	1110.92	1289.734
421	72.996	17.6312	90.828	17.9819	12.9556	10.9457	41.8833	0.0	41.883	1110.92	1243.634
422	71.191	17.6250	88.816	38.6233	29.8959	15.3598	83.8790	0.0	83.879	1110.92	1283.618
423	92.729	21.1294	113.858	42.3264	24.0823	17.3709	83.7796	0.0	83.780	1110.92	1308.561
511	70.675	13.6053	84.280	18.4934	12.7867	11.5811	42.8612	0.0	42.861	1110.92	1238.061
512	68.869	13.3992	82.268	39.1347	29.7270	15.9952	84.8569	0.0	84.857	1110.92	1278.049
513	90.407	16.8005	107.208	42.8378	23.9134	18.0063	84.7575	0.0	84.757	1110.92	1302.888
521	77.768	20.4079	98.176	20.7934	14.5268	12.4721	47.7923	0.0	47.792	1110.92	1256.892
522	75.963	20.0987	96.061	41.4347	31.4672	16.8862	89.7881	0.0	89.788	1110.92	1296.773

(TABLE B.50C CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
523	97.500	23.6031	121.104	45.1378	25.6535	18.8973	89.6886	0.0	89.689	1110.92	1321.716
DBST/G ($/100SM)											
1111	1.406	0.4978	1.904	0.6266	0.3814	0.3530	1.3609	0.0	1.361	45.65	48.910
1112	1.243	0.4978	1.741	0.6310	0.3857	0.3422	1.3589	0.0	1.359	45.65	46.746
1121	1.548	0.9204	2.468	0.5181	0.3624	0.2718	1.1522	0.0	1.152	45.65	49.266
1122	1.380	0.9204	2.300	0.5225	0.3666	0.2610	1.1502	0.0	1.150	45.65	49.096
1211	1.406	0.4958	1.902	0.6295	0.3839	0.3630	1.3767	0.0	1.377	45.65	48.924
1212	1.241	0.4958	1.736	0.6344	0.3881	0.3522	1.3747	0.0	1.375	45.65	48.757
1221	1.548	0.9184	2.466	0.5214	0.3648	0.2818	1.1680	0.0	1.168	45.65	49.280
1222	1.380	0.9184	2.298	0.5259	0.3691	0.2710	1.1660	0.0	1.166	45.65	49.110
DBST/W ($/100SM)											
1111	1.380	0.4803	1.860	0.6198	0.3763	0.3433	1.3394	0.0	1.339	38.11	41.312
1112	1.217	0.4803	1.698	0.6243	0.3807	0.3326	1.3376	0.0	1.338	38.11	41.147
1121	1.522	0.8998	2.422	0.5113	0.3573	0.2622	1.1307	0.0	1.131	38.11	41.664
1122	1.354	0.8998	2.254	0.5157	0.3616	0.2514	1.1287	0.0	1.129	38.11	41.494
1211	1.390	0.4762	1.856	0.6223	0.3782	0.3512	1.3518	0.0	1.352	38.11	41.320
1212	1.215	0.4762	1.691	0.6268	0.3825	0.3404	1.3497	0.0	1.350	38.11	41.153
1221	1.522	0.8977	2.420	0.5138	0.3592	0.2700	1.1431	0.0	1.143	38.11	41.674
1222	1.354	0.8977	2.252	0.5183	0.3635	0.2592	1.1410	0.0	1.141	38.11	41.505

TABLE B.5CD: UNIT COSTS OF THE 1970'S TECHNICAL PACKAGES FOR ALL STAGES AT THE PRICES OF A TYPICAL DEVELOPING COUNTRY.

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
SITE PREP ($/HA)											
11	12.093	17.5972	29.690	334.6667	144.0271	294.9722	773.6653	0.0	773.665	57.60	851.954
21	2.056	2.9133	4.969	72.9035	34.5526	69.1464	175.6024	0.0	175.602	57.60	238.171
31	1.339	1.2973	2.637	62.9347	34.4411	42.0316	139.4074	0.0	139.407	57.60	199.643
EXC/HAUL ($/100BCM)											
2M											
14-0	0.038	0.0	0.038	1.7563	0.8383	0.8065	3.4011	0.0	3.401	0.0	3.439
6M											
1-1	0.359	0.0	0.359	32.5410	17.8091	15.2133	65.5635	0.0	65.564	0.0	65.922
1-2	0.347	0.0	0.347	36.6309	18.8637	19.1342	74.6283	0.0	74.629	0.0	74.976
2-3	0.280	0.0	0.280	41.6060	23.4233	26.8594	91.8889	0.0	91.889	0.0	92.169
2-5	0.260	0.0	0.260	37.0812	22.6443	17.9868	77.7121	0.0	77.712	0.0	77.972
3-4	0.196	0.0	0.196	36.2277	22.9526	22.9192	82.0996	0.0	82.100	0.0	82.296
3-6	0.176	0.0	0.176	29.7633	21.2517	18.0131	69.0275	0.0	69.028	0.0	69.203
4-1	0.352	0.0	0.352	17.6509	10.4399	14.9432	43.0338	0.0	43.034	0.0	43.386
4-2	0.341	0.0	0.341	21.6632	11.4717	18.7909	51.9258	0.0	51.926	0.0	52.266
4-7	0.228	0.0	0.228	12.6726	8.0725	11.0864	31.8314	0.0	31.831	0.0	32.061
5-3	0.259	0.0	0.259	25.4903	12.7944	20.3345	58.6091	0.0	58.609	0.0	58.868
5-5	0.238	0.0	0.238	21.1256	11.9820	11.9724	45.0800	0.0	45.080	0.0	45.319
5-8	0.121	0.0	0.121	8.9832	5.3999	5.8941	20.2772	0.0	20.277	0.0	20.398
6-4	0.179	0.0	0.179	28.4525	15.0755	16.7535	60.2815	0.0	60.281	0.0	60.460
6-6	0.158	0.0	0.158	22.2506	13.3771	12.0996	47.7273	0.0	47.727	0.0	47.885
6-9	0.080	0.0	0.080	10.7408	7.2274	6.0173	23.9855	0.0	23.985	0.0	24.066
7-10	0.125	0.0	0.125	9.5562	5.7865	5.6759	21.0186	0.0	21.019	0.0	21.143
8-11	0.064	0.0	0.064	8.5910	5.2020	5.0805	18.8816	0.0	18.882	0.0	18.946
9-12	0.088	0.0	0.088	10.9614	5.7442	7.5350	24.3406	0.0	24.341	0.0	24.429
10-13	0.064	0.0	0.064	11.9423	6.5359	7.4823	25.9604	0.0	25.960	0.0	26.025
11-14	0.074	0.0	0.074	3.2653	1.5934	2.3237	7.1824	0.0	7.182	0.0	7.256
12-15	0.029	0.0	0.029	2.6513	1.4510	1.7339	5.8361	0.0	5.836	0.0	5.865
13-16	0.015	0.0	0.015	2.9390	1.5537	1.9237	6.3164	0.0	6.316	0.0	6.331
9M											
1-1	0.360	0.0	0.360	32.5889	17.8353	15.2525	65.6768	0.0	65.677	0.0	66.036
1-2	0.347	0.0	0.347	36.6677	18.9806	19.1660	74.7143	0.0	74.714	0.0	75.062
2-3	0.281	0.0	0.281	41.6664	23.4509	26.9113	92.0287	0.0	92.029	0.0	92.309
2-5	0.261	0.0	0.261	37.1862	22.7018	18.0408	77.9289	0.0	77.929	0.0	78.189
3-4	0.197	0.0	0.197	36.2738	22.9737	22.9470	82.1946	0.0	82.195	0.0	82.391
3-6	0.176	0.0	0.176	29.8401	21.2932	18.0538	69.1871	0.0	69.187	0.0	69.363
4-1	0.353	0.0	0.353	17.6988	10.4659	14.9824	43.1471	0.0	43.147	0.0	43.500
4-2	0.341	0.0	0.341	21.7000	11.4886	18.8227	52.0113	0.0	52.011	0.0	52.352
4-7	0.264	0.0	0.264	14.6536	9.3407	12.8282	36.8325	0.0	36.832	0.0	37.096
5-3	0.259	0.0	0.259	25.5506	12.8120	20.3865	58.7491	0.0	58.749	0.0	59.008
5-5	0.239	0.0	0.239	21.2307	12.0395	12.0264	45.2966	0.0	45.297	0.0	45.536
5-8	0.129	0.0	0.129	9.5703	5.7529	6.2793	21.6025	0.0	21.602	0.0	21.732
6-4	0.179	0.0	0.179	28.4986	15.0965	16.7813	60.3765	0.0	60.376	0.0	60.555
6-6	0.159	0.0	0.159	22.3274	13.4191	12.1404	47.8868	0.0	47.887	0.0	48.045
6-9	0.085	0.0	0.085	11.3356	7.6276	6.3505	25.3137	0.0	25.314	0.0	25.398

(TABLE B.5CD CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
7-10	0.130	0.0	0.130	9.9596	6.0368	5.9214	21.9279	0.0	21.928	0.0	22.058
8-11	0.066	0.0	0.066	8.8247	5.3435	5.2269	19.3952	0.0	19.395	0.0	19.461
9-12	0.090	0.0	0.090	11.1361	6.0946	7.7261	24.9569	0.0	24.957	0.0	25.047
10-13	0.065	0.0	0.065	12.1498	6.6494	7.6122	26.4114	0.0	26.411	0.0	26.477
11-14	0.097	0.0	0.097	4.2807	2.0889	3.0463	9.4158	0.0	9.416	0.0	9.513
12-15	0.037	0.0	0.037	3.4678	1.8979	2.2678	7.6334	0.0	7.633	0.0	7.671
13-16	0.020	0.0	0.020	3.9433	2.1581	2.6720	8.7733	0.0	8.773	0.0	8.794
60M											
1-1	0.377	0.0	0.377	33.3904	18.2740	15.9091	67.5736	0.0	67.574	0.0	67.951
1-2	0.360	0.0	0.360	37.5338	19.2769	19.9129	76.7236	0.0	76.724	0.0	77.083
2-3	0.291	0.0	0.291	42.8733	24.0032	27.9496	94.8261	0.0	94.826	0.0	95.117
2-5	0.276	0.0	0.276	38.7622	23.5643	18.8513	81.1778	0.0	81.178	0.0	81.454
3-4	0.205	0.0	0.205	37.6569	23.6065	23.7813	85.0447	0.0	85.045	0.0	85.249
3-6	0.185	0.0	0.185	31.1181	21.9926	18.7330	71.8437	0.0	71.844	0.0	72.029
4-1	0.371	0.0	0.371	18.5003	10.9046	15.6390	45.0439	0.0	45.044	0.0	45.415
4-2	0.353	0.0	0.353	22.5661	11.8849	19.5696	54.0206	0.0	54.021	0.0	54.374
4-7	0.873	0.0	0.873	48.5105	30.9012	42.4385	121.8501	0.0	121.850	0.0	122.723
5-3	0.270	0.0	0.270	26.7575	13.3643	21.4248	61.5466	0.0	61.547	0.0	61.816
5-5	0.255	0.0	0.255	22.8066	12.9020	12.8369	48.5455	0.0	48.546	0.0	48.800
5-8	0.264	0.0	0.264	19.5515	11.7526	12.8282	44.1322	0.0	44.132	0.0	44.396
6-4	0.187	0.0	0.187	29.8816	15.7294	17.6157	63.2267	0.0	63.227	0.0	63.413
6-6	0.167	0.0	0.167	23.6054	14.1185	12.8195	50.5434	0.0	50.543	0.0	50.711
6-9	0.160	0.0	0.160	21.4466	14.4312	12.0150	47.8928	0.0	47.893	0.0	48.053
7-10	0.167	0.0	0.167	12.8233	7.7647	7.6163	28.2043	0.0	28.204	0.0	28.371
8-11	0.087	0.0	0.087	11.6500	7.0543	6.9004	25.6047	0.0	25.605	0.0	25.692
9-12	0.125	0.0	0.125	15.4516	8.4564	10.7185	34.6264	0.0	34.626	0.0	34.751
10-13	0.084	0.0	0.084	15.7232	8.6050	9.8519	34.1801	0.0	34.180	0.0	34.265
11-14	0.439	0.0	0.439	19.3613	9.4476	13.7780	42.5868	0.0	42.587	0.0	43.026
12-15	0.168	0.0	0.168	15.6426	8.5609	10.2299	34.4334	0.0	34.433	0.0	34.602
13-16	0.106	0.0	0.106	20.3467	11.1354	13.7869	45.2690	0.0	45.269	0.0	45.375
100M											
1-1	0.391	0.0	0.391	34.0125	18.6144	16.4187	69.0457	0.0	69.046	0.0	69.437
1-2	0.369	0.0	0.369	38.1972	19.5804	20.4850	78.2626	0.0	78.263	0.0	78.632
2-3	0.299	0.0	0.299	43.7785	24.4174	28.7283	96.9242	0.0	96.924	0.0	97.223
2-5	0.288	0.0	0.288	39.9704	24.2255	19.4727	83.6686	0.0	83.669	0.0	83.957
3-4	0.211	0.0	0.211	38.7172	24.0917	24.4210	87.2299	0.0	87.230	0.0	87.440
3-6	0.192	0.0	0.192	32.1082	22.5345	19.2592	73.9019	0.0	73.902	0.0	74.094
4-1	0.385	0.0	0.385	19.1224	11.2451	16.1486	46.5160	0.0	46.516	0.0	46.901
4-2	0.363	0.0	0.363	23.2295	12.1884	20.1417	55.5596	0.0	55.560	0.0	55.922
4-7	1.339	0.0	1.339	74.3788	47.3794	65.0690	186.8271	0.0	186.827	0.0	188.166
5-3	0.278	0.0	0.278	27.6627	13.7784	22.2035	63.6447	0.0	63.645	0.0	63.922
5-5	0.267	0.0	0.267	24.0148	13.5633	13.4583	51.0364	0.0	51.036	0.0	51.303
5-8	0.367	0.0	0.367	27.1860	16.3419	17.8374	61.3652	0.0	61.365	0.0	61.732
6-4	0.193	0.0	0.193	30.9419	16.2145	18.2553	65.4118	0.0	65.412	0.0	65.605
6-6	0.174	0.0	0.174	24.5955	14.6604	13.3457	52.6016	0.0	52.602	0.0	52.776
6-9	0.227	0.0	0.227	30.3332	20.4109	16.9935	67.7375	0.0	67.738	0.0	67.964
7-10	0.177	0.0	0.177	13.5858	8.2265	8.0693	29.8816	0.0	29.882	0.0	30.059

(TABLE 8.5CD CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR			EQUIPMENT				HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
	SKILLED	UNSKILLED	TOTAL	INT/DEP	MAINT/MISC	FUEL	TOTAL				
8-11	0.091	0.0	0.091	12.1732	7.3711	7.2103	26.7546	0.0	26.755	0.0	26.846
9-12	0.131	0.0	0.131	16.1951	8.8633	11.2352	36.2936	0.0	36.294	0.0	36.425
10-13	0.094	0.0	0.094	17.4782	9.5655	10.9513	37.9949	0.0	37.995	0.0	38.089
11-14	0.630	0.0	0.630	27.7842	13.5577	19.7720	61.1139	0.0	61.114	0.0	61.744
12-15	0.242	0.0	0.242	22.5199	12.3247	14.7273	49.5719	0.0	49.572	0.0	49.814
13-16	0.154	0.0	0.154	29.6251	16.2133	20.0738	65.9122	0.0	65.912	0.0	66.066
165M											
1-1	0.405	0.0	0.405	34.6465	18.9614	16.9381	70.5462	0.0	70.546	0.0	70.951
1-2	0.379	0.0	0.379	38.9974	19.9009	21.0899	79.8971	0.0	79.897	0.0	80.265
2-3	0.307	0.0	0.307	44.7139	24.8454	29.5330	99.0922	0.0	99.092	0.0	99.399
2-5	0.300	0.0	0.300	41.1524	24.8724	20.0806	86.1053	0.0	86.105	0.0	86.405
3-4	0.217	0.0	0.217	39.7775	24.5769	25.0606	89.4150	0.0	89.415	0.0	89.632
3-6	0.198	0.0	0.198	33.0677	23.0596	19.7691	75.8964	0.0	75.896	0.0	76.095
4-1	0.398	0.0	0.398	15.7564	11.5921	16.6680	48.0165	0.0	48.016	0.0	48.415
4-2	0.373	0.0	0.373	23.9297	12.5088	20.7456	57.1841	0.0	57.184	0.0	57.557
4-7	1.828	0.0	1.828	101.5552	64.6908	88.8437	255.0895	0.0	255.090	0.0	256.917
5-3	0.286	0.0	0.286	28.5981	14.2064	23.0092	65.9127	0.0	65.913	0.0	66.099
5-5	0.279	0.0	0.279	25.1960	14.2101	14.0662	53.4731	0.0	53.473	0.0	53.752
5-8	0.480	0.0	0.480	35.5181	21.3504	23.3043	80.1729	0.0	80.173	0.0	80.652
6-4	0.199	0.0	0.199	32.0022	16.6997	18.8950	67.5969	0.0	67.597	0.0	67.796
6-6	0.181	0.0	0.181	25.5550	15.1855	13.8556	54.5961	0.0	54.596	0.0	54.777
6-9	0.286	0.0	0.286	38.2751	25.7548	21.4428	85.4727	0.0	85.473	0.0	85.759
7-10	0.193	0.0	0.193	14.8100	8.9677	8.7963	32.5740	0.0	32.574	0.0	32.767
8-11	0.098	0.0	0.098	13.0104	7.8780	7.7061	28.5945	0.0	28.594	0.0	28.692
9-12	0.142	0.0	0.142	17.5204	9.5886	12.1498	39.2599	0.0	39.259	0.0	39.401
10-13	0.100	0.0	0.100	18.6831	10.2250	11.7052	40.6133	0.0	40.613	0.0	40.714
11-14	0.952	0.0	0.952	41.9763	20.4829	29.8715	92.3307	0.0	92.331	0.0	93.282
12-15	0.367	0.0	0.367	34.0629	18.6420	22.2761	74.9810	0.0	74.981	0.0	75.349
13-16	0.233	0.0	0.233	45.0049	24.6304	30.4951	100.1304	0.0	100.130	0.0	100.364
500M											
1-1	0.472	0.0	0.472	37.7091	20.6375	19.4470	77.7936	0.0	77.794	0.0	78.265
1-2	0.426	0.0	0.426	42.1958	21.4100	23.9336	87.5395	0.0	87.539	0.0	87.965
2-3	0.346	0.0	0.346	49.1795	26.8887	33.3746	109.4428	0.0	109.443	0.0	109.789
2-5	0.357	0.0	0.357	46.8520	27.9917	23.0119	97.8556	0.0	97.856	0.0	98.212
3-4	0.246	0.0	0.246	44.9946	26.9183	29.1477	99.9607	0.0	99.961	0.0	100.206
3-6	0.230	0.0	0.230	37.6731	25.5800	22.2165	85.4696	0.0	85.470	0.0	85.699
4-1	0.465	0.0	0.465	22.8190	13.2681	19.1768	55.2639	0.0	55.264	0.0	55.729
4-2	0.420	0.0	0.420	27.2281	14.0181	23.5903	64.8365	0.0	64.837	0.0	65.256
4-7	4.499	0.0	4.499	249.9350	159.2089	218.6511	627.7947	0.0	627.795	0.0	632.293
5-3	0.324	0.0	0.324	33.0637	16.2497	26.8498	76.1633	0.0	76.163	0.0	76.488
5-5	0.335	0.0	0.335	30.9464	17.3294	16.9975	65.2234	0.0	65.223	0.0	65.559
5-8	0.979	0.0	0.979	72.5284	43.5977	47.5876	163.7135	0.0	163.713	0.0	164.693
6-4	0.228	0.0	0.228	37.1194	19.0411	21.9821	78.1426	0.0	78.143	0.0	78.371
6-6	0.212	0.0	0.212	30.1604	17.7059	16.3030	64.1693	0.0	64.169	0.0	64.381
6-9	0.574	0.0	0.574	76.7251	51.6274	42.9836	171.3360	0.0	171.336	0.0	171.910
7-10	0.269	0.0	0.269	20.6095	12.4795	12.2410	45.3299	0.0	45.330	0.0	45.599
8-11	0.131	0.0	0.131	17.4053	10.5392	10.3093	38.2530	0.0	38.254	0.0	38.384

(TABLE 8.5CD CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
9-12	0.189	0.0	0.189	23.3713	12.7907	16.2137	52.3759	0.0	52.376	0.0	52.565
10-13	0.133	0.0	0.133	24.7945	13.5696	15.5346	53.8987	0.0	53.899	0.0	54.032
11-14	2.670	0.0	2.670	117.7830	57.4737	83.8175	259.0742	0.0	259.074	0.0	261.744
12-15	1.023	0.0	1.023	95.0588	52.0240	62.1655	209.2482	0.0	209.248	0.0	210.271
13-16	0.660	0.0	0.660	127.1988	69.6136	86.1892	283.0015	0.0	283.001	0.0	283.661
800M											
1-1	0.508	0.0	0.508	39.3839	21.5541	20.8190	81.7571	0.0	81.757	0.0	82.265
1-2	0.452	0.0	0.452	44.0201	22.2447	25.5070	91.7718	0.0	91.772	0.0	92.224
2-3	0.367	0.0	0.367	51.5933	27.9931	35.4512	115.0377	0.0	115.038	0.0	115.404
2-5	0.388	0.0	0.388	50.0301	29.7310	24.6464	104.4076	0.0	104.408	0.0	104.796
3-4	0.261	0.0	0.261	47.6146	28.1620	29.7885	105.5660	0.0	105.566	0.0	105.827
3-6	0.246	0.0	0.246	40.0909	26.9033	23.5013	90.4955	0.0	90.496	0.0	90.742
4-1	0.502	0.0	0.502	24.4938	14.1847	20.5499	59.2274	0.0	59.227	0.0	59.729
4-2	0.446	0.0	0.446	29.0524	14.9527	25.1617	69.0689	0.0	69.069	0.0	69.514
4-7	5.885	0.0	5.885	326.9585	208.2731	286.0337	821.2656	0.0	821.266	0.0	827.151
5-3	0.345	0.0	0.345	35.4775	17.3542	28.9264	81.7581	0.0	81.758	0.0	82.103
5-5	0.367	0.0	0.367	34.0746	19.0688	18.6320	71.7753	0.0	71.775	0.0	72.142
5-8	1.259	0.0	1.259	93.2519	56.0607	61.1913	210.5139	0.0	210.514	0.0	211.773
6-4	0.243	0.0	0.243	39.8393	20.2856	23.6229	83.7479	0.0	83.748	0.0	83.991
6-6	0.228	0.0	0.228	32.5782	19.0292	17.5879	69.1952	0.0	69.195	0.0	69.424
6-9	0.731	0.0	0.731	97.7169	65.7525	54.7438	218.2132	0.0	218.213	0.0	218.944
7-10	0.329	0.0	0.329	25.2251	15.2743	14.9824	55.4817	0.0	55.482	0.0	55.811
8-11	0.155	0.0	0.155	20.6840	12.5246	12.2513	45.4599	0.0	45.460	0.0	45.615
9-12	0.203	0.0	0.203	25.0516	13.7103	17.1924	55.9543	0.0	55.954	0.0	56.157
10-13	0.141	0.0	0.141	26.0832	14.2749	16.1695	56.5276	0.0	56.528	0.0	56.669
11-14	4.188	0.0	4.188	184.7050	90.1293	131.4411	406.2751	0.0	406.275	0.0	410.463
12-15	1.612	0.0	1.612	149.7362	81.9480	97.9229	329.6069	0.0	329.607	0.0	331.219
13-16	1.047	0.0	1.047	201.8287	110.4574	136.7581	449.0442	0.0	449.044	0.0	450.091
SPR/COMP ($/100BCM)											
98%											
11	0.088	0.0	0.088	7.3165	3.9224	5.3162	16.5552	0.0	16.555	0.0	16.643
12	0.114	0.0	0.114	12.3777	6.8234	8.4313	27.6324	0.0	27.632	0.0	27.746
13	0.108	0.0	0.108	8.6220	5.1191	5.5559	19.2970	0.0	19.297	0.0	19.405
14	0.159	0.0	0.159	10.6550	5.5159	6.7476	22.9184	0.0	22.918	0.0	23.077
21	0.057	0.0	0.057	7.9254	4.2557	5.8740	18.0551	0.0	18.055	0.0	18.112
22	0.082	0.0	0.082	12.9865	7.1566	8.9891	29.1323	0.0	29.132	0.0	29.215
23	0.077	0.0	0.077	9.2308	5.4524	6.1137	20.7969	0.0	20.797	0.0	20.874
24	0.128	0.0	0.128	11.2638	5.8491	7.3054	24.4183	0.0	24.418	0.0	24.546
31	0.048	0.0	0.048	2.5462	1.2153	2.2395	6.0010	0.0	6.001	0.0	6.049
32	0.073	0.0	0.073	7.6074	4.1163	5.3546	17.0782	0.0	17.078	0.0	17.151
33	0.068	0.0	0.068	3.9516	2.4120	2.4792	8.7428	0.0	8.743	0.0	8.811
34	0.119	0.0	0.119	5.8047	2.0087	3.6708	12.3642	0.0	12.364	0.0	12.483
41	0.041	0.0	0.041	2.5487	1.2165	2.2329	5.9981	0.0	5.998	0.0	6.039
42	0.067	0.0	0.067	7.6099	4.1175	5.3480	17.0753	0.0	17.075	0.0	17.142
43	0.062	0.0	0.062	3.8541	2.4132	2.4726	8.7399	0.0	8.740	0.0	8.802

(TABLE B.5CD CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
44	0.112	0.0	0.112	5.0872	2.8099	3.6642	12.3613	0.0	12.361	0.0	12.474
SURFACING											
GRAVEL ($/100CCM)											
11	0.143	0.0	0.143	6.5771	3.7641	4.8736	15.2147	0.0	15.215	274.68	290.037
12	0.126	0.0	0.126	9.0616	5.6906	5.7752	20.5275	0.0	20.527	274.69	295.333
13	0.208	0.0	0.208	12.2757	6.1772	7.6497	26.1026	0.0	26.103	274.68	300.999
21	0.129	0.0	0.129	8.7898	4.9750	6.4803	20.2451	0.0	20.245	274.69	295.054
22	0.112	0.0	0.112	11.2744	6.9016	7.3819	25.5579	0.0	25.558	274.68	300.353
23	0.194	0.0	0.194	14.4884	7.3882	9.2564	31.1330	0.0	31.133	274.69	306.007
31	0.119	0.0	0.119	3.3605	1.9108	2.8114	8.0827	0.0	8.093	274.69	282.891
32	0.102	0.0	0.102	5.8451	3.8373	3.7131	13.3954	0.0	13.395	274.68	288.177
33	0.184	0.0	0.184	9.0591	4.3239	5.5975	18.9706	0.0	18.971	274.68	293.834
41	0.116	0.0	0.116	3.6056	2.0277	2.9699	8.6032	0.0	8.603	274.68	283.397
42	0.099	0.0	0.099	6.7301	3.9543	3.8715	13.9159	0.0	13.916	274.69	288.695
43	0.182	0.0	0.192	9.3042	4.4409	5.7460	19.4911	0.0	19.491	274.68	294.353
51	0.211	0.0158	0.227	10.1981	5.0515	9.4710	24.7207	0.0	24.721	274.69	299.627
52	0.194	0.0158	0.210	12.6926	6.9782	10.3727	30.0335	0.0	30.033	274.69	304.923
53	0.277	0.0150	0.293	15.8967	7.4648	12.2471	35.6096	0.0	35.609	274.69	310.592
WBM ($/100CCM)											
111	1.368	0.0706	1.439	42.4915	24.1977	46.0919	112.7812	0.0	112.781	417.30	531.524
112	1.329	0.0687	1.398	86.7332	57.8286	64.7034	209.2650	0.0	209.265	417.30	627.967
113	1.768	0.0909	1.859	97.6786	46.2871	73.6799	217.6455	0.0	217.646	417.30	636.899
121	1.512	0.1131	1.625	48.0989	27.6492	49.7483	125.4963	0.0	125.496	417.30	544.426
122	1.475	0.1118	1.587	92.3404	61.2801	68.3598	221.9800	0.0	221.980	417.30	640.871
123	1.912	0.1341	2.046	103.2859	49.7385	77.3163	230.3605	0.0	230.361	417.30	649.711
211	1.352	0.0706	1.423	44.9422	25.4842	47.7995	118.1260	0.0	118.126	417.30	536.853
212	1.316	0.0687	1.385	89.0838	59.1151	66.4111	214.6097	0.0	214.610	417.30	633.298
213	1.753	0.0909	1.844	100.0293	47.5736	75.3875	222.9903	0.0	222.990	417.30	642.138
221	1.496	0.1131	1.609	50.4494	28.9357	51.4559	130.8410	0.0	130.841	417.30	549.755
222	1.460	0.1118	1.572	94.6911	62.5666	70.0674	227.3248	0.0	227.325	417.30	646.200
223	1.897	0.1341	2.031	105.6365	51.0250	79.0439	235.7054	0.0	235.705	417.30	655.040
311	1.339	0.0706	1.410	38.9187	22.1523	43.7955	104.8665	0.0	104.867	417.30	523.581
312	1.305	0.0687	1.374	83.1693	55.7832	62.4070	201.3503	0.0	201.350	417.30	620.028
313	1.742	0.0909	1.833	94.1058	44.2417	71.3835	209.7309	0.0	209.731	417.30	628.863
321	1.483	0.1131	1.596	44.5260	25.6038	47.4519	117.5816	0.0	117.582	417.30	536.482
322	1.447	0.1110	1.558	88.7676	59.2346	66.0634	214.0655	0.0	214.065	417.30	632.923
323	1.884	0.1341	2.018	99.7131	47.6931	75.0399	222.4459	0.0	222.446	417.30	641.763
411	1.337	0.0706	1.407	39.1547	22.2649	43.9480	105.3676	0.0	105.368	417.30	524.077
412	1.300	0.0687	1.369	83.3963	55.8959	62.5595	201.8514	0.0	201.851	417.30	620.524
413	1.737	0.0909	1.828	94.3417	44.3541	71.5359	210.2318	0.0	210.232	417.30	629.364
421	1.491	0.1131	1.594	44.7619	25.7164	47.6044	118.0827	0.0	118.083	417.30	536.980
422	1.444	0.1118	1.556	89.0035	59.3473	66.2159	214.5664	0.0	214.566	417.30	633.426
423	1.881	0.1341	2.015	99.9490	47.8057	75.1923	222.9470	0.0	222.947	417.30	642.266
511	1.434	0.0863	1.520	45.9496	25.3831	50.6233	121.9559	0.0	121.956	417.30	540.776
512	1.397	0.0850	1.482	90.1911	59.0139	69.2348	218.4397	0.0	218.440	417.30	637.226
513	1.834	0.1066	1.940	101.1366	47.4724	79.2113	226.8202	0.0	226.820	417.30	646.065
521	1.577	0.1295	1.707	51.5568	28.8345	54.2797	134.6709	0.0	134.671	417.30	553.692
522	1.541	0.1275	1.668	95.7984	62.4654	72.8912	231.1548	0.0	231.155	417.30	650.127

(TABLE B.5CD CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR SKILLED	LABOR UNSKILLED	LABOR TOTAL	EQUIPMENT INT/DEP	EQUIPMENT MAINT/MISC	EQUIPMENT FUEL	EQUIPMENT TOTAL	HORSE	EQUIPMENT AND HORSE	MATERIALS	TOTAL
523	1.978	0.1498	2.127	106.7439	50.9239	81.8676	239.5353	0.0	239.535	417.30	656.967
DBST/G ($/100SM)											
1111	0.029	0.0032	0.032	1.5218	0.7570	1.5459	3.8247	0.0	3.925	107.50	111.359
1112	0.025	0.0032	0.029	1.5081	0.7655	1.5003	3.7740	0.0	3.774	107.50	111.304
1121	0.031	0.0058	0.037	1.2671	0.7193	1.1749	3.1612	0.0	3.161	107.50	110.697
1122	0.028	0.0058	0.034	1.2534	0.7275	1.1293	3.1102	0.0	3.110	107.50	110.645
1211	0.029	0.0031	0.032	1.5299	0.7619	1.5929	3.8846	0.0	3.885	107.50	111.416
1212	0.025	0.0031	0.028	1.5162	0.7704	1.5472	3.8339	0.0	3.834	107.50	111.363
1221	0.031	0.0058	0.037	1.2751	0.7239	1.2218	3.2209	0.0	3.221	107.50	110.759
1222	0.028	0.0058	0.034	1.2615	0.7324	1.1762	3.1701	0.0	3.170	107.50	110.705
DBST/W ($/100SM)											
1111	0.028	0.0030	0.031	1.5053	0.7470	1.5007	3.7530	0.0	3.753	84.90	88.681
1112	0.025	0.0030	0.028	1.4918	0.7556	1.4556	3.7029	0.0	3.703	84.90	88.636
1121	0.031	0.0057	0.037	1.2505	0.7090	1.1297	3.0892	0.0	3.089	84.90	88.025
1122	0.027	0.0057	0.033	1.2368	0.7175	1.0841	3.0384	0.0	3.038	84.90	87.971
1211	0.028	0.0030	0.031	1.5115	0.7507	1.5377	3.8000	0.0	3.800	84.90	88.730
1212	0.025	0.0030	0.028	1.4978	0.7592	1.4921	3.7492	0.0	3.749	84.90	88.676
1221	0.031	0.0057	0.037	1.2568	0.7128	1.1667	3.1362	0.0	3.136	84.90	88.072
1222	0.027	0.0057	0.033	1.2431	0.7213	1.1211	3.0854	0.0	3.085	84.90	88.019

TABLE B.6A : THE AMOUNT OF INVESTMENT AT THE PRICES OF 1974 AND THE AMOUNT OF LABOR REQUIRED FOR THE GIVEN RATE OF EXECUTION FOR THE 1920'S TECHNICAL PACKAGES FOR ALL STAGES.

STAGE/TECHNICAL PACKAGE NUMBER	LABOR (UNSKILLED MEN/UNIT)			INVESTMENT ($1000/UNIT)		
	SKILLED	UNSKILLED	TOTAL	EQUIPMENT	HORSE	TOTAL
SITE PREP (HA/HR)						
11	211.392	861.6621	1073.054	6.02	14.21	20.23
21	41.787	21.6954	63.482	625.50	0.0	625.50
EXC/HAUL (100BCM/HR)						
6M						
1-1	27.875	153.1668	181.041	8.00	0.0	8.00
1-2	28.000	152.9052	180.905	11.02	0.0	11.02
2-1	22.695	126.3528	149.048	8.55	1.82	10.37
2-2	22.820	126.0912	148.911	11.58	1.82	13.39
3-1	22.445	125.0443	147.489	19.12	0.0	19.12
3-2	22.570	124.7832	147.353	22.15	0.0	22.15
4-3	3.278	19.7769	23.055	1.62	9.17	10.79
5-4	3.053	15.7091	18.762	2.16	9.46	11.62
6-5	7.206	49.8217	57.028	7.59	16.78	24.37
7-6	0.946	0.0	0.946	16.36	0.0	16.36
10-7	5.130	7.5419	12.671	165.35	1.79	167.14
10-8	5.115	7.6126	12.727	186.40	0.0	186.40
10-9	13.612	4.3164	17.928	300.19	0.0	300.19
100M						
1-1	27.875	273.0579	300.932	15.11	0.0	15.11
1-2	28.000	257.9636	285.963	19.93	0.0	19.93
2-1	22.695	246.2440	268.939	15.66	1.82	17.48
2-2	22.820	231.1497	253.970	20.48	1.82	22.30
3-1	22.445	244.9361	267.381	26.24	0.0	26.24
3-2	22.570	229.8418	252.412	31.05	0.0	31.05
4-3	3.278	60.9799	64.257	4.27	32.06	36.33
5-4	3.053	36.1793	39.232	5.28	26.52	31.80
6-5	7.206	61.8161	69.022	12.36	23.44	35.81
7-6	5.905	0.0	5.905	102.15	0.0	102.15
8-7	2.052	13.7078	15.760	33.98	11.02	45.00
9-7	3.903	9.2214	13.125	58.02	4.24	62.27
10-7	5.130	12.5306	17.660	172.37	4.56	176.93
10-8	5.115	9.2345	14.349	198.99	0.0	198.99
10-9	15.939	4.3164	20.255	334.39	0.0	334.39
800M						
1-1	27.875	1160.5752	1188.449	67.77	0.0	67.77
1-2	28.000	1035.6873	1063.687	85.85	0.0	85.85
2-1	22.695	1133.7612	1156.456	68.32	1.82	70.14
2-2	22.820	1008.8733	1031.693	86.40	1.82	88.22
3-1	22.445	1132.4531	1154.898	78.89	0.0	78.89
3-2	22.570	1007.5652	1030.135	96.97	0.0	96.97
4-3	3.278	365.9253	369.204	23.92	201.50	225.42
5-4	3.053	187.7764	190.829	28.37	152.87	181.23
6-5	7.206	150.6162	157.823	47.73	72.78	120.51
7-6	42.663	0.0	42.663	738.02	0.0	738.02
8-7	2.052	50.6327	52.684	85.88	31.53	117.42
9-7	3.903	46.1462	50.050	109.93	24.76	134.69
10-7	5.130	49.4555	54.585	224.27	25.08	249.35
10-8	5.115	21.2288	26.343	292.09	0.0	292.09
10-9	33.154	4.3164	37.471	587.39	0.0	587.39
SPR/COMP (100BCM/HR)						
33%						
11	9.283	48.5137	57.797	3.40	1.38	4.78

(TABLE B.6A CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR (UNSKILLED MEN/UNIT) SKILLED	UNSKILLED	TOTAL	INVESTMENT ($1000/UNIT) EQUIPMENT	HORSE	TOTAL
21	5.805	4.2772	10.032	12.40	4.75	17.15
98%						
11	11.310	53.1964	64.506	15.31	6.58	21.89
21	5.805	8.9598	14.765	24.31	9.96	34.27
12	9.809	47.2711	57.080	14.24	0.0	14.24
22	7.382	3.0346	10.416	23.24	3.37	26.61
32	4.829	0.0	4.829	50.82	0.0	50.82
SURFACING						
GRAVEL (100CCM/HR)						
11	8.232	47.2449	55.477	10.99	4.71	15.70
21	2.652	16.6116	19.264	15.41	6.16	21.57
12	12.236	43.0070	55.243	27.77	0.0	27.77
22	5.730	12.3737	18.104	32.18	1.45	33.64
WBM (100CCM/HR)						
111	50.369	124.6916	175.061	368.19	9.69	377.88
211	42.312	74.8176	117.130	373.88	11.58	385.45
DBST/G (100 SM/HR)						
1111	2.327	10.1501	12.477	9.90	0.0	9.90
1121	1.752	4.5780	6.330	26.05	0.0	25.05
DBST/W (100 SM/HR)						
1111	2.327	10.1501	12.477	9.90	0.0	9.90
1121	1.752	4.5780	6.330	26.05	0.0	26.05

NOTE: LABOR IS EXPRESSED IN UNITS OF UNSKILLED MEN; THAT IS, THE ACTUAL NUMBER OF SKILLED MEN REQUIRED IS WEIGHTED BY THE RATIO OF THE SKILLED WAGE TO THE UNSKILLED WAGE FOR THE PERIOD OF THE TECHNOLOGY; THIS FACTOR FOR THE 1920'S IS 1.91.

TABLE 8.6B : THE AMOUNT OF INVESTMENT AT THE PRICES OF 1974
AND THE AMOUNT OF LABOR REQUIRED FOR THE GIVEN RATE OF
PRODUCTION FOR THE 1950'S TECHNICAL PACKAGES FOR ALL STAGES.

STAGE/TECHNICAL PACKAGE NUMBER	LABOR (UNSKILLED MEN/UNIT) SKILLED	UNSKILLED	TOTAL	INVESTMENT ($1000/UNIT) EQUIPMENT	HORSE	TOTAL
SITE PREP (HA/HR)						
11	206.155	1227.8425	1433.997	24.37	0.0	24.
21	26.147	21.6954	47.842	478.32	0.0	478.
31	17.849	21.6954	39.545	281.70	0.0	281.
EXC/HAUL (100ECE/HR)						
6M						
1-1	3.131	0.0	3.131	124.75	0.0	124.
1-2	2.706	0.0	2.706	156.66	0.0	156.
1-3	2.646	0.0	2.646	127.58	0.0	127.
1-4	2.511	0.0	2.511	140.48	0.0	140.
2-1	3.226	0.0	3.226	157.80	0.0	157.
2-2	2.801	0.0	2.801	190.98	0.0	190.9
2-3	2.741	0.0	2.741	161.06	0.0	161.0
2-4	2.605	0.0	2.605	174.56	0.0	174.
3-1	2.611	0.0	2.611	137.65	0.0	137.6
3-2	2.186	0.0	2.186	162.64	0.0	162.
3-3	2.126	0.0	2.126	138.17	0.0	138.
3-4	1.991	0.0	1.991	147.78	0.0	147.
5-5	2.157	0.0	2.157	57.82	0.0	57.
6-6	2.017	0.0	2.017	70.99	0.0	70.
7-7	0.943	0.0	0.943	44.39	0.0	44.
8-8	0.629	0.0	0.629	10.24	0.0	10.
9-9	0.343	0.0	0.343	7.28	0.0	7.
10-10	0.279	0.0	0.279	8.01	0.0	8.0
10CM						
1-1	3.744	0.0	3.744	137.88	0.0	137.
1-2	2.992	0.0	2.992	170.43	0.0	170.4
1-3	3.150	0.0	3.150	142.90	0.0	142.9
1-4	2.797	0.0	2.797	152.80	0.0	152.8
2-1	3.839	0.0	3.839	170.93	0.0	170.
2-2	3.087	0.0	3.087	204.75	0.0	204.7
2-3	3.245	0.0	3.245	176.37	0.0	176.
2-4	2.892	0.0	2.892	186.88	0.0	186.
3-1	3.224	0.0	3.224	150.79	0.0	150.7
3-2	2.472	0.0	2.472	176.41	0.0	176.
3-3	2.630	0.0	2.630	153.48	0.0	153.
3-4	2.277	0.0	2.277	160.10	0.0	160.
4-2	1.330	0.0	1.330	74.42	0.0	74.
4-4	1.135	0.0	1.135	61.00	0.0	61.0
5-5	2.917	0.0	2.917	85.47	0.0	85.4
6-6	2.555	0.0	2.555	89.92	0.0	89.9
7-7	1.089	0.0	1.089	53.29	0.0	53.2
8-8	6.785	0.0	6.785	110.46	0.0	110.4
9-9	3.693	0.0	3.693	78.50	0.0	78.5
10-10	2.804	0.0	2.804	80.42	0.0	80.4
6CCM						
1-1	4.835	0.0	4.835	161.26	0.0	161.2
1-2	3.503	0.0	3.503	195.01	0.0	195.0
1-3	4.050	0.0	4.050	170.21	0.0	170.2
1-4	3.306	0.0	3.306	174.72	0.0	174.7
2-1	4.930	0.0	4.930	194.31	0.0	194.3
2-2	3.598	0.0	3.598	229.33	0.0	229.3
2-3	4.145	0.0	4.145	203.69	0.0	203.6
2-4	3.401	0.0	3.401	208.80	0.0	208.8

(TABLE B.6B CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR (UNSKILLED MEN/UNIT)			INVESTMENT ($1000/UNIT)		
	SKILLED	UNSKILLED	TOTAL	EQUIPMENT	HORSE	TOT
3-1	4.315	0.0	4.315	174.17	0.0	174.17
3-2	2.983	0.0	2.983	200.99	0.0	200.99
3-3	3.530	0.0	3.530	180.80	0.0	180.8
3-4	2.786	0.0	2.786	182.01	0.0	182.01
4-2	1.841	0.0	1.841	99.00	0.0	99.0
4-4	1.644	0.0	1.644	82.92	0.0	82.92
5-5	6.817	0.0	6.817	200.63	0.0	200.6
6-6	5.450	0.0	5.450	207.03	0.0	207.0
7-7	2.760	0.0	2.760	138.48	0.0	138.48
8-8	52.236	0.0	52.236	850.42	0.0	850.42
9-9	28.518	0.0	28.518	606.21	0.0	606.2
10-10	21.462	0.0	21.462	615.54	0.0	615.54
SBB/COMP (1000CM/HR) 98%						
11	2.122	0.0	2.122	35.49	0.0	35.4
12	1.507	0.0	1.507	29.68	0.0	29.6
13	1.558	0.0	1.558	23.40	0.0	23.4
14	1.369	0.0	1.369	17.76	0.0	17.76
21	1.818	0.0	1.818	37.84	0.0	37.8
22	1.203	0.0	1.203	32.03	0.0	32.0
23	1.254	0.0	1.254	25.75	0.0	25.7
24	1.065	0.0	1.065	20.11	0.0	20.1
31	1.597	0.0	1.597	25.60	0.0	25.6
32	0.982	0.0	0.982	19.79	0.0	19.7
33	1.033	0.0	1.033	13.52	0.0	13.5
34	0.843	0.0	0.843	7.87	0.0	7.8
41	1.499	0.0	1.499	26.76	0.0	26.76
42	0.884	0.0	0.884	20.95	0.0	20.95
43	0.935	0.0	0.935	14.68	0.0	14.6
44	0.745	0.0	0.745	9.03	0.0	9.0
SURFACING						
GRAVEL (1000CM/HR)						
11	1.843	0.0	1.843	29.73	0.0	29.7
12	1.356	0.0	1.356	16.27	0.0	16.2
21	1.708	0.0	1.708	35.08	0.0	35.0
22	1.221	0.0	1.221	21.63	0.0	21.6
31	1.442	0.0	1.442	21.96	0.0	21.9
32	0.956	0.0	0.956	8.50	0.0	8.5
41	1.369	0.0	1.369	23.44	0.0	23.4
42	0.882	0.0	0.882	9.98	0.0	9.9
51	2.054	0.3806	2.434	44.06	0.0	44.0
52	1.567	0.3806	1.948	30.60	0.0	30.6
WBM (1000CM/HR)						
111	14.596	2.9011	17.497	273.62	0.0	273.6
112	11.295	2.4093	13.704	129.88	0.0	129.8
211	14.308	2.9011	17.209	276.21	0.0	276.2
212	11.007	2.4093	13.416	132.47	0.0	132.4
311	14.083	2.9011	16.984	263.96	0.0	263.9
312	10.782	2.4093	13.191	120.22	0.0	120.2
411	13.985	2.9011	16.886	265.07	0.0	265.0
412	10.684	2.4093	13.093	121.33	0.0	121.3
511	14.700	3.2818	17.982	286.94	0.0	286.9
512	11.399	2.7900	14.189	143.20	0.0	143.2
DBST/G (100 SM/HR)						
1111	0.302	0.1439	0.446	5.93	0.0	5.9
1112	0.267	0.1439	0.411	5.52	0.0	5.5
1121	0.307	0.1923	0.500	5.16	0.0	5.1
1122	0.272	0.1923	0.465	4.75	0.0	4.7

(TABLE B.6B CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR (UNSKILLED MEN/UNIT) SKILLED	UNSKILLED	TOTAL	INVESTMENT ($1000/UNIT) EQUIPMENT	HORSE	TOT.
2111	0.302	0.1334	0.436	5.90	0.0	5.90
2112	0.267	0.1334	0.400	5.49	0.0	5.49
2121	0.307	0.1831	0.491	5.13	0.0	5.13
2122	0.272	0.1831	0.455	4.72	0.0	4.72
DEST/W (10C SM/FF)						
1111	0.302	0.1439	0.446	5.93	0.0	5.93
1112	0.267	0.1439	0.411	5.52	0.0	5.52
1121	0.307	0.1923	0.500	5.16	0.0	5.16
1122	0.272	0.1923	0.465	4.75	0.0	4.75
2111	0.302	0.1334	0.436	5.90	0.0	5.90
2112	0.267	0.1334	0.400	5.49	0.0	5.49
2121	0.307	0.1831	0.491	5.13	0.0	5.13
2122	0.272	0.1831	0.455	4.72	0.0	4.72

NOTE: LABOR IS EXPRESSED IN UNITS OF UNSKILLED MEN; THAT IS, THE ACTUAL NUMBER OF SKILLED MEN REQUIRED IS WEIGHTED BY THE RATIO OF THE SKILLED WAGE TO THE UNSKILLED WAGE FOR THE PERIOD OF THE TECHNOLOGY; THIS FACTOR FOR THE 1950'S IS 1.34.

TABLE B.6C : THE AMOUNT OF INVESTMENT AT THE PRICES OF 1974 AND THE AMOUNT OF LABOR REQUIRED FOR THE GIVEN RATE OF PRODUCTION FOR THE 1970'S TECHNICAL PACKAGES FOR ALL STAGES.

STAGE/TECHNICAL PACKAGE NUMBER	LABOR (UNSKILLED MEN/UNIT)			INVESTMENT ($1000/UNIT)		
	SKILLED	UNSKILLED	TOTAL	EQUIPMENT	HORSE	TOTAL
SITE PREP (HA/HR)						
11	75.660	351.9443	427.605	988.32	0.0	988.32
21	12.863	58.2662	71.129	181.46	0.0	181.46
31	8.379	25.9455	34.325	169.70	0.0	169.70
EXC/HAUL (1000BCM/HR)						
6M						
1-1	2.244	0.0	2.244	95.30	0.0	95.30
1-2	2.170	0.0	2.170	106.39	0.0	106.39
2-3	1.753	0.0	1.753	141.42	0.0	141.42
2-5	1.624	0.0	1.624	139.19	0.0	139.19
3-4	1.229	0.0	1.229	125.48	0.0	125.48
3-6	1.100	0.0	1.100	118.34	0.0	118.34
4-1	2.205	0.0	2.205	50.48	0.0	50.48
4-2	2.131	0.0	2.131	61.36	0.0	61.36
4-7	1.427	0.0	1.427	38.18	0.0	38.18
5-3	1.619	0.0	1.619	66.14	0.0	66.14
5-5	1.489	0.0	1.489	63.65	0.0	63.65
5-8	0.759	0.0	0.759	27.06	0.0	27.06
6-4	1.118	0.0	1.118	74.33	0.0	74.33
6-6	0.988	0.0	0.988	67.04	0.0	67.04
6-9	0.502	0.0	0.502	32.36	0.0	32.36
7-10	0.779	0.0	0.779	32.02	0.0	32.02
8-11	0.403	0.0	0.403	28.78	0.0	28.78
9-12	0.550	0.0	0.550	32.72	0.0	32.72
10-13	0.402	0.0	0.402	35.98	0.0	35.98
11-14	0.463	0.0	0.463	8.72	0.0	8.72
12-15	0.179	0.0	0.179	7.99	0.0	7.99
13-16	0.092	0.0	0.092	8.55	0.0	8.55
10M						
1-1	2.445	0.0	2.445	99.29	0.0	99.29
1-2	2.309	0.0	2.309	110.63	0.0	110.63
2-3	1.871	0.0	1.871	146.66	0.0	146.66
2-5	1.804	0.0	1.804	147.89	0.0	147.89
3-4	1.318	0.0	1.318	131.48	0.0	131.48
3-6	1.200	0.0	1.200	125.41	0.0	125.41
4-1	2.406	0.0	2.406	54.47	0.0	54.47
4-2	2.270	0.0	2.270	65.61	0.0	65.61
4-7	8.377	0.0	8.377	224.09	0.0	224.09
5-3	1.737	0.0	1.737	71.38	0.0	71.38
5-5	1.669	0.0	1.669	72.35	0.0	72.35
5-8	2.296	0.0	2.296	81.91	0.0	81.91
6-4	1.206	0.0	1.206	80.33	0.0	80.33
6-6	1.098	0.0	1.098	74.10	0.0	74.10
6-9	1.419	0.0	1.419	91.39	0.0	91.39
7-10	1.108	0.0	1.108	45.52	0.0	45.52
8-11	0.571	0.0	0.571	40.78	0.0	40.78
9-12	0.820	0.0	0.820	48.79	0.0	48.79
10-13	0.589	0.0	0.589	52.66	0.0	52.66
11-14	3.941	0.0	3.941	74.17	0.0	74.17
12-15	1.517	0.0	1.517	67.85	0.0	67.85
13-16	0.962	0.0	0.962	89.26	0.0	89.26
8COM						
1-1	3.180	0.0	3.180	113.85	0.0	113.85
1-2	2.827	0.0	2.827	126.42	0.0	126.42

(TABLE B.6C CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR (UNSKILLED MEN/UNIT)			INVESTMENT ($1000/UNIT)		
	SKILLED	UNSKILLED	TOTAL	EQUIPMENT	HORSE	TOTAL
2-3	2.295	0.0	2.295	165.49	0.0	165.49
2-5	2.430	0.0	2.430	178.20	0.0	178.20
3-4	1.633	0.0	1.633	152.93	0.0	152.93
3-6	1.540	0.0	1.540	149.46	0.0	149.46
4-1	3.141	0.0	3.141	69.03	0.0	69.03
4-2	2.787	0.0	2.787	81.40	0.0	81.40
4-7	36.922	0.0	36.922	985.07	0.0	985.07
5-3	2.160	0.0	2.160	90.22	0.0	90.22
5-5	2.296	0.0	2.296	102.66	0.0	102.66
5-8	7.877	0.0	7.877	280.98	0.0	280.98
6-4	1.522	0.0	1.522	101.78	0.0	101.78
6-6	1.429	0.0	1.429	93.15	0.0	93.15
6-9	4.571	0.0	4.571	294.40	0.0	294.40
7-10	2.057	0.0	2.057	84.51	0.0	84.51
8-11	0.971	0.0	0.971	69.30	0.0	69.30
9-12	1.268	0.0	1.268	75.48	0.0	75.48
10-13	0.882	0.0	0.882	78.58	0.0	78.58
11-14	26.200	0.0	26.200	493.10	0.0	493.10
12-15	10.085	0.0	10.085	451.13	0.0	451.13
13-16	6.551	0.0	6.551	608.08	0.0	608.08
SPR/COMP (100BCM/HR) 98%						
11	0.550	0.0	0.550	21.57	0.0	21.57
12	0.710	0.0	0.710	37.58	0.0	37.58
13	0.678	0.0	0.678	22.20	0.0	22.20
14	0.995	0.0	0.995	27.93	0.0	27.93
21	0.355	0.0	0.355	23.40	0.0	23.40
22	0.516	0.0	0.516	39.41	0.0	39.41
23	0.483	0.0	0.483	24.03	0.0	24.03
24	0.800	0.0	0.800	29.76	0.0	29.76
31	0.298	0.0	0.298	6.64	0.0	6.64
32	0.458	0.0	0.458	22.65	0.0	22.65
33	0.426	0.0	0.426	7.27	0.0	7.27
34	0.743	0.0	0.743	13.00	0.0	13.00
41	0.259	0.0	0.259	6.65	0.0	6.65
42	0.419	0.0	0.419	22.65	0.0	22.65
43	0.386	0.0	0.386	7.27	0.0	7.27
44	0.704	0.0	0.704	13.00	0.0	13.00
SURFACING GRAVEL (100CCM/HR)						
11	0.894	0.0	0.894	21.07	0.0	21.07
12	0.787	0.0	0.787	20.40	0.0	20.40
13	1.303	0.0	1.303	29.82	0.0	29.82
21	0.807	0.0	0.807	27.74	0.0	27.74
22	0.701	0.0	0.701	27.07	0.0	27.07
23	1.216	0.0	1.216	36.49	0.0	36.49
31	0.743	0.0	0.743	10.84	0.0	10.84
32	0.637	0.0	0.637	10.17	0.0	10.17
33	1.152	0.0	1.152	19.59	0.0	19.59
41	0.729	0.0	0.729	11.48	0.0	11.48
42	0.622	0.0	0.622	10.81	0.0	10.81
43	1.138	0.0	1.138	20.23	0.0	20.23
51	1.321	0.3165	1.637	26.43	0.0	26.43
52	1.214	0.3165	1.531	25.76	0.0	25.76
53	1.735	0.3165	2.051	35.18	0.0	35.18
WBM (100CCM/HR)						
111	8.560	1.4126	9.973	139.69	0.0	139.69
112	8.314	1.3734	9.688	146.88	0.0	146.88

(TABLE B.6C CONTINUED)

STAGE/TECHNICAL PACKAGE NUMBER	LABOR (UNSKILLED MEN/UNIT) SKILLED	UNSKILLED	TOTAL	INVESTMENT ($1000/UNIT) EQUIPMENT	HORSE	TOTAL
113	11.064	1.8181	12.882	213.97	0.0	213.97
121	9.460	2.2628	11.723	156.89	0.0	156.89
122	9.231	2.2367	11.468	164.07	0.0	164.07
123	11.964	2.6814	14.646	231.16	0.0	231.16
211	8.462	1.4126	9.874	146.78	0.0	146.78
212	8.233	1.3734	9.606	153.96	0.0	153.96
213	10.966	1.8181	12.784	221.05	0.0	221.05
221	9.362	2.2628	11.625	163.97	0.0	163.97
222	9.133	2.2367	11.369	171.16	0.0	171.16
223	11.866	2.6814	14.547	238.24	0.0	238.24
311	8.380	1.4126	9.793	128.41	0.0	128.41
312	8.167	1.3734	9.541	135.60	0.0	135.60
313	10.900	1.8181	12.719	202.68	0.0	202.68
321	9.280	2.2628	11.543	145.60	0.0	145.60
322	9.051	2.2367	11.288	152.79	0.0	152.79
323	11.784	2.6814	14.466	219.88	0.0	219.88
411	8.364	1.4125	9.776	129.02	0.0	129.02
412	8.134	1.3734	9.508	136.21	0.0	136.21
413	10.868	1.8181	12.686	203.30	0.0	203.30
421	9.264	2.2628	11.527	146.22	0.0	146.22
422	9.035	2.2367	11.271	153.40	0.0	153.40
423	11.768	2.6814	14.449	220.49	0.0	220.49
511	8.969	1.7266	10.696	144.46	0.0	144.46
512	8.740	1.7034	10.440	151.65	0.0	151.65
513	11.473	2.1320	13.605	218.74	0.0	218.74
521	9.869	2.5898	12.459	161.65	0.0	161.65
522	9.640	2.5506	12.191	168.84	0.0	168.84
523	12.373	2.9953	15.369	235.93	0.0	235.93
DBST/G (100 SM/HR)						
1111	0.178	0.0632	0.242	3.89	0.0	3.89
1112	0.158	0.0632	0.221	3.38	0.0	3.38
1121	0.196	0.1168	0.313	3.66	0.0	3.66
1122	0.175	0.1168	0.292	3.16	0.0	3.16
1211	0.178	0.0629	0.241	3.91	0.0	3.91
1212	0.157	0.0629	0.220	3.40	0.0	3.40
1221	0.196	0.1165	0.313	3.68	0.0	3.68
1222	0.175	0.1165	0.292	3.18	0.0	3.18
DBST/W (100 SM/HR)						
1111	0.175	0.0610	0.236	3.85	0.0	3.85
1112	0.155	0.0610	0.215	3.34	0.0	3.34
1121	0.193	0.1142	0.307	3.62	0.0	3.62
1122	0.172	0.1142	0.286	3.12	0.0	3.12
1211	0.175	0.0604	0.236	3.86	0.0	3.86
1212	0.154	0.0604	0.215	3.36	0.0	3.36
1221	0.193	0.1139	0.307	3.64	0.0	3.64
1222	0.172	0.1139	0.286	3.13	0.0	3.13

NOTE: LABOR IS EXPRESSED IN UNITS OF UNSKILLED MEN; THAT IS, THE ACTUAL NUMBER OF SKILLED MEN REQUIRED IS WEIGHTED BY THE RATIO OF THE SKILLED WAGE TO THE UNSKILLED WAGE FOR THE PERIOD OF THE TECHNOLOGY; THIS FACTOR FOR THE 1970'S IS 1.25.

Table B.7a: Capital requirements of the 1920's technical packages for excavation/hauling at 100 meters, where capital is measured in various ways.

Technical package number	Measure of Capital Requirements		
	Depreciation cost at 1974 ($/100 BCM)	Investment cost at 1930 ($1000/100 BCM per hr)	Investment cost under developing conditions ($1000/100 BCM per hr)
1-1	8.00	2.58	1.29
1-2	10.41	3.40	1.70
2-1	7.98	3.14	1.59
2-2	10.39	3.96	2.00
3-1	10.10	4.48	22.61
3-2	12.51	5.30	23.02
4-3	2.05	8.89	4.98
5-4	1.75	7.65	4.27
6-5	2.09	8.08	4.43
7-6	10.81	17.44	202.80
8-7	4.46	8.60	4.48
9-7	7.03	10.99	49.58
10-7	12.58	30.59	320.85
10-8	16.69	33.97	395.00
10-9	24.03	57.09	663.80

Table B.7b: Capital requirements of the 1970's technical packages for excavation/hauling at 100 meters, where capital is measured in various ways.

Technical package number	Measure of Capital Requirements		
	Depreciation cost at 1974 ($/100 BCM)	Investment cost at 1930 ($1000/100 BCM per hr)	Investment cost under developing conditions ($1000/100 BCM per hr)
1-1	10.25	16.95	197.11
1-2	11.51	18.89	219.64
2-3	11.15	25.04	291.15
2-5	10.00	25.25	293.61
3-4	10.72	22.45	261.03
3-6	8.73	21.41	248.96
4-1	5.76	9.30	108.14
4-2	7.00	11.20	130.24
4-7	22.41	38.26	444.88
5-3	8.33	12.19	141.71
5-5	7.24	12.35	143.64
5-8	8.19	13.98	162.61
6-4	9.32	13.72	159.48
6-6	7.41	12.65	147.11
6-9	9.14	15.60	181.43
7-10	3.79	7.77	90.36
8-11	3.40	6.96	80.96
9-12	4.88	8.33	96.87
10-13	5.27	8.99	104.54
11-14	8.95	12.66	147.26
12-15	6.78	11.58	134.70
13-16	8.93	15.24	177.19

APPENDIX C

PROJECT DESIGNS AND COSTS

C.1 Project Design

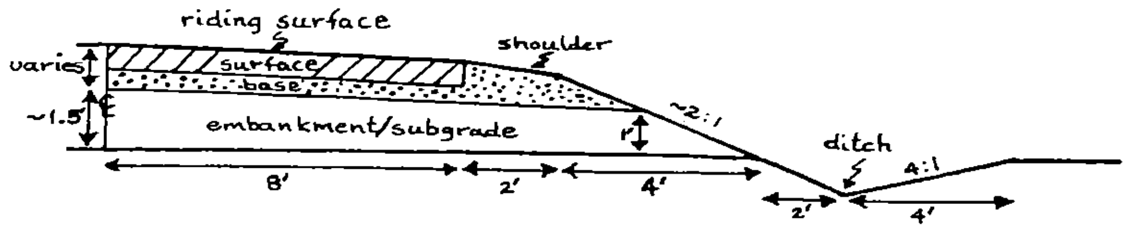
Certain aspects of the project design not covered in Section 3.2, including some further details of the design standards and alignments used in the analysis and the characteristics and design of the materials used in the various layers, are discussed in Section C.11. Section C.12 proceeds with some further discussion of the derivation of the construction quantities for the excavation/hauling, spreading/compaction, site preparation, and surfacing stages of the various projects. All sources cited in these two sections are listed in Section C.13.

C.11 Design Standards

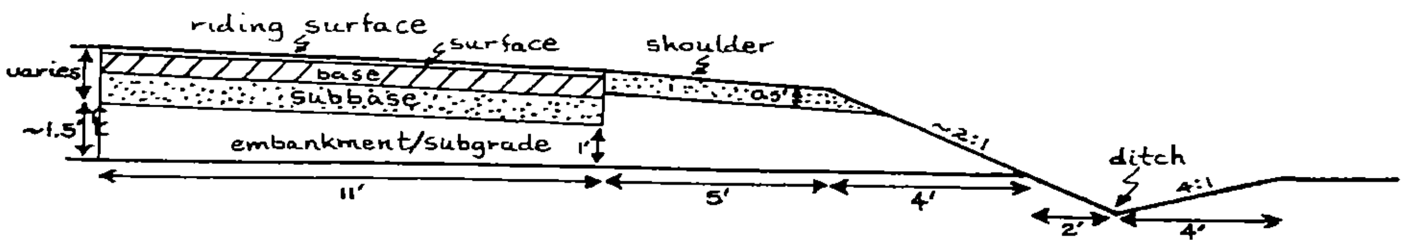
As it is desirable to build rather different roads for different design standards, rolling terrain with reasonably steep grades was selected, with the road crossing it in going from point A to point B. Two sets of design standards, at reasonably opposite ends of the spectrum for today's two lane, low volume, rural roads, are defined for two different traffic profiles as follows (2, 3, 4, 6, 9, 11):

	Low Standard	High Standard
Design Speed	25 mph	60 mph
Maximum Grade	9%	4 (some 6) %
Minimum Radius of Curvature	230 ft	1300 ft
Minimum Length of Vertical Curves	400 ft	600 ft
Initial Traffic	80 ADT	400 ADT
Truck Percentage	20 %	30 %
Annual Growth Rate Over 15 Years	10%	10%

Low Standard Cross Section:



High Standard Cross Section:



It might additionally be noted that the critical length of grades is not used in the design as low volume roads are being considered, and that no spirals are used since the scale of the map did not allow it. These standards are basically in agreement with those set forth by the American Association of State Highway Officials (AASHO) (2), for low volume, rural roads, with the exception of the widths which reflect the views of Oglesby and Altenhofen (6), among others, who believe AASHO's widths are overdesigned for such roads.

Given these design standards and a U.S. Geological Survey topographic map of rolling terrain with two points selected some 16 kilometers (10 miles) apart, several possible alignments connecting the two points were laid out for each design standard, assuming no intermediate controls such as townships and quarries. Earthwork quantities (cut and fill) were then estimated for each plan. For the purposes of the study at hand, the intermediate alignment, in terms of road length and earthwork quantities, for both the low and high standard designs is selected for use in the project-level analysis; the details of these two alignments, as required by the HCM, are given in Table C.1. A few other random details about the general project that the HCM needs include: rainfall - 800 mm/year, seasons - 4 months wet and 8 months dry, and elevation - 550 meters.

Gravel, waterbound macadam, and double bituminous surface treatment constitute the surfaces used in the current research. Various characteristics of these materials are needed for use both in designing the surfaces and in estimating their deterioration over time. The gravel, to be used as a surface, base, or subbase, is assumed to be a well-graded gravel with some 10 percent fines and to be compacted to 100-105 percent of standard AASHO compaction. The California Bearing Ratio (CBR) of this material in a soaked state is 55 percent according to Yoder (12). Using the correlations between CBR and material coefficient developed by the Illinois Division of Highways (1), such gravel has a layer coefficient of 0.12 when used as a subbase and 0.11 as a base; similar figures are reported by various states in the AASHTO Interim Guide for Design of Pavement Structures 1972 (1). Lacking similar data for gravel surfaces, a layer coefficient of 0.10 is assumed, in line with the figures above and with those standardly used in the HCM. In determining surface conditions, for the eventual estimation of maintenance and user costs, the

Table C.1a: Details of the individual segments of the alignment for the low standard design.

Segment Number	Length (km)	Curvature (°/km)	Road rise (M/km)	Road fall (M/km)	Ground rise (M/km)	Ground fall (M/km)
100	0.823	0	11.1	0	11.1	0
101	2.225	0	41.8	0	41.8	0
102	0.305	0	0	20.0	0	20.0
103	1.036	241.31	32.4	0	32.4	0
104	1.341	0	3.4	0	3.4	0
105	1.463	0	0	32.3	0	32.3
106	2.225	134.83	35.6	0	35.6	0
107	0.427	23.42	0	71.4	0	71.4
108	0.457	175.05	0	53.3	0	53.3
109	0.853	222.74	28.6	0	28.6	0
110	1.890	55.56	0	9.7	0	9.7
111	1.341	44.74	13.6	0	13.6	0
112	2.621	5.72	60.5	0	60.5	0

Note: Total length is 17.01 km.

Table C.1b: Details of the individual segments of the alignment for the high standard design.

Segment Number	Length (km)	Curvature (°/km)	Road rise (M/km)	Road fall (M/km)	Ground rise (M/km)	Ground fall (M/km)
200	3.901	34.61	33.6	0	33.6	0
201	0.914	38.29	3.3	3.3	6.6	6.6
202	2.377	0	0	7.7	0	7.7
203	0.610	32.79	0	40.0	0	40.0
204	2.073	103.71	35.3	0	38.2	2.9
205	1.250	84.00	0	35.4	4.9	43.9
206	0.396	126.26	46.2	0	53.9	0
207	1.097	0	0	5.6	0	5.6
208	1.219	0	41.3	11.3	45.0	15.0
209	1.036	82.05	88.2	0	88.2	0
210	1.737	43.18	17.5	0	17.5	0

Note: Total length is 16.61 km.

HCM uses the deterioration model of the Transport and Road Research Laboratory (TRRL) (8) for gravel surfaces; an initial roughness of 3250 mm/km is assumed (8).

Waterbound macadam is used as a base or surface. AASHTO (1) cites figures ranging from 0.14 to 0.20 for the layer coefficient of a wbm base, the data being gathered from various states. The midpoint of the range, 0.17, is used in this study; Huang (4) substantiates this somewhat by cutting an inch off his base when a wbm, as opposed to gravel or crushed rock, base is used beneath a flexible pavement, with crushed rock bases having a material coefficient of about 0.14 (1). For wbm as a surface, the bottom of the range of material coefficients, 0.14, is used. As no deterioration model for wbm surfaces could be found, TRRL's model for double bituminous surface treated roads (8) is used. This is not as unreasonable as it may seem, however, in that the exact model used, such as curves for roughness and cracking, varies with the modified structural number of the surface; also the initial roughness is specified as 3250 mm/km, more like a gravel than a dbst road.

For double bituminous surface treated roads, TRRL (8) suggests a material coefficient of 0.10, while the HCM uses one of 0.20. The actual value is not too critical in that the layer is so thin it has little influence on the modified structural number of the surface, which is the only place the layer coefficient is used. A figure of 0.10 is used in the current research, since the design and deterioration of the dbst road is pretty much based on TRRL's work (7,8). Using TRRL's deterioration model for surface treated roads, an initial roughness of 2300 mm/km is assumed (8).

The surface design requires knowledge of the traffic expected over the design life of the road and the CBR of the subgrade, as well as the layer coefficients of the materials being used. Actually only the thickness of the gravel layer has to be designed, since a wbm surface or base is assumed to be 15.2 cm (6 in.), as this represents standard design practice, and the thickness of dbst is determined primarily by the size of the crushed stone used instead of by the amount, with 2.2 cm (7/8 in.) being the thickness used. Following TRRL's design procedure for flexible pavements (7), the basis of the gravel thickness design is a chart relating subbase thickness to traffic over the life of the road and CBR of the subgrade for a surface dressed road with a 6 in. base of gravel, crushed rock, cement or lime-stabilized soil, or bitumen-stabilized sand. This is obviously fine for the dbst road, but it may result in slight underdeisgning of the wbm and especially the gravel road, although it does not appear to be serious as they seem to perform satisfactorily when run in the HCM.

The traffic is needed in terms of cumulative standard axles (8200 kilogram [18 kip] loads) over the life of the project. The inital average daily traffic is as follows:

	Cars	SU trucks	2-S2 trucks	3-S2 trucks
Low standard	64	8	5	3
High standard	280	60	36	24

Using the gross weights and axle configurations of the four vehicles (Table C.3), equivalence factors for converting axles to standard axles (7), and a chart relating cumulative number of vehicles over project life to initial traffic, design life (15 years), and annual growth rate (10%) (7), these ADT's are respectively converted to 265,000 and 1,998,400 cumulative standard axles in both directions over the life of the project. The narrow width of the low standard design necessitates inflating 265,000 actual cumulative standard axles to 368,200 effective cumulative standard axles because of the tendency of people to drive in the middle when there is no on-coming traffic.

Using these traffic figures and a subgrade CBR of 7.0 percent, the following layer thicknesses are designed:

Project	Subbase	Base	Surface
L114	-	-	gravel - 29.2 cm (11.5 in.)
L214	-	gravel - 14.0 cm (5.5 in.)	wbm 15.2 cm (6.0 in.)
L311,L314, L315,L316, L317	-	gravel - 29.2 cm (11.5 in.)	dbst 2.2 cm (7/8 in.)
H215	-	gravel - 17.8 cm (7.0 in.)	wbm 15.2 cm (6.0 in.)
H312,H313, H315,H317	-	gravel - 33.0 cm (13.0 in.)	dbst 2.2 cm (7/8 in.)
H415	gravel - 17.8 cm (7.0 in.)	wbm 15.2 cm (6.0 in.)	dbst 2.2 cm (7/8 in.)

This just leaves the surfaces on the 3.5 percent CBR subgrade. The two improperly designed ones (p L334 and p H335) are designed for a 7 percent CBR, and their layer thicknesses, therefore, are as above for projects L314 and H315, respectively. For the two properly designed surfaces (p L324 and p H325), the modified structural number is used to design the gravel layer, such that the properly designed roads with the 7 percent CBR (p L314 and H315) and the 3.5 percent CBR (p L324 and H325) have the same modified structural number; this is done under the assumption that two such roads should behave the same. The equation for the modified structural number of a surface is as follows (1, 8):

$$SN' = \sum_{i=1}^{n} a_i t_i + 3.51(\log_{10} CBR) - 0.85(\log_{10} CBR)^2 - 1.43$$

where
- n = number of layers
- a_i = material coefficient of layer i
- t_i = thickness of layer i (in.)
- CBR = California Bearing Ratio (%)

SN' for the two dbst surfaces on the 7 percent CBR are as follows:

$$\text{p L314: } SN' = .11(11.5) + .10(7/8) + 3.51(\log_{10}7) - 0.85(\log_{10}7)^2 - 1.43$$

$$= .11(11.5) + .10(7/8) + .93$$

$$= 2.29$$

p H315: $SN' = .11(13.0) + .10(7/8) + 3.51(\log_{10}7) - 0.85(\log_{10}7)^2 - 1.43$

$= .11(13.0) + .10(7/8) + .93$

$= 2.45$

For the two dbst surfaces on the 3.5 percent CBR, where t represents the thickness of the gravel layer, then:

p L324: $SN' = 2.29 = .11(t) + .10(7/8) + 3.51(\log_{10}3.5) - 0.85(\log_{10}3.5)^2 - 1.4$

$2.29 = .11(t) + .10(7/8) + .23$

$t = 17.9$ in.

p H325: $SN' = 2.45 = .11(t) + .10(7/8) + 3.51(\log_{10}3.5) - 0.85(\log_{10}3.5)^2 - 1.4$

$2.45 = .11(t) + .10(7/8) + .23$

$t = 19.4$ in.

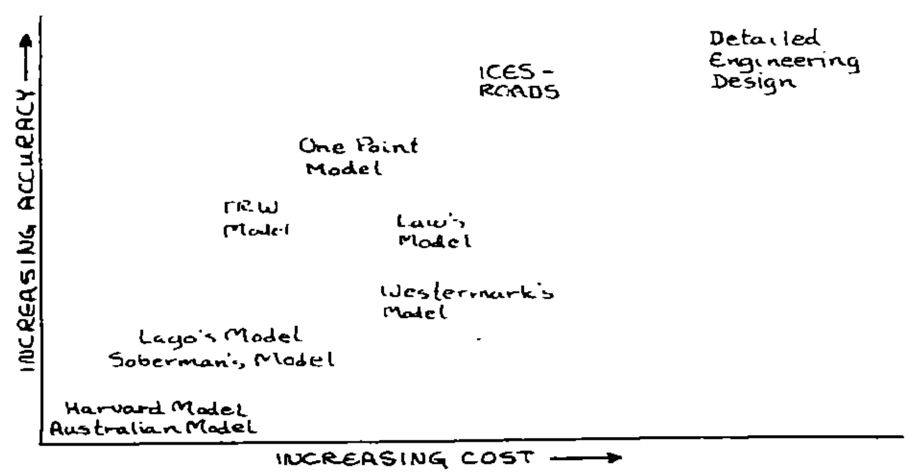
The design of the surfaces for the two properly designed projects on a 3.5 percent CBR is thus as follows:

Project	Base	Surface
L324	gravel - 45.4 cm (17.9 in.)	dbst - 2.2 cm (7/8 in.)
H325	gravel - 49.2 cm (19.4 in.)	dbst - 2.2 cm (7/8 in.)

Finally, gravel shoulders are assumed in all cases. For the low standard road, their thickness is taken as equivalent to that of the surfacing materials since the shoulders are so narrow; a fixed thickness of 15.2 cm (6 in.) is used in the high standard case.

C.12 Construction Quantities

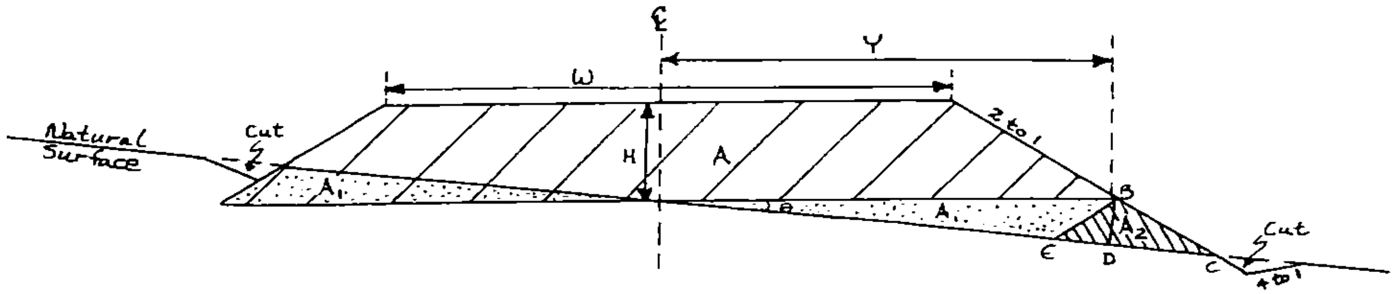
Excavation/Hauling: There are many ways of doing earthwork quantity estimates of highway construction. The accuracy of the results depends upon the information available, time and money available, and method used, with the first factor generally predominating and determining the other two. In the case at hand, it is assumed that the only information available is that displayed on a U.S. Geological Survey topographic map with 20 foot contours and that two points some 10 miles apart are to be linked. Given this, it was felt that one of the intermediate design methodologies should be adopted rather than the very crude or very detailed methods. McCoomb (5) does a comprehensive review of the many models available for estimating earthwork quantities, and comes up with the following sketch relating accuracy of the estimate and cost of collecting and processing the data:

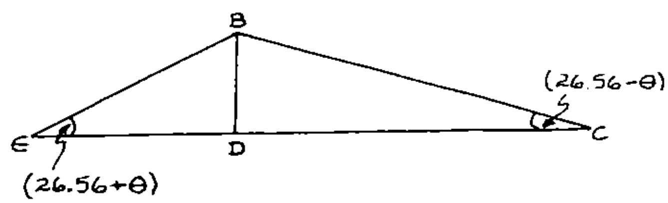


The Australian model, for example, assumes the average height of cut or depth of fill to be 1, 2, 4, or 8 feet, depending upon whether the terrain is flat, rolling, hilly, or mountanous, respectively; at the opposite end of the spectrum is the detailed engineering design for which detailed survey data is required, detailed cross sections are plotted, end areas are found by planimeter, and then the average end area method is applied for computing the final earthwork volumes.

In the case at hand, a lack of data as well as of time precluded the use of detailed design, and as for ICES-ROADS, given the data available, its results would be no better than those of the one point model. The HCM, in turn, requires the road profile for use in estimating user costs; this suggests that the one point model may as well be used, since it is more accurate than the other models and its data requirements are complementary to those of the HCM. The basic one point model calls for computing the area of the cross section at each station, and using the average end area method to compute volumes; only the centerline height difference between the terrain and road profile is required. Because the area chosen for the study is a rolling to almost mountainous region, however, it was felt that the error incurred by neglecting side slope would be significant, and this is therefore included as briefly outlined below.

For the case of fill:





Fill area = $A + A_2$

$$A = WH + 2H^2$$

$$BD = Y \, Sin\theta$$

$$ED = Y \, Sin\theta \, [Cot(26.56 + \theta)]$$

$$DC = YSin\theta \, [Cot(26.56 - \theta)]$$

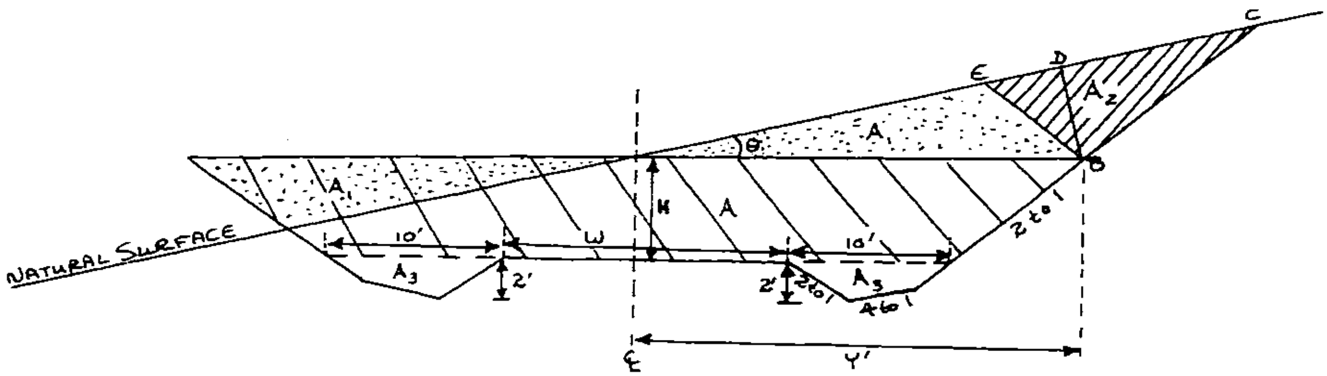
$$A_2 = \frac{1}{2} BD \cdot (ED + DC)$$

$$= \frac{1}{2} Y^2 \, sin^2\theta \, [Cot(26.56 + \theta) + Cot(26.56 - \theta)]$$

$= Y^2K$, where K is constant for a given cross slope

Cut area = 3 ft^2/ditch

For the case of cut:



$$\text{Cut area} = A + 2A_3 + A_2$$

$$A = \left[\frac{(W + 20) + (W + 20 + 4H)}{2}\right]\cdot H$$

$$= (W + 20 + 2H)\cdot H$$

$$BD = Y' \sin\theta$$

$$ED = Y' \sin\theta\,[\cot(26.56 + \theta)]$$

$$DC = Y' \sin\theta\,[\cot(26.56 - \theta)]$$

$$A_2 = \frac{1}{2}\,BD\cdot(ED + DC)$$

$$= \frac{1}{2}\,(Y')^2 \sin^2\theta\,[\cot(26.56 + \theta) + \cot(26.56 - \theta)]$$

$$= (Y')^2 K\text{, where K is constant as above}$$

$$A_3 = 11\ ft^2$$

Note: The 26.56° comes from the assumption of batter slopes of 2 to 1.

Given a contour interval of 20 feet, it seemed reasonable to space stations every 200 feet. At each station then, the centerline height difference between terrain and road profile is estimated. The side slope input is the average cross slope in the vicinity of the road, and no attempt was made to obtain a weighted average cross slope, as again the contour interval does not lend itself to greater accuracy. Centerline height difference is taken in 2 foot intervals, and cross slope in intervals of 5 percent. Batter slopes of 2 to 1 are assumed for all cuts and fills. Although this conflicts somewhat with the current practice of varying the batter slopes with the height of cut and fill, it seems a reasonable simplifying assumption to make; moreover, these are somewhat steeper than usual, but this is not unreasonable since it helps reduce the amount of earthwork and the roads under consideration are, after all, low volume ones (2). Narrowing of the table drain in cuts would have substantially reduced earthworks in some areas, but it was not done as the cuts are lengthy and no run-off information is available. No real attempt was made to balance earthworks, as alternative excavation/hauling scenarios as well as alternative technical packages for doing the work are to be considered in the course of the project-level analysis.

Three alignments were laid out for each design standard, two completely separate routes (Routes 1 and 2), and in the case of the low standard road a slight modification of Route 1 (Route 1A), and in that of the high standard road a combination of the first two routes (Route 1-2). The earthworks were then estimated. The results are as follows:

Route	Length(mi)	Cut(bcy)	Fill(ccy)
Low standard:			
1	10.57	22,313	75,447
2	10.44	35,384	85,080
1A	10.74	13,380	74,289
High standard:			
1	10.68	768,541	323,523
2	9.45	1,619,790	831,073
1-2	10.32	770,158	370,326

The two intermediate alternatives, Route 1 for the low standard and Route 1-2 for the high standard, are used throughout the rest of the project-level analysis.

Given the basic earthwork quantities in terms of cut and fill volumes for the two design standards, the distribution of the cut between fill and spoil and of fill between cut and borrow remains to be determined along with the haul distances. This requires knowledge of the escavation/hauling scenarios of interest.* Rather than going to a method as sophisticated as mass-haul diagrams, it is decided to simply review the cut and fill volumes given at 200 foot intervals along each

*Generally only the projects depicting alternative excavation/hauling scenarios are indicated in this discussion, as the projects depicting alternative surface materials and subgrade strength/surface design combinations assume a single excavation/hauling scenario for each design standard.

road with two line haul distances (200 feet and 1640 feet) in mind, estimating the percentages of cut which can go to fill. All materials taken directly from the ditch (low standard: 56% of the cut; high standard: 1.6% of the cut) go to fill. In cases where there is sideborrow, they are included with it in terms of haul distance; when there is no sideborrow, the ditch materials are hauled an average distance of 6 ft which is rounded up to 7 ft for the analysis. For the 200 ft line haul case, an additional 22% of the cut, coming from the road, goes to fill in the low standard case (p L311, L314, L316), and only 5.6 % in the high standard case (p H312); given the 1640 ft line haul, the figures are respectively 44% (11% of the fill at 98% compaction) (p L315, L317), and 42% (7% of the fill at 98% compaction) (p H313, H315, H317). In discussing the high and low standard cases side by side, it is important to remember the difference in the magnitude of their earthwork (cut: 1 to 35; fill: 1 to 5; cut + fill: 1 to 11) and also the distribution of materials between cut and fill, the low standard case having a lot of fill and little cut and the high standard the opposite.

The remainder of the fill, then, must come from borrow, the actual haul distances varying with the assumption as to type of borrow and the quantity and distribution of the material involved. In the low standard case (p L311), the remaining fill is reasonably distributed along the road and can thus all be sideborrowed from one side at an average haul distance of 21 ft. In the high standard case (p H312, H313), however, the remaining fill is large in quantity and unevenly distributed. It is assumed that sideborrow areas on both sides of the road are some 3 ft deep and 12 ft across, providing some 3.8 bcy of material per foot of road. The quantities of fill still needed on a section by section basis (i.e., generally every 200 ft) are converted to quantity needed per foot, and for those sections where the need is below or not too far above 3.8 bcy/ft, the need is assumed satisfied with sideborrow at an average haul distance of 24 feet, while for sections with significantly larger needs, it is assumed that near pit borrow is more appropriate. Sideborrow takes care of 28% of the need for borrow in the case of the 200 ft line haul (p H312), while it handles 60% in the case of the 1640 ft line haul (p H313). The haul distance for sideborrow in all cases is rounded up to 30 ft.

All remaining fill materials thus come from pit borrow. In the two high standard cases with some sideborrow (p H312, H313), the pits are assumed to be some 10 ft beyond the sideborrow area, as an allowance for topsoil spoil; in the cases where all borrow comes from nearby pits (p L314, L315, H315), the pits are assumed to be some 20 ft beyond the ditch such that there is not a sharp drop-off right by the road. Pits containing some 7500 bcy of material are assumed (e.g., 450 ft by 75 ft by 6 ft for elevating graders and 300 ft by 75 ft by 9 ft for power shovels - greater depth being limited by suitability of materials). Fill requirements on a section by section basis are thus lumped to pit size, and haul distances, including at the pit, to the road, and along the road, are estimated, with the final average haul distance being a weighted average. This in the low standard case is some 1564 ft (p L314) or 1607 ft (p L315) depending upon the line haul; in the high standard cases with sideborrow, it is 453 ft (p H312) or 306 ft (p H313) again depending on line haul, while in that without sideborrow, it is 574 ft (p H315). The assumed minimum size of the pit is penalizing the low standard case (p L314, L315) by resulting in a long haul along the road. The low standard near pit borrow distances are rounded to 1640 ft, while those for the high standard are rounded to 330 (was 306) ft and 540 (were 453 and 574) ft. The far pit borrow scenarios (p L316, L317, H317) are handled exactly like the respective near pit borrow ones (p L314, L315, H315) except that the pit is assumed to be 1000 ft from the ditch instead of 20 ft, yielding a set of haul distances 980 ft longer; the final distance used for the low standard case is 2625 ft and for the high is 1640 ft.

Before proceeding to discuss spoil, it should be noted that fill quantities are estimated in ccy and their conversion to bcy depends upon the level of compaction. In the case of 98% compaction:

from Section B.12 $$\frac{\text{compacted thickness}}{\text{loose thickness}} = 0.65,$$

and $$\frac{\text{bank thickness}}{\text{loose thickness}} = 0.80,$$

thus $$\frac{\text{bank thickness}}{\text{compacted thickness}} = 1.23$$

Assuming that only the depth and not the cross-sectional area changes with compaction, then 1.23 is the factor for converting ccy to bcy.

Similarly in the 93% compaction case, the factor is 1.16. In the projects with 93% compaction (p L324, L334, H325, H335) then, less fill is needed, with the difference in the excavation/hauling quantities showing up in the amount borrowed from the pit.

All of the cut which cannot be used for fill and all of the topsoil removed from the roadbed including the ditches and from all borrow areas go to spoil. The quantity of topsoil removed from the vicinity of the roadbed depends upon whether or not sideborrowing is being done and upon the width (including ditches) and length of the road, the thickness being constant at 6 in. In the low standard case with sideborrow (p L311), an average topsoil removal width of 57 ft is used, while for those cases without sideborrow (p L314, L315, L316, L317), 40 ft, the width to the outside edge of the ditch, is used; similarly in the high standard cases, the figures are 81 ft (p H312, H313), and 52 ft (p H315, H317), respectively. Quantities coming from pit areas are calculated by dividing the volume of borrow from the pit by the average depth of the pit, 25 yd, to arrive at the area of topsoil removal, which when multiplied by 1/6 yd gives the volume of spoil material. In the low standard case, most of the spoil is from topsoil removal, while in the high standard case it is largely from cut for the road. As for haul distances, materials from the vicinity of the roadbed are assumed to be spoiled somewhat beyond the ditch, except in cases with sideborrow when these materials, along with the topsoil from the borrow area, are assumed to be spoiled beyond the sideborrow area; as for spoiling topsoil from borrow pits, this is assumed to be done around the periphery. Weighting these various haul distances by the volumes of material involved results in average distances of 14 ft (p L311) and 11 ft (p L314, L315, L316, L317) in the low standard case, and of 18 ft (p H312, H313) and 17 ft (p H315, H317) in the high standard; these are rounded to 20 ft and 30 ft, respectively.

Spreading/Compaction: Silty clay is assumed to be the common soil in the area of the road, as it is one of the few materials for which a relationship could be found in the literature between the amount of compaction and subgrade strength. For silty clay, compaction in the range of 95 - 100% standard AASHO (giving a dry density of 100-105 lb/ft^3) at $\pm$ 2 percent of the optimum moisture content (a molding water content of 16 - 20%) results in a soaked California Bearing Ratio (CBR) in the range of 2.0 - 12% (10, 11). For the 98% compaction case, 7.0% is thus used as the soaked CBR of the subgrade. Similarly, compaction in the range of 91 - 96% standard AASHO (giving a dry density of 95.5 - 100.5 (lb/ft^3) at the above moisture content results in a soaked CBR in the range of 2.5 - 5.5% (10, 11). For the 93% compaction case, 3.5% is therefore used as the soaked CBR of the subgrade.

The quantity of spreading/compaction is simply taken as the volume of fill material in bank measure. As noted above, the factor for converting compacted to bank measure varies with the level of compaction, being 1.23 for 98% compaction and 1.16 for 93% compaction.

Site Preparation: As in the case of topsoil removal which goes to spoil, the roadbed including the ditches and all borrow areas must be cleared of brush and trees. The quantity of site preparation thus consists of these areas plus an additional 5 feet on either side of the road beyond the ditch and an additional 10 percent on the pits, as an allowance for brush encroachment and working space.

For certain site preparation technical packages (e.g., 1950 tp 31), the width of the area to be cleared is a factor in resource productivity. In the low standard case, site preparation widths of 67 and 50 ft are encountered for the roadbed (respectively with and without sideborrow) and 75 ft for the borrow pits, averaging out to some 60 ft or so; in the high standard case, widths of 91, 62, and 75 ft are encountered, averaging to some 75 ft.

Surfacing: Gravel and waterbound macadam surfacing are measured in volumetric units as a function of the surface design in terms of layer thickness, the road cross section, and the length of the route, while double bituminous surface treatment is measured in units of area as a function of the road cross section and length. The basic relations are as follows:

gravel and wbm layers:

$$\text{volume (cy)} = \frac{\text{end area (ft}^2\text{) x length (mi) x 5280 ft/mi}}{27\ \text{ft}^3\text{/cy}}$$

dbst layer:

$$\text{area (sy)} = \frac{\text{width (ft) x length (mi) x 5280 ft/mi}}{9\ \text{ft}^2\text{/sy}}$$

The lengths of the low and high standard designs are respectively 10.57 mi and 10.32 mi. The width of the surface, and thus that of the dbst layer, is 16 ft in the low standard case and 22 ft in the high standard. The end areas for the gravel and wbm layers are as follows:

gravel and wbm surface, base, and subbase:

$$\text{end area (ft}^2) = \frac{\text{layer thickness (in.)}}{12 \text{ in./ft}} \times \text{width (ft)}$$

gravel shoulders (both) - low standard:

$$\text{end area (ft}^2) = 2 \left[\frac{\text{base + surface thickness (in.)}}{12 \text{ in./ft}} \times 2 \text{ ft} \right]$$

$$+ \left[\frac{\text{base + surface thickness (in.)}}{12 \text{ in./ft}} \times 2 \text{ ft} \right]$$

$$= \frac{\text{base + surface thickness}}{2}$$

gravel shoulders (both) - high standard:

$$\text{end area (ft}^2) = 2 \left[\frac{6 \text{ in.}}{12 \text{ in./ft}} \times 5 \text{ ft} \right] + \left[\frac{6 \text{ in.}}{12 \text{ in./ft}} \times 1 \text{ ft} \right]$$

$$= 5.5$$

Thicknesses of the various subbase, base, and surface layers are given in Section C.11.

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C.2 Project Costs

Construction costs can be estimated by simply combining the construction quantities for the various stages of construction with the unit costs of the technical packages derived in the stage-level analysis. In order to complete these costs and bring them more in line with maintenance and user costs, overhead and profit is included at 20 percent of total direct costs, i.e., labor, equipment, and materials (1, 6, 23). Minor structures are still left out, however, as their share of total costs is small, and no major structures are assumed to be necessary.

This leaves the maintenance and user costs shares of project costs to be determined for 1974, 1930, and developing conditions. As these costs occur over the 15 year life of the road, a discount rate is needed in order to bring the costs back to the present or to annualize them; with the help of the statistical tables of the Federal Reserve Bulletin (5), rates of 8%, 3.5%, and 15% are estimated as roughly representative of the rate at which long-term bonds might be floated under 1974, 1930, and developing conditions, respectively. Some further discussion of the derivation and lists of the maintenance policies and unit costs used in the project-level analysis are given in Section C.21; the same is done for vehicle characteristics, utilization, and costs in Section C.22. Any sources cited in the course of these discussions and listings are given in Section C.23.

C.21 Maintenance Policies and Costs

Maintenance policies and technologies of today are assumed throughout the analysis. The personnel associated with the HCM served as a primary source of information in the development of the policies, based on their experience in applying the model; Harger (7) also proved to be useful in the particular case of waterbound macadam surfacing. The basic objective is to develop maintenance policies which minimize maintenance and user costs and result in all of the roads being in reasonably poor condition at the end of 15 years, the assumed design life, such that their salvage values are low and reasonably comparable so as to justify their being ignored. The policies are developed by basically a trial and error process, using the HCM to test alternative policies.

Maintenance of gravel surfaces (p L114) may consist of grading during the dry and wet seasons, spot regravelling, and resurfacing; in the current project only the blading and resurfacing are done. The final maintenance policy consists, for the first 12 years, of grading once each season (i.e., once in 8 months in the dry season and once in 4 months in the wet) and resurfacing to a thickness of 29.2 cm (original depth of gravel) when the gravel reaches 15 cm in thickness; at year 13, the policy changes to just include blading. This results in the resurfacing of all segments of the road once in its 15-year life.

Maintenance of waterbound macadam surfaces (p L214, L215) may consist of calcium chloride treatments in the first year and oiling thereafter, surface patching, and periodic application of a level course. For the low standard road (p L214), maintenance entails 3 calcium chloride treatments in the first year, oiling once a year thereafter, and surface patching each year such that 100% of the cracks are filled; the surface patching is done with a bituminous mix as is standardly used for double bituminous surface treated roads. Because of its additional traffic, the high standard road (p H215) requires, in addition to the above maintenance, a level course in year 9 (the routine oiling and surface patching are not done in this year); this level course consists of filling all ruts and low spots with a bituminous mix, generally amounting to about 2 cm of material over some 30% of the road (an average of 0.6 cm over the entire road), and then oiling the whole surface.

Maintenance of double bituminous surface treated roads consists of surface patching and periodic application of a chip seal, level course, or overlay. The dbst projects fall into several groups on the basis of maintenance policy. For the low standard dbst road on a gravel base, projects L311, L314, L315, L316, and L317, and high standard dbst road on a wbm base and gravel subbase, project H415, and adequate maintenance policy entails surface patching each year such that 100% of the cracks are filled and application of a chip seal in years 5 and 10; a chip seal is a layer of bitumen followed by a layer of fine crushed rock, generally with a greater proportion of bitumen to aggregate than is used in the original surface treatment. The high standard dbst road on a gravel base, projects H312, H313, H315 and H317, requires the routine surface patching on a yearly basis, a chip seal in year 5, and a level course in year 9; the level course is like that for the wbm surface, except that it is followed by a chip seal rather than by oiling. The only projects left are those on the 3.5% CBR subgrade; of these, the projects which are properly designed, projects L324 and H325, exhibit the same behavior, and thus require the same maintenance policies, as those on the 7% CBR subgrade, projects L314 and H315, respectively. The improperly designed projects, L334 and H335, call for the routine surface patching and application of an overlay, except in year 15, whenever the surface roughness gets over 4000 mm/km; an overlay consists of a tack coat of bitumen followed by the application of a 1 cm thickness of bituminous mix and a chip seal. This policy results in an overlay every other year for the low standard road, and one every year, but 1 and 15, for the high standard road; this is a lot of maintenance.

Routine maintenance performed annually on the various projects includes blading of gravel shoulders (included with surface grading for the gravel road, p L114), brush and vegetation control within 1.5 meters (5 feet) on either side of the road beyond the ditch, and culvert/ditch cleaning.

The unit costs of the various maintenance activities are, by and large, derived in the same way. For each activity, one or more sets of productivity data, generally taken from maintenance studies, studies of alternative design standards, and engineering texts, are used. This data most often specifies a crew of men and equipment with the times required for each to complete a given activity, plus materials quantities where applicable. The equipment hours are then priced for 1974 using equipment rental rates from Means (13) and from conversations with engineers at Warren Brothers (29). The labor and materials are priced at 1974 simply using the prices in the construction phase of the study. Labor, equipment, and materials costs are then summed, and 20 percent added for overhead and profit to arrive at the unit cost for each activity. In cases where more than one set of productivity data are available, the average of the unit costs is used.

Maintenance costs for 1930 and developing countries are also needed. The U.S. Federal Highway Administration has published a highway maintenance and operation cost index (20, 27) since 1935 which can reasonably be extrapolated back to 1930, yielding a figure of 24 (1967 = 100) for that year; at the time of the study, figures only up to 1973 were available, so the index was extrapolated forward to 1974, yielding a figure of 150 (1967 = 100). The ratio of these two numbers gives an indexing factor of 0.16, which, when applied to the 1974 unit costs, adjusts them to the unit costs at 1930.

Deriving such an indexing factor for developing conditions is less straightforward. Given some cost figures for maintenance operations in Ethiopia (14), these were compared with the U.S. figures derived above for 1974; dropping the top and bottom figures, the ratio is found to range from 0.34 to 0.63, averaging at 0.49. A comparison of the costs of the least-cost technical packages under developing conditions to those under 1974 U.S. conditions for the various stages of construction gives a ratio ranging from 0.25 to 1.01, averaging at

0.61; similarly using developing conditions except for 1974 equipment and associated items, a ratio ranging from 0.24 to 0.79, averaging at 0.54 is found. Looking over these figures, 0.55 is selected as the indexing factor to be used in adjusting the 1974 unit costs for maintenance to those under developing conditions.

Table C.2 gives the unit costs, under 1974, 1930 and developing conditions, of the various maintenance activities discussed in the policies section, as well as the sources upon which their derivation is based.

C.22 Vehicle Characteristics, Utilization, and Costs

Transport technologies of today are assumed throughout the analysis, resulting in one set of vehicle characteristics and utilization data, as in the case of maintenance policies, although user costs are needed for various price conditions. A car, a single-unit truck (SU truck), and two semi-trailer combinations, one with two axles on the cab (2-S2 truck) and one with three (3-S2 truck) make up the vehicle set, selected on the basis of their representativeness of the range of vehicles and the availability of data. Table C.3 gives the basic characteristics and utilization data, along with the sources for these vehicles, as required by the HCM.

Vehicle cost data for 1974 is, in general, reasonably available from a variety of reliable sources. When comparable data is available from more than one source, the figure used is generally an average; when updating of the data is required, the wholesale price and labor wage indexes of the U.S. Bureau of Labor Statistics (BLS) (22) are

Table C.2: Unit costs ($/unit) and their sources for the various activities involved in highway maintenance under 1974, 1930, and developing conditions.

Activity	Units	Economic Conditions: 1974 Price	Economic Conditions: 1974 Source	Economic Conditions: 1930 Price[a]	Economic Conditions: Developing Country Price[a]
Gravel road maintenance:					
Dry season grading	km of road	28.66	9,13,15	4.59	15.76
Wet season grading	km of road	28.66	9,13,15	4.59	15.76
Gravel resurfacing	CCM of gravel	23.06[b]	9,13	3.69[b]	12.68[b]
Wbm road maintenance:					
Calcium chloride treatment	SM of road	0.04[c]	7,8,12,13,29	0.006[c]	0.022[c]
Oiling	SM of road	0.28	7,10,29,31	0.04	0.15
Surface patching	SM of area repaired	8.13	8,9,10,13,29,31	1.30	4.47
Level course[d]	CCM of material	117.54	7,9,10,13,29,31	18.81	64.65
Dbst road maintenance:					
Surface patching	SM of area repaired	8.13	8,9,10,13,29,31	1.30	4.47
Chip seal	SM of road	0.71	9,10,13,29	0.11	0.39
Level course[e]	CCM of material	189.20	9,10,13,29	30.27	104.06
Overlay[e]	CCM of material	116.99	8,9,10,13,29	18.72	64.34
Routine maintenance:					
Grading gravel shoulders	km of road	82.97	10,13	13.28	45.63
Brush control	ha of area cleared	30.75	4,8	4.92	16.91
Culvert/ditch cleaning	CM of muck removed	23.47	8,10,13	3.76	12.91

(Table C.2 continued)

[a]See text for description of derivation of prices.

Indexing factor: 0.16 for 1930 (20, 27)
0.55 for developing country (14 and estimate)

[b]Assuming resurfacing is done over the full 6.10 meters of road surface width.

[c]Cost of one treatment.

[d]Includes oiling.

[e]Includes chip seal.

Table C.3: Vehicle characteristics and utilization data and their sources.

	Vehicle name				Source
	Car	SU truck	2-S2 truck	3-S2 truck	
Fuel type	gasoline	gasoline	gasoline	diesel	-
Brake horsepower	187	165	210	218	30
Maximum cruising speed (km/hr)	110[a]	110[a]	110[a]	110[a]	-
Unloaded vehicle weight (metric tons)	1.6	2.6	10.0	13.6	16,17,30
Maximum load (metric tons)	0.4	3.5	15.1	18.7	30
Axle configuration[b] -type/% gross weight	sngl/33.3	sngl/20.0	sngl/7.7	sngl/6.0	30
-type/% gross weight	sngl/66.7	sngl/80.0	sngl/30.8	dbl/47.0	30
-type/% gross weight	-	-	dbl/61.5	dbl/47.0	30
Annual utilization (hrs)	372	446	1,171	1,464	9,26,30
Annual km driven	23,800	25,000	65,600	82,000	9,26,30
Normal vehicle life (yrs)	8	10	10	10	9,26,30

(Table C.3 continued)

[a]The HCM assumes maximum speeds at or below these values; using these figures thus means that no constraints will be placed on vehicle operation due to limitations in its power.

[b]The HCM recommends using the following fractions when axle load information is not available:

steering axle $\frac{1}{T-1}$

each other axle group $\frac{N}{T-1}$

where T = total number of tires on vehicle

N = number of tires in axle group

used. It might be noted that the fuel costs used are different from those used in conjunction with construction equipment, since retail rather than wholesale prices are assumed here; interest rates are taken as being the same, however. Overhead and value of time savings are taken as zero due to a lack of data. Finally, finding annual insurance costs and registration, license, and inspection fees for trucks presented the most difficulties by far and merits some further explanation.

The U.S. Interstate Commerce Commission (28) gives the following figures for Class I common carriers of general freight involved in intercity service at the end of 1973:*

Vehicle Type	Number	Value
Trucks	51,537	$ 322,178,272
Truck-tractors	109,917	$1,445,151,179
Semi-trailers	234,154	$1,116,556,971
Full Trailers	1,945	$ 11,637,067

Insurance for the above vehicles (cargo loss and damage, fire, theft, collision, public liability and property damage, and other insurance expenses) - $246,868,772

Vehicle licenses and registration fees - $154,538,335

Each vehicle is given an insurance cost and license and registration cost on the basis of its value (i.e., the average value of a truck of its type) as a percentage of the total value of all vehicles. Costs

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*Class I carriers are defined as those having one million dollars or more average annual gross operating revenues; intercity service means at least 50 percent of the carriers revenues come from intercity business.

for the single-unit truck are based on the data for trucks, while costs for the two larger trucks are based on the data for truck-tractors with semi-trailers.

In order to arrive at costs under 1930 conditions, the individual items constituting vehicle cost data are generally indexed back separately from 1974, as no convenient overall index exists as in maintenance. With a certain amount of extrapolation of the BLS's consumer price index for various vehicle related items (21, 22), and use of their wholesale price index for motor vehicles and equipment (22), the basic vehicle data for 1974 is indexed back to 1930. Similarly, the prices of petroleum products are indexed by means of ratios of the prices used in the construction phase of the research or by means of the BLS consumer and wholesale price indexes (21, 22). Labor costs are generally handled somewhat more directly by means of a 1957 BLS bulletin (25). Total user costs (undiscounted) over the life of the road as determined by the HCM using this 1930's data are some 18 percent of those using the 1974 data.

Vehicle cost figures under developing conditions are largely based on logic and a certain amount of fact, much as in the case of the materials costs. Keeping in mind the vehicle information available in a few developing country case studies (2, 14, 18, 19), and the general comments of various authors (3, 11), costs are developed in line with the set of economic conditions used in the construction cost phase. Vehicle and tire costs are thus taken as somewhat less than twice the 1974 U.S. figures, as vehicles are generally driven over a longer time in developing countries. Insurance is left about the same, and fees for registration, licensing, and inspection are half the 1974 figures which is probably still a little high. Labor, petroleum products, and interest rate are based directly on the figures used in the construction cost phase of the research, although maintenance labor is taken as twice the skilled wage rate due to scarcity and helper costs as twice the unskilled rate as compensation for expenses incurred on the road. Using these figures for developing conditions, the HCM computes total user costs over the life of the road, the final result being some 90 percent of 1974 user costs (both undiscounted).

Table C.4 gives the vehicle cost data under 1974, 1930, and developing conditions, as well as the sources upon which the figures are based.

Table C.4a: Vehicle cost data in dollars and their sources at the prices of 1974.

Cost Item	Car	SU truck	2-S2 truck	3-S2 truck	Source
Vehicle cost new less tires	4,340	7,500	23,300	30,000	17,26,30
Tire cost (1 tire)	33	122	187	290	16,17,22,26,30
Annual insurance cost	162	540	1,500	1,500	26,28
Annual registration, licensing, and inspection fees	47	350	1,000	1,000	26,28
Maintenance labor (per hour)	12.00	6.73	6.73	6.73	22,26,28
Driver cost (per month)	0	925	1,110	1,292	22,24
Helper cost (per month)	0	855	1,082	1,193	22,24

	Unit Price/Rate	Source
Petroleum products:		
gasoline (liter)	0.13	17,26
diesel fuel (liter)	0.11	17
oil (liter)	0.72	17,26
Interest rate (%)	11.5	5

Table C.4b: Vehicle cost data in dollars and their sources at the prices of 1930.

Cost Item	Car	SU truck	2-S2 truck	3-S2 truck	Source
Vehicle cost new less tires	1,351	2,287	7,105	9,149	17,22,26,30
Tire cost (1 tire)	9	37	57	88	16,17,22,26,30
Annual insurance cost	28	92	255	255	21,22,26,28
Annual registration, licensing, and inspection fees	23	169	482	482	21,22,26,28
Maintenance labor (per hour)	1.21	0.68	0.68	0.68	22,24,25,26,28
Driver cost (per month)	0	104	104	104	25
Helper cost (per month)	0	80	80	80	25

	Unit Price/Rate	Source
Petroleum products:		
gasoline (liter)	0.06	17,21,22,26
diesel fuel (liter)	0.03	17,22
oil (liter)	0.25	17,21,22,26
Interest rate (%)	5.0	5

Table C.4c: Vehicle cost data in dollars under developing conditions.

Cost Item	Car	SU truck	2-S2 truck	3-S2 truck
Vehicle cost new less tires	7,810	13,500	41,900	54,000
Tire cost (1 tire)	59	220	337	522
Annual insurance cost	162	540	1,500	1,500
Annual registration, licensing and inspection fees	24	175	500	500
Maintenance labor (per hour)	0.40	0.40	0.40	0.40
Driver cost (per month)	0	33	33	33
Helper cost (per month)	0	17	17	17

	Unit Price/Rate
Petroleum products:	
gasoline (liter)	0.50
diesel fuel (liter)	0.40
oil (liter)	2.70
Interest rate (%)	20.0

Note: See text for discussion of the derivation of these prices.

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C.3 Tables of Project Results

Combining the project quantities with the unit costs of the least-cost technical packages for various technology and price periods and the various maintenance and user cost data via the HCM for the appropriate price periods yields the project-level results, as given in Table C.5, for each project under various technology and price conditions. Table C.5A gives project costs using the least cost technical packages of the 1920's at the prices of 1930 (C.5AA), 1974 (C.5AB), and a developing country (C.5AC); similarly C.5B covers the least cost packages of the 1950's and C.5C the 1970's. Table C.5D gives project costs using the least-cost technical packages over all technology periods (1920-70 mix) at the prices of a typical developing country. The numbers beside the names of the stages of construction designate the technical package used in the activity, except where more than one package is used when the number of packages in the least-cost set is given. All costs in the table are given in $1000, except those labeled /TRAFFIC which are given in dollars per standard axle.

TABLE C.6AA: PROJECT COSTS IN $1000 USING THE BEST-PRACTICE TECHNICAL PACKAGES OF THE 1920'S AT THE PRICES OF 1930.

PROJECT COST ($1000) \ PROJECT NUMBER		L114	L214	L314	H215	H315	H415
SITE PREP	21	2.3700	2.3700	2.3700	2.9646	2.9646	2.9646
EXCAVATION/HAULING							
DITCH	5-4	1.1487	1.1487	1.1487	1.1208	1.1208	1.1208
6M	7-6	0.6488	0.6488	0.6488	0.0	0.0	0.0
9M	7-6	0.0	0.0	0.0	7.3682	7.3682	7.3682
60M	7-6	0.2509	0.2509	0.2509	0.0	0.0	0.0
100M	AVE 2	0.0	0.0	0.0	0.0	0.0	0.0
165M	9-7	0.0	0.0	0.0	12.9502	12.9502	12.9502
L-500M	7-6	0.0	0.0	0.0	46.3464	46.3464	46.3464
P-500M	10-8	13.8768	13.8768	13.8768	35.4978	35.4978	35.4978
800M	10-8	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL		15.9252	15.9252	15.9252	103.2834	103.2834	103.2834
SPREADING/COMPACTION							
98%	32	3.4222	3.4222	3.4222	16.8218	16.8218	16.8218
93%		0.0	0.0	0.0	0.0	0.0	0.0
SURFACING							
GRAVEL	22	3.6057	2.2414	3.6707	3.0535	4.8943	3.0535
WBM	211	0.0	9.1224	0.0	12.3080	0.0	12.3080
DBST/G	1121	0.0	0.0	3.7852	0.0	5.0683	0.0
DBST/W	1121	0.0	0.0	0.0	0.0	0.0	5.0683
TOTAL W/O SURF MAT		25.3231	33.0812	29.1731	138.4313	133.0323	143.4995
TOTAL W/ALL MAT		204.1440	224.8801	222.5735	398.6650	390.9629	417.2751
SKILLED LABOR		4.7315	6.8559	5.4156	31.9062	29.9347	32.8009
UNSKILLED LABOR		7.0985	10.7159	8.8418	24.7555	22.2169	27.0976
/TRAFFIC		0.0446	0.0663	0.0540	0.0284	0.0261	0.0300
CAPITAL		13.4931	15.5094	14.6759	81.7695	80.8807	83.6010
/TRAFFIC		0.0509	0.0585	0.0561	0.0409	0.0405	0.0418
MATERIALS		178.8210	191.7990	193.4003	260.2339	257.9309	273.7759
/TRAFFIC		0.6748	0.7236	0.7298	0.1302	0.1291	0.1370
OVERHEAD & PROFIT		40.8288	44.9760	44.5147	79.7330	78.1926	83.4550
TOTAL CONSTR COSTS		244.9728	269.8560	267.0881	478.3979	469.1553	500.7300
/TRAFFIC		0.9244	1.0183	1.0079	0.2394	0.2348	0.2506
MAINT COSTS (NPV)		60.7000	64.2000	43.0000	93.2000	70.8000	40.2000
/TRAFFIC		0.2291	0.2423	0.1623	0.0466	0.0354	0.0201
EQUIV ANNUAL MAINT		5.2706	5.5745	3.7337	8.0926	6.1476	3.4906
USER COSTS (NPV)		763.2000	699.8999	658.5000	4294.6016	4096.1992	3896.1001
/TRAFFIC		2.8800	2.6411	2.4849	2.1490	2.0497	1.9496
EQUIV ANNUAL USER		66.2687	60.7723	57.1776	372.9001	355.6729	338.2983
TOTAL PROJECT COSTS		1068.8726	1033.9558	968.5881	4866.1992	4636.1523	4437.0273
/TRAFFIC		4.0335	3.9017	3.6550	2.4350	2.3199	2.2203

TABLE C.5AA: PROJECT COSTS IN $1000 USING THE BEST-PRACTICE TECHNICAL PACKAGES OF THE 1920'S AT THE PRICES OF 1935.

PROJECT COST($1000)	PROJECT NUMBER	L314	L324	L334	H315	H325	H335
SITE PREP	21	2.3700	2.3515	2.3535	2.9646	2.9324	2.8820
EXCAVATION/HAULING							
DITCH	5-4	1.1487	1.1487	1.1407	1.1208	1.1206	1.1209
6M	7-6	0.6498	0.6454	0.6454	0.0	0.0	0.0
9M	7-6	0.0	0.0	0.0	7.3682	7.3294	7.3294
60M	7-6	0.2509	0.2509	0.2509	0.0	0.0	0.0
100M	AVE 2	0.0	0.0	0.0	0.0	0.0	0.0
165M	9-7	0.0	0.0	0.0	12.9502	10.1265	10.1265
L-500M	7-6	0.0	0.0	0.0	46.3464	46.3464	46.3464
P-500M	10-8	13.8768	12.8908	12.8908	35.4978	35.4978	35.4978
800M	10-8	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL		15.9252	14.9358	14.9358	103.2814	100.4209	100.4209
SPREADING/COMPACTION							
98%	32	3.4222	0.0	0.0	16.8218	0.0	0.0
93%	31	0.0	3.0180	3.0180	0.0	14.8190	14.8190
SURFACING							
GRAVEL	22	3.6707	5.6955	3.6707	4.9943	6.0549	4.8943
WBM	211	0.0	0.0	0.0	0.0	0.0	0.0
DBST/G	1121	3.7852	3.7852	3.7852	5.0683	5.0683	5.0683
DBST/W	1121	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL W/O SURF MAT		29.1733	24.7891	27.7632	133.0323	130.0551	129.0944
TOTAL W/ALL MAT		222.5735	323.6057	221.1635	390.9629	485.7197	386.0151
SKILLED LABOR		5.4156	5.2340	4.7403	20.9347	27.1926	25.7121
UNSKILLED LABOR		8.9819	10.0225	8.9595	22.2169	23.9433	22.9077
/TRAFFIC		0.0540	0.0576	0.0517	0.0261	0.0256	0.0249
CAPITAL		14.9750	14.5316	14.0645	90.8837	78.9192	78.4646
/TRAFFIC		0.0561	0.0544	0.0531	0.0495	0.0395	0.0373
MATERIALS		193.4003	298.8191	193.4003	257.9309	355.6646	257.9307
/TRAFFIC		0.7299	1.1098	0.7298	0.1241	0.1783	0.1241
OVERHEAD & PROFIT		44.5147	64.7213	44.2327	78.1926	97.1433	77.2030
TOTAL CONSTR COSTS		267.0881	389.3279	265.3961	469.1553	582.8635	463.2190
/TRAFFIC		1.0079	1.4654	1.0015	0.2360	0.2917	0.2319
MAINT COSTS (NPV)		43.0000	43.0000	114.9000	70.8000	70.8000	241.2000
/TRAFFIC		0.1623	0.1623	0.4335	0.0354	0.0354	0.1207
EQUIV ANNUAL MAINT		3.7337	3.7337	9.9768	6.1478	6.1478	20.9434
USER COSTS (NPV)		658.5000	658.5000	688.8000	4096.1992	4096.1992	4180.1992
/TRAFFIC		2.4849	2.4849	2.5997	2.0497	2.0497	2.0918
EQUIV ANNUAL USER		57.1776	57.1776	59.8085	355.6729	355.6729	362.9656
TOTAL PROJECT COSTS		968.5881	1099.8279	1069.0959	4636.1573	4749.9594	4885.6172
/TRAFFIC		3.6553	4.1126	4.0343	2.3199	2.3769	2.4443

TABLE C.5AA: PROJECT COSTS IN $1000 USING THE BEST-PRACTICE TECHNICAL PACKAGES OF THE 1920'S AT THE PRICES OF 1930.

PROJECT COST ($1000) \ PROJECT NUMBER		L311	L314	L315	H312	H313	H315	L316	L317	H317
SITE PREP	21	2.8655	2.3700	2.3535	4.6823	3.6583	2.9646	2.3700	2.3535	2.9646
EXCAVATION/HAULING										
DITCH	5-4	0.5743	1.1487	1.1487	0.0	0.2133	1.1208	1.1487	1.1487	1.1208
6M	7-6	0.8093	0.6488	0.5826	0.0	0.0	0.0	0.6488	0.5826	0.0
9M	7-6	1.2119	0.0	0.0	13.9162	8.8438	7.3682	0.0	0.0	7.3682
60M	7-6	0.2509	0.2509	0.0	2.2077	0.0	0.0	0.2509	0.0	0.0
100M	AVE 2	0.0	0.0	0.0	0.0	4.0594	0.0	0.0	0.0	0.0
165M	9-7	0.0	0.0	0.0	30.8802	0.0	12.9502	0.0	0.0	0.0
L-500M	7-6	0.0	0.0	3.5655	0.0	46.3464	46.3464	0.0	3.5655	46.3464
P-500M	10-8	0.0	13.8768	12.9629	0.0	35.4978	35.4978	0.0	0.0	57.8883
800M	10-8	0.0	0.0	0.0	0.0	0.0	0.0	17.6850	16.5203	0.0
TOTAL		2.8464	15.9252	18.2597	47.0041	94.9606	103.2834	19.7334	21.8170	112.7237
SPREADING/COMPACTION										
99%	32	3.4222	3.4222	3.4222	16.8218	16.8218	16.8218	3.4222	3.4222	16.8218
93%		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SURFACING										
GRAVEL	22	3.6707	3.6707	3.6707	4.8943	4.8943	4.8943	3.6707	3.6707	4.8943
WBM	211	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DBST/G	1121	3.7852	3.7852	3.7852	5.0683	5.0683	5.0683	3.7852	3.7852	5.0683
DBST/W	1121	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL W/O SURF MAT		16.5900	29.1733	31.4913	78.4706	125.4031	133.0323	32.9815	35.0487	142.4726
TOTAL W/ALL MAT		209.9902	222.5735	224.8915	336.4014	383.3337	390.9629	226.3817	228.4489	400.4033
SKILLED LABOR		4.4688	5.4156	6.1777	19.1543	29.5501	29.9347	5.4156	6.1777	30.4467
UNSKILLED LABOR		4.3481	8.6618	8.5386	18.3336	17.1937	22.2169	10.2666	9.8922	23.7150
/TRAFFIC		0.0333	0.0540	0.0558	0.0188	0.0234	0.0261	0.0592	0.0606	0.0271
CAPITAL		7.7731	14.8759	16.7150	40.9827	78.6593	80.8607	17.2993	18.9788	88.3100
/TRAFFIC		0.0293	0.0561	0.0631	0.0205	0.0394	0.0405	0.0653	0.0716	0.0442
MATERIALS		193.4003	193.4003	193.4003	257.9309	257.9309	257.9309	193.4003	193.4003	257.9309
/TRAFFIC		0.7298	0.7298	0.7298	0.1291	0.1291	0.1291	0.7298	0.7298	0.1291
OVERHEAD & PROFIT		41.9980	44.5147	44.9783	67.2803	76.6667	78.1926	45.2763	45.6898	80.0807
TOTAL CONSTR COSTS		251.9883	267.0881	269.8696	403.6814	460.0002	469.1553	271.6580	274.1387	480.4839
/TRAFFIC		0.9509	1.0079	1.0184	0.2020	0.2302	0.2348	1.0251	1.0345	0.2404
MAINT COSTS (NPV)		43.0000	43.0000	43.0000	70.8000	70.8000	70.8000	43.0000	43.0000	70.8000
/TRAFFIC		0.1623	0.1623	0.1623	0.0354	0.0354	0.0354	0.1623	0.1623	0.0354
EQUIV ANNUAL MAINT		3.7337	3.7337	3.7337	6.1476	6.1476	6.1476	3.7337	3.7337	6.1476
USER COSTS (NPV)		658.5000	658.5000	658.5000	4096.1992	4096.1992	4096.1992	658.5000	658.5000	4096.1992
/TRAFFIC		2.4849	2.4849	2.4849	2.0497	2.0497	2.0497	2.4849	2.4849	2.0497
EQUIV ANNUAL USER		57.1776	57.1776	57.1776	355.6729	355.6729	355.6729	57.1776	57.1776	355.6729
TOTAL PROJECT COSTS		953.4680	968.5681	971.3696	4570.6797	4626.9961	4636.1523	973.1580	975.6387	4647.4805
/TRAFFIC		3.5981	3.6550	3.6655	2.2872	2.3153	2.3199	3.6723	3.6817	2.3256

TABLE C.5A8: PROJECT COSTS IN $1000 USING THE BEST-PRACTICE TECHNICAL PACKAGES OF THE 1920'S AT THE PRICES OF 1974.

PROJECT COST($1000) \ PROJECT NUMBER		L114	L214	L314	H215	H315	H415
SITE PREP	21	17.3348	17.3348	17.3348	21.6836	21.6836	21.6836
EXCAVATION/HAULING							
DITCH	5-4	13.9525	13.9525	13.9525	13.6140	13.6140	13.6140
6M	7-6	3.9670	3.9670	3.9670	0.0	0.0	0.0
9M	7-6	0.0	0.0	0.0	44.9160	44.9160	44.9160
60M	7-6	1.5337	1.5337	1.5337	0.0	0.0	0.0
100M	AVE 2	0.0	0.0	0.0	0.0	0.0	0.0
165M	9-7	0.0	0.0	0.0	138.1790	138.1790	138.1790
L-500M	7-6	0.0	0.0	0.0	282.8999	282.8999	282.8999
P-500M	10-8	128.7287	128.7287	128.7287	329.2954	329.2954	329.2954
800M	10-9	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL		148.1819	148.1819	148.1819	808.9041	808.9041	808.9041
SPREADING/COMPACTION							
98%	32	27.6829	27.6829	27.6829	136.0751	136.0751	136.0751
93%		0.0	0.0	0.0	0.0	0.0	0.0
SURFACING							
GRAVEL	22	45.9140	28.5412	46.7413	38.8821	62.3217	38.8921
WBM	211	0.0	116.1594	0.0	156.7229	0.0	156.7229
OBST/G	1121	0.0	0.0	43.9950	0.0	58.9077	0.0
OBST/W	1121	0.0	0.0	0.0	0.0	0.0	58.9077
TOTAL W/O SURF MAT		239.1136	337.8999	283.9358	1162.2676	1087.8916	1221.1750
TOTAL W/ALL MAT		580.1052	689.8518	668.9568	1639.9053	1601.4668	1741.1039
SKILLED LABOR		53.0497	76.7939	60.7110	357.1550	335.1384	367.1782
UNSKILLED LABOR		121.7458	183.8008	152.2577	424.6562	381.0022	464.7271
/TRAFFIC		0.6596	0.9834	0.8037	0.3912	0.3584	0.4163
CAPITAL		64.3191	77.3034	70.9664	380.4553	371.7505	309.2686
/TRAFFIC		0.2427	0.2917	0.2678	0.1904	0.1860	0.1948
MATERIALS		340.9919	351.9519	385.0212	477.6377	513.5747	519.9285
/TRAFFIC		1.2868	1.3281	1.4529	0.2390	0.2570	0.2602
OVERHEAD & PROFIT		116.0210	137.9707	133.7913	327.9810	320.2932	348.2207
TOTAL CONSTR COSTS		696.1262	827.9245	802.7469	1967.8862	1921.7600	2089.3245
/TRAFFIC		2.6269	3.1239	3.0292	0.9947	0.9616	1.0455
MAINT COSTS (NPV)		256.5000	312.5000	198.6000	437.3999	312.3999	187.0000
/TRAFFIC		0.9679	1.1792	0.7494	0.2189	0.1563	0.0936
EQUIV ANNUAL MAINT		29.9669	36.5094	23.2024	51.1014	36.4977	21.8472
USER COSTS (NPV)		2858.8999	2555.3000	2415.8000	16431.1516	15774.6992	15170.8008
/TRAFFIC		10.7883	9.6426	9.1162	9.2221	7.8937	7.5915
EQUIV ANNUAL USER		334.0051	298.5356	282.2378	1919.6453	1842.9579	1772.4043
TOTAL PROJECT COSTS		3811.5261	3695.6245	3417.1479	18836.3867	18098.9555	17447.1250
/TRAFFIC		14.3831	13.9458	12.8949	9.4257	9.0114	8.7305

TABLE C.6AB: PROJECT COSTS IN $1000 USING THE BEST-PRACTICE TECHNICAL PACKAGES OF THE 1920'S AT THE PRICES OF 1974.

PROJECT COST ($1000) \ PROJECT NUMBER		L311	L314	L315	H312	H313	H315	L316	L317	H317
SITE PREP	21	20.9588	17.3348	17.2140	34.2468	26.7574	21.6836	17.3348	17.2140	21.6836
EXCAVATION/HAULING										
DITCH	5-4	6.9762	13.9525	13.9525	0.0	2.5903	13.6140	13.9525	13.9525	13.6140
6M	7-6	4.9487	3.9670	3.5622	0.0	0.0	0.0	3.9670	3.5622	0.0
9M	7-6	7.3875	0.0	0.0	84.8321	53.9110	44.9160	0.0	0.0	44.9160
60M	7-6	1.5337	1.5337	0.0	13.4970	0.0	0.0	1.5337	0.0	0.0
100M	AVE 2	0.0	0.0	0.0	0.0	33.8475	0.0	0.0	0.0	0.0
165M	9-7	0.0	0.0	0.0	329.4922	0.0	138.1790	0.0	0.0	0.0
L-500M	7-6	0.0	0.0	21.7637	0.0	282.8999	282.8999	0.0	21.7637	282.8999
P-500M	10-8	0.0	128.7287	120.2509	0.0	329.2954	329.2954	0.0	0.0	537.0015
800M	10-8	0.0	0.0	0.0	0.0	0.0	0.0	161.3868	150.7582	0.0
TOTAL		20.8461	148.1819	159.5293	427.8213	702.5439	808.9041	180.8401	190.0367	878.4312
SPREADING/COMPACTION										
98%	32	27.6829	27.6629	27.6829	136.0751	136.0751	136.0751	27.6829	27.6829	136.0751
93%		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SURFACING										
GRAVEL	22	46.7413	46.7413	46.7413	62.3217	62.3217	62.3217	46.7413	46.7413	62.3217
WBM	211	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DBST/G	1121	43.9950	43.9950	43.9950	58.9077	58.9077	58.9077	43.9950	43.9950	58.9077
DBST/W	1121	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL W/O SURF MAT		160.2241	283.9358	295.1624	719.3718	986.6052	1087.8916	316.5937	325.6697	1157.4187
TOTAL W/ALL MAT		545.2449	668.9568	680.1833	1232.9470	1500.1804	1601.4668	701.6150	710.6907	1670.9939
SKILLED LABOR		50.6607	60.7118	69.2236	214.4815	330.8713	335.1384	60.7118	69.2236	340.9944
UNSKILLED LABOR		74.4589	152.2577	147.3975	314.2825	294.8511	381.0022	175.3377	168.9575	406.7908
/TRAFFIC		0.4699	0.8037	0.8174	0.2646	0.3131	0.3584	0.8908	0.6988	0.3742
CAPITAL		35.7046	70.9664	78.5414	190.6086	360.8826	371.7505	80.5446	87.4888	409.6331
/TRAFFIC		0.1347	0.2678	0.2964	0.0954	0.1806	0.1860	0.3039	0.3301	0.2050
MATERIALS		385.0212	385.0212	385.0212	513.5747	513.5747	513.5747	385.0212	385.0212	513.5747
/TRAFFIC		1.4529	1.4529	1.4529	0.2570	0.2570	0.2570	1.4529	1.4529	0.2570
OVERHEAD & PROFIT		109.0490	133.7913	136.0367	246.5894	300.0359	320.2932	140.3230	142.1381	334.1987
TOTAL CONSTR COSTS		654.2937	802.7480	816.2200	1479.5364	1800.2163	1921.7600	841.9377	852.8286	2005.1926
/TRAFFIC		2.4690	3.0292	3.0801	0.7404	0.9008	0.9616	3.1771	3.2182	1.0034
MAINT COSTS (NPV)		198.6000	198.6000	198.6000	312.3999	312.3999	312.3999	198.6000	198.6000	312.3999
/TRAFFIC		0.7494	0.7494	0.7494	0.1563	0.1563	0.1563	0.7494	0.7494	0.1563
EQUIV ANNUAL MAINT		23.2024	23.2024	23.2024	36.4977	36.4977	36.4977	23.2024	23.2024	36.4977
USER COSTS (NPV)		2415.8000	2415.8000	2415.8000	15774.6992	15774.6992	15774.6992	2415.8000	2415.8000	15774.6992
/TRAFFIC		9.1162	9.1162	9.1162	7.8937	7.8937	7.8937	9.1162	9.1162	7.8937
EQUIV ANNUAL USER		282.2378	282.2378	282.2378	1842.9578	1842.9578	1842.9578	282.2378	282.2378	1842.9578
TOTAL PROJECT COSTS		3268.6936	3417.1479	3430.6199	17566.6328	17887.3125	18008.8555	3456.3376	3467.2285	18092.2891
/TRAFFIC		12.3347	12.8949	12.9457	8.7903	8.9508	9.0116	13.0428	13.0839	9.0534

TABLE C.5AC: PROJECT COSTS IN $1000 USING THE LEAST-COST TECHNICAL PACKAGES OF THE 1920'S AT THE PRICES OF A TYPICAL DEVELOPING COUNTRY.

PROJECT COST($1000) \ PROJECT NUMBER		L114	L214	L314	H215	H315	H415
SITE PREP	11	5.0103	5.0103	5.0103	6.2672	6.2672	6.2672
EXCAVATION/HAULING							
DITCH	AVE 2	0.2599	0.2599	0.2599	0.2536	0.2536	0.2536
6M	AVE 2	1.1601	1.1601	1.1601	0.0	0.0	0.0
9M	AVE 2	0.0	0.0	0.0	11.8777	11.8777	11.8777
60M	5-4	0.1993	0.1993	0.1993	0.0	0.0	0.0
100M	8-7	0.0	0.0	0.0	0.0	0.0	0.0
165M	8-7	0.0	0.0	0.0	4.1327	4.1327	4.1327
L-500M	6-5	0.0	0.0	0.0	40.4325	40.4325	40.4325
P-500M	8-7	4.5150	4.5150	4.5150	0.0	0.0	0.0
800M	9-7	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL		6.1343	6.1343	6.1343	56.6964	56.6964	56.6964
SPREADING/COMPACTION							
98%	21	2.3877	2.3877	2.3877	11.7369	11.7369	11.7369
99%	21	0.0	0.0	0.0	0.0	0.0	0.0
SURFACING							
GRAVEL	21	0.8462	0.5269	0.8614	0.7166	1.1485	0.7166
WBM	AVE 2	0.0	21.1365	0.0	29.5175	0.0	29.5175
DBST/G	1111	0.0	0.0	8.2494	0.0	11.0456	0.0
DBST/W	1111	0.0	0.0	0.0	0.0	0.0	11.0456
TOTAL W/O SURF MAT		14.3704	35.1947	22.6433	103.9365	96.8946	114.9801
TOTAL W/ALL MAT		105.9533	144.6616	205.3999	252.3744	331.0742	357.6937
SKILLED LABOR		1.4546	2.0308	1.6577	7.1554	6.6477	7.4251
UNSKILLED LABOR		3.3132	3.8373	3.7393	22.4750	22.3317	23.0389
/TRAFFIC		0.0180	0.0221	0.0204	0.0148	0.0145	0.0152
CAPITAL		6.5684	26.2845	14.2038	70.4937	54.1096	80.7107
/TRAFFIC		0.0248	0.0992	0.0536	0.0353	0.0271	0.0404
MATERIALS		94.6172	112.5092	185.7992	152.2454	247.9854	246.4943
/TRAFFIC		0.3570	0.4246	0.7011	0.0762	0.1241	0.1233
OVERHEAD & PROFIT		21.1907	28.9323	41.0800	50.4749	66.2148	71.5317
TOTAL CONSTR COSTS		127.1440	173.5939	246.4799	302.8491	397.2888	429.1932
/TRAFFIC		0.4798	0.6551	0.9301	0.1515	0.1981	0.2149
MAINT COSTS (NPV)		82.7000	113.2000	72.4000	152.9000	107.4000	67.8000
/TRAFFIC		0.3121	0.4272	0.2732	0.0765	0.0537	0.0339
EQUIV ANNUAL MAINT		14.1436	19.3595	12.3819	26.1489	18.3679	11.5952
USER COSTS (NPV)		1589.6301	1493.8939	1408.5000	8672.8944	8226.8009	7884.9000
/TRAFFIC		5.9985	5.6562	5.3151	4.3399	4.1167	3.9456
EQUIV ANNUAL USER		271.8533	256.3418	240.8816	1493.2398	1406.9473	1349.4583
TOTAL PROJECT COSTS		1799.4435	1705.6918	1727.3796	9124.6445	8731.4883	8381.7891
/TRAFFIC		6.7906	6.7385	6.5186	4.5680	4.3692	4.1943

TABLE C.9AC: PROJECT COSTS IN $1000 USING THE LEAST-COST TECHNICAL PACKAGES OF THE 1920'S AT THE PRICES OF A TYPICAL DEVELOPING COUNTRY.

PROJECT COST ($1000)	PROJECT NUMBER	L314	L324	L334	H315	H325	H335
SITE PREP	11	5.0103	4.9754	4.9754	6.2672	6.0926	6.0926
EXCAVATION/HAULING							
DITCH	AVE 2	0.2599	0.2599	0.2599	0.2536	0.2536	0.2536
6M	AVE 2	1.1601	1.1542	1.1542	0.0	0.0	0.0
9M	AVE 2	0.0	0.0	0.0	11.8777	11.8151	11.8151
60M	5-4	0.1993	0.1993	0.1993	0.0	0.0	0.0
100M	8-7	0.0	0.0	0.0	0.0	0.0	0.0
165M	8-7	0.0	0.0	0.0	4.1327	3.2316	3.2316
L-500M	6-5	0.0	0.0	0.0	40.4325	40.4325	40.4325
P-500M	8-7	4.5150	4.1942	4.1942	0.0	0.0	0.0
800M	8-7	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL		6.1343	5.8075	5.8075	56.6964	55.7328	55.7328
SPREADING/COMPACTION							
98%	21	2.3877	0.0	0.0	11.7369	0.0	0.0
93%	21	0.0	1.3193	1.3193	0.0	6.4780	6.4780
SURFACING							
GRAVEL	21	0.8614	1.3366	0.8614	1.1485	1.6110	1.1485
WBM	AVE 2	0.0	0.0	0.0	0.0	0.0	0.0
DBST/G	1111	8.2494	8.2494	8.2494	11.0456	11.0456	11.0456
DBST/W	1111	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL W/O SURF MAT		22.6430	21.6881	21.2130	86.8946	80.9600	80.4975
TOTAL W/ALL MAT		205.3999	255.8699	203.9698	331.0742	375.1897	324.6772
SKILLED LABOR		1.6577	1.6701	1.6183	6.6477	6.4983	6.4479
UNSKILLED LABOR		3.7393	3.6379	3.4825	22.3319	21.3863	21.2351
/TRAFFIC		0.0204	0.0200	0.0192	0.0145	0.0140	0.0139
CAPITAL		14.2038	13.3591	13.0911	54.1096	49.3760	49.1152
/TRAFFIC		0.0536	0.0504	0.0494	0.0271	0.0247	0.0246
MATERIALS		185.7992	237.2030	185.7780	247.9854	297.9292	247.8794
/TRAFFIC		0.7011	0.8951	0.7010	0.1241	0.1491	0.1240
OVERHEAD & PROFIT		41.0800	51.1740	40.7939	66.2148	75.0379	64.9354
TOTAL CONSTR COSTS		246.4799	307.0437	244.7637	397.2888	450.2275	389.6125
/TRAFFIC		0.9301	1.1587	0.9236	0.1988	0.2253	0.1950
MAINT COSTS (NPV)		72.4000	72.4000	194.2000	107.4000	107.4000	403.8999
/TRAFFIC		0.2732	0.2732	0.7328	0.0537	0.0537	0.2021
EQUIV ANNUAL MAINT		12.3818	12.3818	33.2121	18.3675	18.3675	69.0749
USER COSTS (NPV)		1408.5000	1408.5000	1488.1001	8226.8008	8226.8008	8554.8008
/TRAFFIC		5.3151	5.3151	5.6155	4.1167	4.1167	4.2808
EQUIV ANNUAL USER		240.8916	240.8816	254.4948	1406.9470	1406.9470	1463.0417
TOTAL PROJECT COSTS		1727.3796	1787.9436	1927.0637	8731.4883	8784.4258	9348.3125
/TRAFFIC		6.5184	6.7470	7.2719	4.3692	4.3957	4.6779

TABLE C.5AC: PROJECT COSTS IN $1000 USING THE LEAST-COST TECHNICAL PACKAGES OF THE 1970'S AT THE PRICES OF A TYPICAL DEVELOPING COUNTRY.

PROJECT COST($1000) \ PROJECT NUMBER		L311	L314	L315	H312	H313	H315	L316	L317	H317
SITE PREP	11	6.0577	5.0103	4.9754	9.8983	7.7336	5.2672	5.0103	4.9754	6.2672
EXCAVATION/HAULING										
DITCH	AVE 2	0.1299	0.2599	0.2599	0.0	0.0402	0.2536	0.2599	0.2599	0.2536
6M	AVE 2	1.4471	1.1601	1.0417	0.0	0.0	0.0	1.1601	1.0417	0.0
9M	AVE 2	1.9536	0.0	0.0	22.4331	14.2563	11.8777	0.0	0.0	11.8777
60M	5-4	0.1993	0.1993	0.0	1.7539	0.0	0.0	0.1993	0.0	0.0
100M	8-7	0.0	0.0	0.0	0.0	1.4216	0.0	0.0	0.0	0.0
165M	8-7	0.0	0.0	0.0	9.8546	0.0	4.1327	0.0	0.0	0.0
L-500M	6-5	0.0	0.0	1.2442	0.0	40.4325	40.4325	0.0	1.2442	40.4325
P-500M	8-7	0.0	4.5150	4.2177	0.0	0.0	0.0	0.0	0.0	7.2651
800M	8-7	0.0	0.0	0.0	0.0	0.0	0.0	6.2691	5.9562	0.0
TOTAL		3.7300	6.1343	6.7634	34.0416	56.1587	55.6964	7.8884	8.4027	59.8483
SPREADING/COMPACTION										
90T	21	2.3877	2.3877	2.3877	11.7369	11.7369	11.7369	2.3877	2.3877	11.7369
93T	21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SURFACING										
GRAVEL	21	0.8614	0.8614	0.8614	1.1485	1.1485	1.1485	0.8614	0.8614	1.1485
WBM	AVE 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DBST/G	1111	8.2494	8.2494	8.2494	11.0456	11.0456	11.0456	8.2494	8.2494	11.0456
DBST/W	1111	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL W/O SURF MAT		21.2861	22.6430	23.2373	67.8710	87.8233	85.8946	24.3971	24.8753	90.347[illegible]
TOTAL W/ALL MAT		204.0430	205.3999	205.9941	312.0505	332.0029	331.0742	207.1540	207.6327	334.2266
SKILLED LABOR		1.0896	1.6577	1.6769	6.7246	6.9409	6.6477	1.6577	1.6769	6.6477
UNSKILLED LABOR		3.6266	3.7393	4.0036	14.0229	22.8071	22.3319	4.1952	4.4294	23.1567
/TRAFFIC		0.0238	0.0234	0.0214	0.0134	0.0149	0.0145	0.0221	0.023[illegible]	0.0149
CAPITAL		12.0918	14.2038	14.5358	41.1133	53.3794	54.1096	15.5020	15.7486	56.4371
/TRAFFIC		0.0456	0.0536	0.0549	0.0206	0.0267	0.0271	0.0585	0.0594	0.0282
MATERIALS		186.4352	185.7992	185.7780	250.1902	248.8750	247.9854	185.7992	185.778[illegible]	247.9854
/TRAFFIC		0.7035	0.7011	0.7010	0.1252	0.1245	0.1241	0.7011	0.701[illegible]	0.1241
OVERHEAD & PROFIT		40.8096	41.0800	41.1988	62.4101	66.4006	66.2148	41.4308	41.5265	66.845[illegible]
TOTAL CONSTR COSTS		244.8516	246.4799	247.1930	374.4604	398.4031	397.2888	248.5847	249.1592	401.[illegible]
/TRAFFIC		0.9240	0.9301	0.9328	0.1874	0.1994	0.1988	0.9381	0.9402	0.2007
MAINT COSTS (NPV)		72.4000	72.4000	72.4000	107.4000	107.4000	107.4000	72.4000	72.400	107.400
/TRAFFIC		0.2732	0.2732	0.2732	0.0537	0.0537	0.0537	0.2732	0.2732	0.0537
EQUIV ANNUAL MAINT		12.3818	12.3818	12.3818	18.3675	18.3675	18.3675	12.3818	12.3818	18.3675
USER COSTS (NPV)		1408.5000	1408.5000	1408.5000	8226.8008	8226.8009	8226.8008	1408.5000	1408.500	8226.[illegible]
/TRAFFIC		5.3151	5.3151	5.3151	4.1167	4.1167	4.1167	5.3151	5.3151	4.1167
EQUIV ANNUAL USER		240.8816	240.8816	240.8816	1406.9470	1406.9470	1406.9470	240.8816	240.8816	1406.947
TOTAL PROJECT COSTS		1725.7515	1727.3796	1728.0928	8708.6602	8732.6016	8731.4883	1729.4946	1730.0591	8735.26[illegible]
/TRAFFIC		6.5123	6.5184	6.5211	4.3578	4.3698	4.3692	6.5264	6.528[illegible]	4.371[illegible]

TABLE C.58A: PROJECT COSTS IN $1000 USING THE BEST-PRACTICE TECHNICAL PACKAGES OF THE 1950'S AT THE PRICES OF 1930.

PROJECT COST ($1000) \ PROJECT NUMBER		L114	L214	L314	H215	H315	H415
SITE PREP	31	1.0269	1.0269	1.0269	1.2845	1.2845	1.2845
EXCAVATION/HAULING							
DITCH	11-0	0.1042	0.1042	0.1042	0.1017	0.1017	0.1017
6M	AVE 2	0.2274	0.2274	0.2274	0.0	0.0	0.0
9M	AVE 2	0.0	0.0	0.0	2.8690	2.8690	2.8690
60M	7-7	0.1164	0.1164	0.1164	0.0	0.0	0.0
100M	AVE 2	0.0	0.0	0.0	0.0	0.0	0.0
165M	AVE 2	0.0	0.0	0.0	3.4791	3.4791	3.4791
L-500M	7-7	0.0	0.0	0.0	15.3012	15.3012	15.3012
P-500M	4-4	2.2947	2.2947	2.2947	0.0	0.0	0.0
800M	4-4	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL		2.7427	2.7427	2.7427	21.7510	21.7510	21.7510
SPREADING/COMPACTION							
98%	AVE 2	0.8882	0.8882	0.8882	4.3660	4.3660	4.3660
93%		0.0	0.0	0.0	0.0	0.0	0.0
SURFACING							
GRAVEL	AVE 2	0.4752	0.2954	0.4838	0.4024	0.6450	0.4024
WPM	AVE 5	0.0	2.5162	0.0	3.3949	0.0	3.3949
DBST/G	AVE 8	0.0	0.0	0.5809	0.0	0.7778	0.0
DBST/W	AVE 8	0.0	0.0	0.0	0.0	0.0	0.7778
TOTAL W/O SURF MAT		5.1330	7.4694	5.7224	31.1988	28.8242	31.9765
TOTAL W/ALL MAT		183.9538	199.2683	199.1226	291.4326	286.7549	305.7522
SKILLED LABOR		1.5713	2.4064	1.7308	8.9361	8.0181	9.1448
UNSKILLED LABOR		0.2864	0.4361	0.3487	0.5521	0.4416	0.6354
/TRAFFIC		0.0070	0.0107	0.0078	0.0047	0.0042	0.0049
CAPITAL		3.2753	4.6329	3.6430	21.7105	20.3645	22.1963
/TRAFFIC		0.0124	0.0175	0.0137	0.0109	0.0102	0.0111
MATERIALS		178.8210	191.7990	193.4003	260.2339	257.9309	273.7759
/TRAFFIC		0.6748	0.7238	0.7298	0.1302	0.1291	0.1370
OVERHEAD & PROFIT		36.7908	39.8536	39.8245	58.2865	57.3510	61.1504
TOTAL CONSTR COSTS		220.7446	239.1219	238.9471	349.7190	344.1057	366.9026
/TRAFFIC		0.8330	0.9023	0.9017	0.1750	0.1722	0.1836
MAINT COSTS (NPV)		60.7000	64.2000	43.0000	93.2000	70.8000	40.2000
/TRAFFIC		0.2291	0.2423	0.1623	0.0466	0.0354	0.0201
EQUIV ANNUAL MAINT		5.2706	5.5745	3.7337	8.0926	6.1476	3.4906
USER COSTS (NPV)		763.2000	699.8999	658.5000	4294.6016	4096.1992	3896.1001
/TRAFFIC		2.8800	2.6411	2.4849	2.1490	2.0497	1.9496
EQUIV ANNUAL USER		66.2687	60.7723	57.1776	372.9001	355.6729	338.2983
TOTAL PROJECT COSTS		1044.6445	1003.2217	940.4470	4737.5195	4511.1016	4303.1992
/TRAFFIC		3.9421	3.7857	3.5489	2.3707	2.2574	2.1533

TABLE C.5BA: PROJECT COSTS IN $1000 USING THE BEST-PRACTICE TECHNICAL PACKAGES OF THE 1950'S AT THE PRICES OF 1930.

PROJECT COST ($1000) \ PROJECT NUMBER		L311	L314	L315	H312	H313	H315	L316	L317	H317
SITE PREP	31	1.2416	1.0269	1.0197	2.0287	1.5851	1.2845	1.0269	1.0197	1.2845
EXCAVATION/HAULING										
DITCH	11-0	0.0521	0.1042	0.1042	0.0	0.0193	0.1017	0.1042	0.1042	0.1017
6M	AVE 2	0.2836	0.2274	0.2042	0.0	0.0	0.0	0.2274	0.2042	0.0
9M	AVE 2	0.4719	0.0	0.0	5.4186	3.4436	2.8690	0.0	0.0	2.8690
60M	7-7	0.1164	0.1164	0.0	1.0246	0.0	0.0	0.1164	0.0	0.0
100M	AVE 2	0.0	0.0	0.0	0.0	1.2184	0.0	0.0	0.0	0.0
165M	AVE 2	0.0	0.0	0.0	8.2961	0.0	3.4791	0.0	0.0	0.0
L-500M	7-7	0.0	0.0	0.4709	0.0	15.3012	15.3012	0.0	0.4709	15.3012
P-500M	4-4	0.0	2.2947	2.1436	0.0	0.0	0.0	0.0	0.0	3.7026
800M	4-4	0.0	0.0	0.0	0.0	0.0	0.0	2.6715	2.4956	0.0
TOTAL		0.9240	2.7427	2.9228	14.7394	19.9825	21.7510	3.1195	3.2748	21.9744
SPREADING/COMPACTION										
98%	AVE 2	0.8882	0.8882	0.8882	4.3660	4.3660	4.3660	0.8882	0.8882	4.3660
93%		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SURFACING										
GRAVEL	AVE 2	0.4838	0.4838	0.4838	0.6450	0.6450	0.6450	0.4838	0.4838	0.6450
WBM	AVE 5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DBST/G	AVE 8	0.5809	0.5809	0.5809	0.7778	0.7778	0.7778	0.5809	0.5809	0.7778
DBST/W	AVE 8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL W/O SURF MAT		4.1184	5.7224	5.8954	22.5569	27.3563	28.8242	6.0992	6.2473	29.0477
TOTAL W/ALL MAT		197.5186	199.1226	199.2955	280.4875	285.2869	286.7549	199.4994	199.6475	286.9783
SKILLED LABOR		1.4460	1.7308	1.7654	6.9876	7.7757	8.0181	1.8306	1.8586	8.0739
UNSKILLED LABOR		0.4006	0.3487	0.3467	0.6492	0.5255	0.4416	0.3487	0.3467	0.4416
/TRAFFIC		0.0070	0.0078	0.0080	0.0038	0.0042	0.0042	0.0082	0.0083	0.0043
CAPITAL		2.2639	3.6430	3.7833	14.9200	19.0551	20.3645	3.9199	4.0420	20.5321
/TRAFFIC		0.0085	0.0137	0.0143	0.0075	0.0095	0.0102	0.0148	0.0153	0.0103
MATERIALS		193.4003	193.4003	193.4003	257.9309	257.9309	257.9309	193.4003	193.4003	257.9309
/TRAFFIC		0.7298	0.7298	0.7298	0.1291	0.1291	0.1291	0.7298	0.7298	0.1291
OVERHEAD & PROFIT		39.5037	39.8245	39.8591	56.0975	57.0574	57.3513	39.8999	39.9295	57.3956
TOTAL CONSTR COSTS		237.0223	238.9471	239.1546	336.5850	342.3440	344.1057	239.3992	239.5770	344.3738
/TRAFFIC		0.8944	0.9017	0.9025	0.1684	0.1713	0.1722	0.9034	0.9041	0.1723
MAINT COSTS (NPV)		43.0000	43.0000	43.0000	70.8000	70.8000	70.8000	43.0000	43.0000	70.8000
/TRAFFIC		0.1623	0.1623	0.1623	0.0354	0.0354	0.0354	0.1623	0.1623	0.0354
EQUIV ANNUAL MAINT		3.7337	3.7337	3.7337	6.1476	6.1476	6.1476	3.7337	3.7337	6.1476
USER COSTS (NPV)		658.5000	658.5000	658.5000	4096.1992	4096.1992	4096.1992	658.5000	658.5000	4096.1992
/TRAFFIC		2.4849	2.4849	2.4849	2.0497	2.0497	2.0497	2.4849	2.4849	2.0497
EQUIV ANNUAL USER		57.1776	57.1776	57.1776	355.6729	355.6729	355.6729	57.1776	57.1776	355.6729
TOTAL PROJECT COSTS		938.5222	940.4470	940.6545	4503.5820	4509.3398	4511.1016	940.8992	941.0769	4511.3711
/TRAFFIC		3.5416	3.5489	3.5496	2.2536	2.2565	2.2574	3.5506	3.5512	2.2575

TABLE C.58B: PROJECT COSTS IN $1000 USING THE BEST-PRACTICE TECHNICAL PACKAGES OF THE 1950'S AT THE PRICES OF 1974.

PROJECT COST ($1000) \ PROJECT NUMBER		L114	L214	L314	H215	H315	H415
SITE PREP	31	10.9605	10.9605	10.9605	13.7102	13.7102	13.7102
EXCAVATION/HAULING							
DITCH	11-0	0.6153	0.6153	0.6153	0.6003	0.6003	0.6003
6M	AVE 2	1.7287	1.7287	1.7287	0.0	0.0	0.0
9M	AVE 2	0.0	0.0	0.0	21.8120	21.8120	21.8120
60M	7-7	0.8224	0.8224	0.8224	0.0	0.0	0.0
100M	AVE 2	0.0	0.0	0.0	0.0	0.0	0.0
165M	AVE 2	0.0	0.0	0.0	24.5691	24.5691	24.5691
L-500M	7-7	0.0	0.0	0.0	107.2559	107.2559	107.2559
P-500M	4-4	16.3868	16.3868	16.3868	0.0	0.0	0.0
800M	4-4	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL		19.5531	19.5531	19.5531	154.2373	154.2373	154.2373
SPREADING/COMPACTION							
98%	AVE 2	6.8444	6.8444	6.8444	33.6436	33.6436	33.6436
91%		0.0	0.0	0.0	0.0	0.0	0.0
SURFACING							
GRAVEL	AVE 2	3.6996	2.2998	3.7663	3.1330	5.0217	3.1330
WBM	AVE 5	0.0	20.4372	0.0	27.5740	0.0	27.5740
DBST/G	AVE 8	0.0	0.0	4.4849	0.0	6.0051	0.0
DBST/W	AVE 8	0.0	0.0	0.0	0.0	0.0	6.0051
TOTAL W/O SURF MAT		41.0576	60.0950	45.6092	232.2981	212.6179	238.3032
TOTAL W/ALL MAT		382.0493	412.0488	430.6301	709.9358	726.1924	758.2317
SKILLED LABOR		17.6270	26.9825	19.4167	99.8529	89.5725	102.1950
UNSKILLED LABOR		4.9077	7.3773	5.5771	9.4709	7.5708	10.9028
/TRAFFIC		0.0850	0.1297	0.0958	0.0547	0.0486	0.0566
CAPITAL		18.5229	25.7352	20.2154	122.9743	115.4746	125.2054
/TRAFFIC		0.0699	0.0971	0.0763	0.0615	0.0578	0.0627
MATERIALS		340.9919	351.9539	385.0212	477.6377	513.5747	519.9285
/TRAFFIC		1.2868	1.3281	1.4529	0.2390	0.2570	0.2602
OVERHEAD & PROFIT		76.4099	82.4098	86.1260	141.9871	145.2385	151.6463
TOTAL CONSTR COSTS		458.4590	494.4585	516.7561	851.9229	871.4307	909.8779
/TRAFFIC		1.7300	1.8659	1.9500	0.4263	0.4361	0.4553
MAINT COSTS (NPV)		256.5000	312.5000	198.6000	437.3999	312.3999	187.0000
/TRAFFIC		0.9679	1.1792	0.7494	0.2189	0.1563	0.0936
EQUIV ANNUAL MAINT		29.9669	36.5694	23.2026	51.1014	36.4977	21.8472
USER COSTS (NPV)		2858.8999	2555.3000	2415.8000	16431.1016	15774.6992	15170.8008
/TRAFFIC		10.7883	9.6426	9.1162	8.2221	7.8937	7.5915
EQUIV ANNUAL USER		334.0051	298.5356	282.2378	1919.6453	1842.9578	1772.4043
TOTAL PROJECT COSTS		3573.8589	3362.2585	3131.1560	17720.4219	16958.5273	16267.6758
/TRAFFIC		13.4863	12.6876	11.8157	8.8673	8.4861	8.1404

TABLE C.5DB: PROJECT COSTS IN $1000 USING THE BEST-PRACTICE TECHNICAL PACKAGES OF THE 1950'S AT THE PRICES OF 1974.

PROJECT COST ($1000) \ PROJECT NUMBER		L311	L314	L315	H312	H313	H315	L316	L317	H317
SITE PREP	31	13.2519	10.9605	10.8841	21.6537	16.9182	13.7102	10.9605	10.8841	13.7102
EXCAVATION/HAULING										
DITCH	11-0	0.3076	0.6153	0.6153	0.0	0.1142	0.6003	0.6153	0.6153	0.6003
6M	AVE 2	2.1565	1.7287	1.5523	0.0	0.0	0.0	1.7287	1.5523	0.0
9M	AVE 2	3.5875	0.0	0.0	41.1960	26.1801	21.8120	0.0	0.0	21.8120
60M	7-7	0.8224	0.8224	0.0	7.2369	0.0	0.0	0.8224	0.0	0.0
100M	AVE 2	0.0	0.0	0.0	0.0	8.6137	0.0	0.0	0.0	0.0
165M	AVE 2	0.0	0.0	0.0	58.5858	0.0	24.5691	0.0	0.0	0.0
L-500M	7-7	0.0	0.0	3.3005	0.0	107.2559	107.2559	0.0	3.3005	107.2559
P-500M	4-4	0.0	16.3868	15.3076	0.0	0.0	0.0	0.0	0.0	26.4404
800M	4-4	0.0	0.0	0.0	0.0	0.0	0.0	19.0987	17.8409	0.0
TOTAL		6.8740	19.5531	20.7757	107.0186	142.1640	154.2373	22.2650	23.3090	156.1086
SPREADING/COMPACTION										
98%	AVE 2	6.8444	6.8444	6.8444	33.6436	33.6436	33.6436	6.8444	6.8444	33.6436
93%		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SURFACING										
GRAVEL	AVE 2	3.7663	3.7663	3.7663	5.0217	5.0217	5.0217	3.7663	3.7663	5.0217
WBM	AVE 5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DBST/G	AVE 8	4.4849	4.4849	4.4849	6.0051	6.0051	6.0051	4.4849	4.4849	6.0051
DBST/W	AVE 8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL W/O SUPP MAT		35.2215	45.6092	46.7554	173.3427	203.7526	212.6179	48.3211	49.2887	214.4892
TOTAL W/ALL MAT		420.2424	430.6301	431.7764	686.9172	717.3269	726.1924	433.3420	434.3096	728.0637
SKILLED LABOR		16.1966	19.4167	19.7953	78.2338	86.6485	89.5725	20.5130	20.8194	90.2335
UNSKILLED LABOR		7.0031	5.9771	5.9429	11.1276	9.0072	7.5708	5.9771	5.9429	7.5708
/TRAFFIC		0.0875	0.0958	0.0971	0.0447	0.0480	0.0486	0.1000	0.1010	0.0489
CAPITAL		12.0218	20.2154	21.0171	83.9813	107.8968	115.4746	21.8310	22.5263	116.6849
/TRAFFIC		0.0454	0.0763	0.0793	0.0420	0.0540	0.0578	0.0824	0.0850	0.0584
MATERIALS		385.0212	385.0212	385.0212	513.5747	513.5747	513.5747	385.0212	385.0212	513.5747
/TRAFFIC		1.4529	1.4529	1.4529	0.2570	0.2570	0.2570	1.4529	1.4529	0.2570
OVERHEAD & PROFIT		84.0485	86.1260	86.3553	137.3834	143.4654	145.2385	86.6684	86.8619	145.6127
TOTAL CONSTR COSTS		504.2908	516.7561	518.1316	824.3005	860.7922	871.4307	520.0103	521.1714	873.6763
/TRAFFIC		1.9030	1.9500	1.9552	0.4125	0.4307	0.4361	1.9623	1.9667	0.4372
MAINT COSTS (NPV)		198.6000	198.6000	198.6000	312.3999	312.3999	312.3999	198.6000	198.6000	312.3999
/TRAFFIC		0.7494	0.7494	0.7494	0.1563	0.1563	0.1563	0.7494	0.7494	0.1563
EQUIV ANNUAL MAINT		23.2024	23.2024	23.2024	36.4977	36.4977	36.4977	23.2024	23.2024	36.4977
USER COSTS (NPV)		2415.8000	2415.8000	2415.8000	15774.6992	15774.6992	15774.6992	2415.8000	2415.8000	15774.6992
/TRAFFIC		9.1162	9.1162	9.1162	7.8937	7.8937	7.8937	9.1162	9.1162	7.8937
EQUIV ANNUAL USER		282.2378	282.2378	282.2378	1842.9578	1842.9578	1842.9578	282.2378	282.2378	1842.9578
TOTAL PROJECT COSTS		3118.6907	3131.1560	3132.5315	16911.3984	16947.8906	16958.5273	3134.4102	3135.5713	16960.7734
/TRAFFIC		11.7686	11.8157	11.8209	8.4625	8.4807	8.4861	11.8280	11.8323	8.4872

TABLE C.58C: PROJECT COSTS IN $1000 USING THE LEAST-COST TECHNICAL PACKAGES OF THE 1950'S AT THE PRICES OF A TYPICAL DEVELOPING COUNTRY.

PROJECT COST ($1000) \ PROJECT NUMBER		L114	L214	L314	H215	H315	H415
SITE PREP	31	6.2778	6.2778	6.2778	7.8528	7.8528	7.8528
EXCAVATION/HAULING							
DITCH	11-0	0.7788	0.7788	0.7788	0.7599	0.7599	0.7599
6M	9-9	2.1368	2.1368	2.1368	0.0	0.0	0.0
9M	AVE 2	0.0	0.0	0.0	28.5418	28.5418	28.5418
60M	AVE 3	1.3858	1.3858	1.3858	0.0	0.0	0.0
100M	AVE 2	0.0	0.0	0.0	0.0	0.0	0.0
165M	AVE 2	0.0	0.0	0.0	40.9575	40.9575	40.9575
L-500M	7-7	0.0	0.0	0.0	179.8727	179.8727	179.8727
P-500M	4-4	26.8916	26.8916	26.8916	0.0	0.0	0.0
800M	4-4	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL		31.1931	31.1931	31.1931	250.1318	250.1318	250.1318
SPREADING/COMPACTION							
98%	AVE 4	7.2654	7.2654	7.2654	35.7132	35.7132	35.7132
93%		0.0	0.0	0.0	0.0	0.0	0.0
SURFACING							
GRAVEL	AVE 2	3.8751	2.4089	3.9449	3.2816	5.2599	3.2816
WBM	AVE 4	0.0	20.1286	0.0	27.1576	0.0	27.1576
DBST/G	AVE 4	0.0	0.0	4.3078	0.0	5.8751	0.0
DBST/W	AVE 4	0.0	0.0	0.0	0.0	0.0	5.8751
TOTAL W/O SURF MAT		48.6114	67.2737	53.0691	324.1365	304.8323	330.0115
TOTAL W/ALL MAT		140.1864	176.7407	235.8259	472.5764	549.0122	572.6904
SKILLED LABOR		0.3729	0.5610	0.4098	2.0795	1.8740	2.1278
UNSKILLED LABOR		0.0310	0.0462	0.0388	0.0593	0.0492	0.0697
/TRAFFIC		0.0015	0.0023	0.0017	0.0011	0.0010	0.0011
CAPITAL		48.2075	66.6605	52.6205	321.9978	302.9092	327.8140
/TRAFFIC		0.1819	0.2516	0.1986	0.1611	0.1516	0.1640
MATERIALS		91.5750	109.4670	182.7570	148.4400	244.1800	242.6789
/TRAFFIC		0.3456	0.4131	0.6896	0.0743	0.1222	0.1214
OVERHEAD & PROFIT		28.0373	35.3481	47.1652	94.5153	109.8024	114.5381
TOTAL CONSTR COSTS		168.2236	212.0888	282.9910	567.0916	658.8145	687.2283
/TRAFFIC		0.6348	0.8003	1.0679	0.2838	0.3297	0.3439
MAINT COSTS (NPV)		82.7000	113.2000	72.4000	152.9000	107.4000	67.8000
/TRAFFIC		0.3121	0.4272	0.2732	0.0765	0.0537	0.0339
EQUIV ANNUAL MAINT		14.1434	19.3595	12.3818	26.1489	18.3675	11.5952
USER COSTS (NPV)		1589.6001	1498.8999	1408.5000	8672.8984	8226.8008	7884.8008
/TRAFFIC		5.9985	5.6562	5.3151	4.3399	4.1167	3.9456
EQUIV ANNUAL USER		271.8533	256.3418	240.8816	1483.2398	1406.9470	1348.4583
TOTAL PROJECT COSTS		1840.5237	1824.1865	1763.8909	9392.8867	8993.0117	8639.8281
/TRAFFIC		6.9454	6.8837	6.6562	4.7002	4.5001	4.3234

TABLE C.5BC: PROJECT COSTS IN $1000 USING THE LEAST-COST TECHNICAL PACKAGES OF THE 1950'S AT THE PRICES OF A TYPICAL DEVELOPING COUNTRY.

PROJECT COST ($1000) \ PROJECT NUMBER		L311	L314	L315	H312	H313	H315	L316	L317	H317
SITE PREP	31	7.5903	6.2778	6.2341	12.4026	9.6902	7.8528	6.2778	6.2341	7.8528
EXCAVATION/HAULING										
DITCH	11-0	0.3894	0.7788	0.7788	0.0	0.1446	0.7599	0.7788	0.7788	0.7599
6M	9-9	2.6655	2.1368	1.9188	0.0	0.0	0.0	2.1368	1.9188	0.0
9M	AVE 2	4.6944	0.0	0.0	53.9064	34.2577	28.5418	0.0	0.0	28.5418
60M	AVE 3	1.3858	1.3858	0.0	12.1955	0.0	0.0	1.3858	0.0	0.0
100M	AVE 2	0.0	0.0	0.0	0.0	14.3872	0.0	0.0	0.0	0.0
165M	AVE 2	0.0	0.0	0.0	97.6644	0.0	40.9575	0.0	0.0	0.0
L-500M	7-7	0.0	0.0	5.5351	0.0	179.8727	179.8727	0.0	5.5351	179.8727
P-500M	4-4	0.0	26.8916	25.1206	0.0	0.0	0.0	0.0	0.0	43.3902
800M	4-4	0.0	0.0	0.0	0.0	0.0	0.0	31.1840	29.1302	0.0
TOTAL		9.1351	31.1931	33.3533	163.7663	228.6622	250.1318	35.4854	37.3629	252.5645
SPREADING/COMPACTION										
98%	AVE 4	7.2654	7.2654	7.2654	35.7132	35.7132	35.7132	7.2654	7.2654	35.7132
93%		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SURFACING										
GRAVEL	AVE 2	3.9449	3.9449	3.9449	5.2599	5.2599	5.2599	3.9449	3.9449	5.2599
BEM	AVE 4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DBST/G	AVE 4	4.3878	4.3878	4.3878	5.8751	5.8751	5.8751	4.3878	4.3878	5.8751
DBST/W	AVE 4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL W/O SURF MAT		32.3236	53.0691	55.1855	223.0171	285.2002	304.8323	57.3614	59.1951	307.2651
TOTAL W/ALL MAT		215.0804	235.8259	237.9424	467.1968	529.3801	549.0122	240.1182	241.9520	551.4451
SKILLED LABOR		0.3459	0.4098	0.4139	1.6759	1.8189	1.8740	0.4323	0.4350	1.8861
UNSKILLED LABOR		0.0453	0.0388	0.0386	0.0717	0.0583	0.0492	0.0388	0.0386	0.0492
/TRAFFIC		0.0015	0.0017	0.0017	0.0009	0.0009	0.0010	0.0018	0.0018	0.0010
CAPITAL		31.9324	52.6205	54.7330	221.2695	283.3230	302.9092	56.8903	58.7216	305.3296
/TRAFFIC		0.1205	0.1986	0.2065	0.1107	0.1418	0.1516	0.2147	0.2216	0.1528
MATERIALS		182.7570	182.7570	182.7570	244.1800	244.1800	244.1800	182.7570	182.7570	244.1800
/TRAFFIC		0.6896	0.6896	0.6896	0.1222	0.1222	0.1222	0.6896	0.6896	0.1222
OVERHEAD & PROFIT		43.0161	47.1652	47.5885	93.4393	105.8760	109.8024	48.0236	48.3904	110.2890
TOTAL CONSTR COSTS		258.0964	282.9910	285.5308	560.6360	635.2561	658.8145	288.1418	290.3423	661.7339
/TRAFFIC		0.9739	1.0679	1.0775	0.2805	0.3179	0.3297	1.0873	1.0956	0.3311
MAINT COSTS (NPV)		72.4000	72.4000	72.4000	107.4000	107.4000	107.4000	72.4000	72.4000	107.4000
/TRAFFIC		0.2732	0.2732	0.2732	0.0537	0.0537	0.0537	0.2732	0.2732	0.0537
EQUIV ANNUAL MAINT		12.3818	12.3818	12.3818	18.3675	18.3675	18.3675	12.3818	12.3818	18.3675
USER COSTS (NPV)		1408.5000	1408.5000	1408.5000	8226.8008	8226.8008	8226.8008	1408.5000	1408.5000	8226.8008
/TRAFFIC		5.3151	5.3151	5.3151	4.1167	4.1167	4.1167	5.3151	5.3151	4.1167
EQUIV ANNUAL USER		240.8816	240.8816	240.8816	1406.9470	1406.9470	1406.9470	240.8816	240.8816	1406.9470
TOTAL PROJECT COSTS		1738.9963	1763.8909	1766.4307	8894.8359	8969.4531	8993.0117	1769.0417	1771.2422	8995.9336
/TRAFFIC		6.5623	6.6562	6.6658	4.4510	4.4883	4.5001	6.6756	6.6839	4.5016

TABLE C.5CA: PROJECT COSTS IN $1000 USING THE BEST-PRACTICE TECHNICAL PACKAGES OF THE 1970'S AT THE PRICES OF 1930.

PROJECT COST ($1000) \ PROJECT NUMBER		L114	L214	L314	H215	H315	H415
SITE PREP	31	0.9115	0.9115	0.9115	1.1402	1.1402	1.1402
EXCAVATION/HAULING							
DITCH	14-0	0.037[illegible]	0.0377	0.0377	0.0368	0.0368	0.0368
6M	13-16	0.18[illegible]	0.1897	0.1897	0.0	0.0	0.0
9M	AVE 2	0.0	0.0	0.0	2.5498	2.5498	2.5498
60M	8-11	0.0774	0.0774	0.0774	0.0	0.0	0.0
100M	8-11	0.0	0.0	0.0	0.0	0.0	0.0
165M	8-11	0.0	0.0	0.0	2.1497	2.1497	2.1497
L-500M	8-11	0.0	0.0	0.0	7.5866	7.5866	7.5866
P-500M	8-11	1.7795	1.7795	1.7795	0.0	0.0	0.0
800M	8-11	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL		2.0843	2.0843	2.0843	12.3229	12.3229	12.3229
SPREADING/COMPACTION							
98%	AVE 2	0.4232	0.4232	0.4232	2.0800	2.0800	2.0800
93%		0.0	0.0	0.0	0.0	0.0	0.0
SURFACING							
GRAVEL	AVE 2	0.3540	0.2200	0.3604	0.2998	0.4805	0.2998
WDM	AVE 4	0.0	1.7917	0.0	2.4174	0.0	2.4174
DBST/G	AVE 4	0.0	0.0	0.3465	0.0	0.4640	0.0
DBST/W	AVE 4	0.0	0.0	0.0	0.0	0.0	0.4539
TOTAL W/O SURF MAT		3.7730	5.4307	4.1259	18.2603	16.4876	18.7141
TOTAL W/ALL MAT		182.5939	197.2296	197.5261	278.4941	274.4185	292.4900
SKILLED LABOR		0.8676	1.5508	0.9685	4.3608	3.5701	4.4896
UNSKILLED LABOR		0.3415	0.4234	0.3656	0.5377	0.4594	0.5686
/TRAFFIC		0.0046	0.0074	0.0050	0.0025	0.0020	0.0025
CAPITAL		2.4292	3.3219	2.6572	13.1934	12.2897	13.4875
/TRAFFIC		0.0092	0.0125	0.0100	0.0066	0.0061	0.0067
MATERIALS		178.9556	191.9336	193.5349	260.4023	258.0991	273.9443
/TRAFFIC		0.6753	0.7243	0.7303	0.1303	0.1292	0.1371
OVERHEAD & PROFIT		36.5188	39.4459	39.5052	55.6988	54.8837	58.4980
TOTAL CONSTR COSTS		219.1127	236.6755	237.0313	334.1929	329.3020	350.9878
/TRAFFIC		0.8268	0.8931	0.8945	0.1672	0.1648	0.1756
MAINT COSTS (NPV)		60.7000	[illegible]4.2000	43.0000	93.2000	70.8000	40.2000
/TRAFFIC		0.2291	0.2423	0.1623	0.0466	0.0354	0.0201
EQUIV ANNUAL MAINT		5.2706	5.5745	3.7337	8.0926	6.1476	3.4906
USER COSTS (NPV)		763.2000	699.8999	658.5000	4294.6016	4096.1992	3896.1001
/TRAFFIC		2.8800	2.6411	2.4849	2.1490	2.0497	1.9496
EQUIV ANNUAL USER		66.2687	60.7723	57.1776	372.9001	355.6729	338.2983
TOTAL PROJECT COSTS		1043.0125	1000.7754	938.5312	4721.9922	4496.3008	4287.2852
/TRAFFIC		3.9359	3.7765	3.5416	2.3629	2.2500	2.1454

TABLE C.5CA: PROJECT COSTS IN $1000 USING THE BEST-PRACTICE TECHNICAL PACKAGES OF THE 1970'S AT THE PRICES OF 1930.

PROJECT COST ($1000)	PROJECT NUMBER	L311	L314	L315	H312	H313	H315	L316	L317	H317
SITE PREP	31	1.1021	0.9115	0.9052	1.8008	1.4070	1.1402	0.9115	0.9052	1.1402
EXCAVATION/HAULING										
DITCH	14-0	0.0189	0.0377	0.0377	0.0	0.0070	0.0368	0.0377	0.0377	0.0368
6M	13-16	0.2367	0.1897	0.1704	0.0	0.0	0.0	0.1897	0.1704	0.0
9M	AVE 2	0.4194	0.0	0.0	4.8158	3.0604	2.5498	0.0	0.0	2.5498
60M	8-11	0.0774	0.0774	0.0	0.6811	0.0	0.0	0.0774	0.0	0.0
100M	8-11	0.0	0.0	0.0	0.0	0.8107	0.0	0.0	0.0	0.0
165M	8-11	0.0	0.0	0.0	5.1260	0.0	2.1497	0.0	0.0	0.0
L-500M	8-11	0.0	0.0	0.2335	0.0	7.5866	7.5866	0.0	0.2335	7.5866
P-500M	8-11	0.0	1.7795	1.6623	0.0	0.0	0.0	0.0	0.0	2.8712
800M	8-11	0.0	0.0	0.0	0.0	0.0	0.0	2.1193	1.9797	0.0
TOTAL		0.7523	2.0843	2.1038	10.6229	11.4648	12.3229	2.4242	2.4213	13.0445
SPREADING/COMPACTION										
98%	AVE 2	0.4232	0.4232	0.4232	2.0800	2.0800	2.0800	0.4232	0.4232	2.0800
93%		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SURFACING										
GRAVEL	AVE 2	0.3604	0.3604	0.3604	0.4805	0.4805	0.4805	0.3604	0.3604	0.4805
WBM	AVE 4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DBST/G	AVE 4	0.3465	0.3465	0.3465	0.4640	0.4640	0.4640	0.3465	0.3465	0.4640
DBST/W	AVE 4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL W/O SURF MAT		2.9844	4.1259	4.1390	15.4481	15.8963	16.4876	4.4657	4.4565	17.2091
TOTAL W/ALL MAT		196.3847	197.5261	197.5393	273.3789	273.8271	274.4185	197.8660	197.8567	275.1399
SKILLED LABOR		0.7504	0.9685	0.9720	3.3737	3.4551	3.5701	1.0314	1.0307	3.7051
UNSKILLED LABOR		0.4370	0.3656	0.3632	0.7069	0.5594	0.4594	0.3656	0.3632	0.4594
/TRAFFIC		0.0045	0.0050	0.0050	0.0020	0.0020	0.0020	0.0053	0.0053	0.0021
CAPITAL		1.6343	2.6572	2.6702	11.1016	11.6741	12.2897	2.9341	2.9289	12.8763
/TRAFFIC		0.0062	0.0100	0.0101	0.0056	0.0058	0.0061	0.0111	0.0111	0.0064
MATERIALS		193.5630	193.5349	193.5339	258.1968	258.1387	258.0991	193.5349	193.5339	258.0991
/TRAFFIC		0.7304	0.7303	0.7303	0.1292	0.1292	0.1292	0.7303	0.7303	0.1292
OVERHEAD & PROFIT		39.2769	39.5052	39.5078	54.6758	54.7654	54.8837	39.5732	39.5713	55.0280
TOTAL CONSTR COSTS		235.6616	237.0313	237.0471	328.0544	328.5925	329.3020	237.4391	237.4281	330.1677
/TRAFFIC		0.8893	0.8945	0.8945	0.1642	0.1644	0.1648	0.8960	0.8960	0.1652
MAINT COSTS (NPV)		43.0000	43.0000	43.0000	70.8000	70.8000	70.8000	43.0000	43.0000	70.8000
/TRAFFIC		0.1623	0.1623	0.1623	0.0354	0.0354	0.0354	0.1623	0.1623	0.0354
EQUIV ANNUAL MAINT		3.7337	3.7337	3.7337	6.1476	6.1476	6.1476	3.7337	3.7337	6.1476
USER COSTS (NPV)		658.5000	658.5000	658.5000	4096.1992	4096.1992	4096.1992	658.5000	658.5000	4096.1992
/TRAFFIC		2.4849	2.4849	2.4849	2.0497	2.0497	2.0497	2.4849	2.4849	2.0497
EQUIV ANNUAL USER		57.1776	57.1776	57.1776	355.6729	355.6729	355.6729	57.1776	57.1776	355.6729
TOTAL PROJECT COSTS		937.1614	938.5312	938.5469	4495.0508	4495.5898	4496.3008	938.9390	938.9280	4497.1641
/TRAFFIC		3.5365	3.5416	3.5417	2.2493	2.2496	2.2500	3.5432	3.5431	2.2504

TABLE C.6CB: PROJECT COSTS IN $1000 USING THE BEST-PRACTICE TECHNICAL PACKAGES OF THE 1970'S AT THE PRICES OF 1974.

PROJECT COST ($1000) \ PROJECT NUMBER		L114	L214	L314	H215	H315	H415
SITE PREP	31	9.8326	9.8326	9.8326	12.2993	12.2993	12.2993
EXCAVATION/HAULING							
DITCH	14-0	0.3062	0.3062	0.3062	0.2988	0.2988	0.2988
6M	13-16	1.2293	1.2293	1.2293	0.0	0.0	0.0
9M	AVE 2	0.0	0.0	0.0	17.2900	17.2900	17.2900
60M	8-11	0.5317	0.5317	0.5317	0.0	0.0	0.0
100M	8-11	0.0	0.0	0.0	0.0	0.0	0.0
165M	8-11	0.0	0.0	0.0	14.7191	14.7191	14.7191
L-500M	8-11	0.0	0.0	0.0	52.0044	52.0044	52.0044
P-500M	8-11	12.1978	12.1978	12.1978	0.0	0.0	0.0
800M	8-11	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL		14.2650	14.2650	14.2650	84.3123	84.3123	84.3123
SPREADING/COMPACTION							
98%	AVE 2	3.1311	3.1311	3.1311	15.3909	15.3909	15.3909
93%		0.0	0.0	0.0	0.0	0.0	0.0
SURFACING							
GRAVEL	AVE 2	2.9604	1.8402	3.0137	2.5070	4.0183	2.5070
WBM	AVE 4	0.0	14.6664	0.0	19.7880	0.0	19.7880
DBST/G	AVE 4	0.0	0.0	2.6419	0.0	3.5373	0.0
DBST/W	AVE 4	0.0	0.0	0.0	0.0	0.0	3.4610
TOTAL W/O SURF MAT		30.1891	43.7354	32.8843	134.2974	119.5581	137.7584
TOTAL W/ALL MAT		371.1807	355.6892	417.9050	611.9351	633.1326	657.6870
SKILLED LABOR		9.7199	17.3681	10.8489	48.8426	39.9888	50.2856
UNSKILLED LABOR		5.8548	7.2534	6.2666	9.2106	7.8759	9.7412
/TRAFFIC		0.0588	0.0929	0.0646	0.0290	0.0240	0.0300
CAPITAL		14.0663	18.5657	15.2206	75.5586	71.0086	77.0460
/TRAFFIC		0.0531	0.0701	0.0574	0.0378	0.0355	0.0386
MATERIALS		341.5400	352.5020	385.5693	478.3232	514.2603	520.6140
/TRAFFIC		1.2888	1.3302	1.4550	0.2394	0.2573	0.2605
OVERHEAD & PROFIT		74.2361	79.1378	83.5810	122.3870	126.6265	131.5378
TOTAL CONSTR COSTS		445.4167	474.8269	501.4858	734.3220	759.7590	789.2244
/TRAFFIC		1.6808	1.7918	1.8924	0.3675	0.3802	0.3949
MAINT COSTS (NPV)		256.5000	312.5000	198.6000	437.3999	312.3999	187.0000
/TRAFFIC		0.9679	1.1792	0.7494	0.2189	0.1563	0.0936
EQUIV ANNUAL MAINT		29.9669	36.5094	23.2024	51.1014	36.4977	21.8472
USER COSTS (NPV)		2858.8999	2555.3000	2415.8000	16431.1016	15774.6992	15170.8008
/TRAFFIC		10.7803	9.6426	9.1162	8.2221	7.8937	7.5915
EQUIV ANNUAL USER		334.0051	298.5356	282.2378	1919.6453	1842.9578	1772.4043
TOTAL PROJECT COSTS		3560.8167	3342.6270	3115.8857	17602.8203	16846.8555	16147.0234
/TRAFFIC		13.4370	12.6137	11.7581	8.8085	8.4302	8.0800

TABLE C.5CD: PROJECT COSTS IN $1000 USING THE BEST-PRACTICE TECHNICAL PACKAGES OF THE 1970'S AT THE PRICES OF 1974.

PROJECT COST ($1000) \ PROJECT NUMBER		L311	L314	L315	H312	H313	H315	L316	L317	H317
SITE PREP	31	11.8882	9.8326	9.7641	19.4254	15.1772	12.2993	9.8326	9.7641	12.2993
EXCAVATION/HAULING										
DITCH	14-0	0.1531	0.3062	0.3062	0.0	0.0568	0.2988	0.3062	0.3062	0.2988
6M	13-16	1.5335	1.2293	1.1039	0.0	0.0	0.0	1.2293	1.1039	0.0
9M	AVE 2	2.8438	0.0	0.0	32.6553	20.7525	17.2900	0.0	0.0	17.2900
60M	8-11	0.5317	0.5317	0.0	4.6794	0.0	0.0	0.5317	0.0	0.0
100M	8-11	0.0	0.0	0.0	0.0	5.5537	0.0	0.0	0.0	0.0
165M	8-11	0.0	0.0	0.0	35.0982	0.0	14.7191	0.0	0.0	0.0
L-500M	8-11	0.0	0.0	1.6003	0.0	52.0044	52.0044	0.0	1.6003	52.0044
P-500M	8-11	0.0	12.1978	11.3945	0.0	0.0	0.0	0.0	0.0	19.6813
800M	8-11	0.0	0.0	0.0	0.0	0.0	0.0	14.5115	13.5558	0.0
TOTAL		5.0621	14.2650	14.4048	72.4329	78.3675	84.3123	16.5788	16.5662	89.2745
SPREADING/COMPACTION										
98%	AVE 2	3.1311	3.1311	3.1311	15.3909	15.3909	15.3909	3.1311	3.1311	15.3909
93%		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SURFACING										
GRAVEL	AVE 2	3.0137	3.0137	3.0137	4.0183	4.0183	4.0183	3.0137	3.0137	4.0183
WBM	AVE 4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DBST/G	AVE 4	2.6419	2.6419	2.6419	3.5373	3.5373	3.5373	2.6419	2.6419	3.5373
DBST/W	AVE 4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL W/O SURF MAT		25.7369	32.8843	32.9556	114.8048	116.4912	119.5581	35.1980	35.1169	124.5203
TOTAL W/ALL MAT		410.7578	417.9050	417.9763	628.3792	630.0657	633.1326	420.2190	420.1377	638.0947
SKILLED LABOR		8.3984	10.8489	10.8879	37.7639	38.6931	39.9888	11.5471	11.5401	41.5063
UNSKILLED LABOR		7.4906	6.2666	6.2258	12.1182	9.5886	7.8750	6.2666	6.2258	7.8750
/TRAFFIC		0.0600	0.0646	0.0646	0.0250	0.0242	0.0240	0.0672	0.0670	0.0247
CAPITAL		9.1852	15.2206	15.2975	63.8397	67.3633	71.0086	16.8362	16.8067	74.4533
/TRAFFIC		0.0347	0.0574	0.0577	0.0319	0.0337	0.0355	0.0635	0.0634	0.0373
MATERIALS		385.6838	385.5693	385.5654	514.6575	514.4207	514.2603	385.5693	385.5654	514.2603
/TRAFFIC		1.4554	1.4550	1.4550	0.2575	0.2574	0.2573	1.4550	1.4550	0.2573
OVERHEAD & PROFIT		82.1516	83.5810	83.5952	125.6758	126.0131	126.6265	84.0438	84.0275	127.6189
TOTAL CONSTR COSTS		492.9092	501.4858	501.5715	754.0549	756.0786	759.7590	504.2627	504.1650	765.7136
/TRAFFIC		1.8600	1.8924	1.8927	0.3773	0.3783	0.3802	1.9029	1.9025	0.3832
MAINT COSTS (NPV)		198.6000	198.6000	198.6000	312.3999	312.3999	312.3999	198.6000	198.6000	312.3999
/TRAFFIC		0.7494	0.7494	0.7494	0.1563	0.1563	0.1563	0.7494	0.7494	0.1563
EQUIV ANNUAL MAINT		23.2024	23.2024	23.2024	36.4977	36.4977	36.4977	23.2024	23.2024	36.4977
USER COSTS (NPV)		2415.8000	2415.8000	2415.8000	15774.6992	15774.6992	15774.6992	2415.8000	2415.8000	15774.6992
/TRAFFIC		9.1162	9.1162	9.1162	7.8937	7.8937	7.8937	9.1162	9.1162	7.8937
EQUIV ANNUAL USER		282.2378	282.2378	282.2378	1842.9578	1842.9578	1842.9578	282.2378	282.2378	1842.9578
TOTAL PROJECT COSTS		3107.3091	3115.8857	3115.9714	16841.1523	16843.1758	16846.8555	3118.6626	3118.5649	16852.8125
/TRAFFIC		11.7257	11.7581	11.7584	8.4273	8.4283	8.4302	11.7685	11.7682	8.4332

TABLE C.5CC: PROJECT COSTS IN $1000 USING THE LEAST-COST TECHNICAL PACKAGES OF THE 1970'S AT THE PRICES OF A TYPICAL DEVELOPING COUNTRY.

PROJECT COST ($1000) \ PROJECT NUMBER		L114	L214	L314	H215	H315	H415
SITE PREP	31	5.7182	5.7182	5.7182	7.1527	7.1527	7.1527
EXCAVATION/HAULING							
DITCH	14-0	0.3259	0.3259	0.3259	0.3180	0.3180	0.3180
6M	AVE 2	2.3920	2.3920	2.3920	0.0	0.0	0.0
9M	12-15	0.0	0.0	0.0	29.1346	29.1346	29.1346
60M	8-11	0.9633	0.9633	0.9633	0.0	0.0	0.0
100M	8-11	0.0	0.0	0.0	0.0	0.0	0.0
165M	8-11	0.0	0.0	0.0	26.7178	26.7178	26.7178
L-500M	8-11	0.0	0.0	0.0	94.5402	94.5402	94.5402
P-500M	8-11	22.1747	22.1747	22.1747	0.0	0.0	0.0
800M	8-11	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL		25.8558	25.8558	25.8558	150.7107	150.7107	150.7107
SPREADING/COMPACTION							
90%	AVE 2	4.2912	4.2912	4.2912	21.0936	21.0936	21.0936
93%		0.0	0.0	0.0	0.0	0.0	0.0
SURFACING							
GRAVEL	AVE 2	2.8165	1.7508	2.8673	2.3852	3.8230	2.3852
WBM	AVE 3	0.0	13.7870	0.0	18.6015	0.0	18.6015
DBST/G	AVE 4	0.0	0.0	2.6572	0.0	3.5579	0.0
DBST/W	AVE 4	0.0	0.0	0.0	0.0	0.0	3.4684
TOTAL W/O SURF MAT		38.6818	51.4030	41.3897	199.9435	186.3378	203.4120
TOTAL W/ALL MAT		130.2566	160.8699	224.1465	348.3831	430.5173	446.0903
SKILLED LABOR		0.2001	0.3553	0.2252	1.0221	0.8454	1.0542
UNSKILLED LABOR		0.0373	0.0462	0.0421	0.0587	0.0531	0.0650
/TRAFFIC		0.0009	0.0015	0.0010	0.0005	0.0004	0.0006
CAPITAL		36.7913	49.3484	39.4692	196.7950	183.3715	200.2249
/TRAFFIC		0.1388	0.1862	0.1489	0.0985	0.0918	0.1002
MATERIALS		93.2281	111.1201	184.4101	150.5078	246.2478	244.7467
/TRAFFIC		0.3518	0.4193	0.6959	0.0753	0.1232	0.1225
OVERHEAD & PROFIT		26.0513	32.1740	44.8293	69.6766	86.1035	89.2180
TOTAL CONSTR COSTS		156.3080	193.0439	268.9756	418.0596	516.6206	535.3083
/TRAFFIC		0.5898	0.7285	1.0150	0.2092	0.2585	0.2679
MAINT COSTS (NPV)		82.7000	113.2000	72.4000	152.9000	107.4000	67.8000
/TRAFFIC		0.3121	0.4272	0.2732	0.0765	0.0537	0.0339
EQUIV ANNUAL MAINT		14.1434	19.3595	12.3818	26.1489	18.3675	11.5952
USER COSTS (NPV)		1589.6001	1498.8999	1408.5000	8672.8984	8226.8008	7884.8008
/TRAFFIC		5.9985	5.6562	5.3151	4.3399	4.1167	3.9456
EQUIV ANNUAL USER		271.8533	256.3418	240.8816	1483.2388	1406.9470	1348.4583
TOTAL PROJECT COSTS		1828.6079	1805.1438	1749.8755	9243.8555	8850.8203	8487.9062
/TRAFFIC		6.9004	6.8119	6.6033	4.6256	4.4290	4.2474

TABLE C.5CC: PROJECT COSTS IN $1000 USING THE LEAST-COST TECHNICAL PACKAGES OF THE 1970'S AT THE PRICES OF A TYPICAL DEVELOPING COUNTRY.

PROJECT COST ($1000) \ PROJECT NUMBER		L311	L314	L315	H312	H313	H315	L316	L317	H317
SITE PREP	31	6.9136	5.7182	5.6783	11.2969	8.8263	7.1527	5.7182	5.6783	7.1527
EXCAVATION/HAULING										
DITCH	14-0	0.1630	0.3259	0.3259	0.0	0.0605	0.3180	0.3259	0.3259	0.3180
6M	AVE 2	2.9839	2.3920	2.1479	0.0	0.0	0.0	2.3920	2.1479	0.0
9M	12-15	4.7919	0.0	0.0	55.0260	34.9692	29.1346	0.0	0.0	29.1346
60M	8-11	0.9633	0.9633	0.0	8.4767	0.0	0.0	0.9633	0.0	0.0
100M	8-11	0.0	0.0	0.0	0.0	10.0841	0.0	0.0	0.0	0.0
165M	8-11	0.0	0.0	0.0	63.7095	0.0	26.7178	0.0	0.0	0.0
L-500M	8-11	0.0	0.0	2.9092	0.0	94.5402	94.5402	0.0	2.9092	94.5402
P-500M	8-11	0.0	22.1747	20.7143	0.0	0.0	0.0	0.0	0.0	35.7793
800M	8-11	0.0	0.0	0.0	0.0	0.0	0.0	26.3429	24.6080	0.0
TOTAL		8.9020	25.8558	26.0973	127.2123	139.6540	150.7107	30.0241	29.9911	159.7721
SPREADING/COMPACTION										
98%	AVE 2	4.2912	4.2912	4.2912	21.0936	21.0936	21.0936	4.2912	4.2912	21.0936
93%		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SURFACING										
GRAVEL	AVE 2	2.8673	2.8673	2.8673	3.8230	3.8230	3.8230	2.8673	2.8673	3.8230
WBM	AVE 3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DBST/G	AVE 4	2.6572	2.6572	2.6572	3.5579	3.5579	3.5579	2.6572	2.6572	3.5579
DBST/W	AVE 4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL W/O SURF MAT		25.6313	41.3897	41.5913	166.9836	176.9548	186.3378	45.5579	45.4851	195.3992
TOTAL W/ALL MAT		208.3881	224.1465	224.3481	411.1633	421.1343	430.5173	228.3147	228.2419	439.5789
SKILLED LABOR		0.1811	0.2252	0.2258	0.8274	0.8248	0.8454	0.2391	0.2387	0.8761
UNSKILLED LABOR		0.0499	0.0421	0.0419	0.0801	0.0640	0.0531	0.0421	0.0419	0.0531
/TRAFFIC		0.0009	0.0010	0.0010	0.0005	0.0004	0.0004	0.0011	0.0011	0.0005
CAPITAL		23.4015	39.4692	39.6821	162.8101	173.5143	183.3715	43.6236	43.5629	192.4022
/TRAFFIC		0.0883	0.1489	0.1497	0.0815	0.0868	0.0918	0.1646	0.1644	0.0963
MATERIALS		184.7557	184.4101	184.3986	247.4459	246.7316	246.2478	184.4101	184.3986	246.2478
/TRAFFIC		0.6972	0.6959	0.6958	0.1238	0.1235	0.1232	0.6959	0.6958	0.1232
OVERHEAD & PROFIT		41.6776	44.8293	44.8696	82.2327	84.2268	86.1035	45.6629	45.6484	87.9158
TOTAL CONSTR COSTS		250.0657	268.9756	269.2175	493.3958	505.3611	516.6206	273.9775	273.8901	527.4944
/TRAFFIC		0.9436	1.0150	1.0159	0.2469	0.2529	0.2585	1.0339	1.0335	0.2640
MAINT COSTS (NPV)		72.4000	72.4000	72.4000	107.4000	107.4000	107.4000	72.4000	72.4000	107.4000
/TRAFFIC		0.2732	0.2732	0.2732	0.0537	0.0537	0.0537	0.2732	0.2732	0.0537
EQUIV ANNUAL MAINT		12.3818	12.3818	12.3818	18.3675	18.3675	18.3675	12.3818	12.3818	18.3675
USER COSTS (NPV)		1408.5000	1408.5000	1408.5000	8226.8008	8226.8008	8226.8008	1408.5000	1408.5000	8226.8008
/TRAFFIC		5.3151	5.3151	5.3151	4.1167	4.1167	4.1167	5.3151	5.3151	4.1167
EQUIV ANNUAL USER		240.8816	240.8816	240.8816	1406.9470	1406.9470	1406.9470	240.8816	240.8816	1406.9470
TOTAL PROJECT COSTS		1730.9656	1749.8755	1750.1174	8827.5937	8839.5586	8850.8203	1754.8774	1754.7900	8861.6914
/TRAFFIC		6.5319	6.6033	6.6042	4.4173	4.4233	4.4290	6.6222	6.6218	4.4344

TABLE C.50: PROJECT COSTS IN $1000 USING THE LEAST-COST TECHNICAL PACKAGES OVER ALL TECHNOLOGY PERIODS AT THE PRICES OF A TYPICAL DEVELOPING COUNTRY.

PROJECT COST($1000)	PROJECT NUMBER	L114	L214	L314	H215	H315	H415
SITE PREP	11	5.0103	5.0103	5.0103	6.2672	6.2672	6.2672
EXCAVATION/HAULING							
DITCH	AVE2	0.2599	0.2599	0.2599	0.2536	0.2536	0.2536
6M	AVE 2	1.1601	1.1601	1.1601	0.0	0.0	0.0
9M	AVE 2	0.0	0.0	0.0	11.8777	11.8777	11.8777
60M	5-4	0.1993	0.1993	0.1993	0.0	0.0	0.0
100M	8-7	0.0	0.0	0.0	0.0	0.0	0.0
165M	8-7	0.0	0.0	0.0	4.1327	4.1327	4.1327
L-500M	6-5	0.0	0.0	0.0	40.4325	40.4325	40.4325
P-500M	8-7	4.5150	4.5150	4.5150	0.0	0.0	0.0
800M	8-7	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL		6.1343	6.1343	6.1343	56.6964	56.6964	56.6964
SPREADING/COMPACTION							
98%	21	2.3877	2.3877	2.3877	11.7369	11.7369	11.7369
93%	21	0.0	0.0	0.0	0.0	0.0	0.0
SURFACING							
GRAVEL	21	0.8462	0.5260	0.8614	0.7166	1.1485	0.7166
WBM	AVE 3	0.0	11.7870	0.0	18.6015	0.0	18.6015
DBST/G	AVE 4	0.0	0.0	2.6572	0.0	3.5579	0.0
DBST/W	AVE 4	0.0	0.0	0.0	0.0	0.0	3.4694
TOTAL W/O SURF MAT		14.3784	27.8452	17.0509	94.0135	79.4067	97.4870
TOTAL W/ALL MAT		109.9533	137.3121	199.8077	242.4544	323.5867	340.1655
SKILLED LABOR		1.4546	1.5898	1.4807	6.5654	6.4107	6.5926
UNSKILLED LABOR		3.1132	4.2174	3.3230	21.6367	21.7744	21.6450
/TRAFFIC		0.0180	0.0191	0.0191	0.0141	0.0141	0.0141
CAPITAL		6.5604	19.9958	9.2649	62.0140	47.4163	65.4439
/TRAFFIC		0.0248	0.0755	0.0347	0.0110	0.0237	0.0327
MATERIALS		94.6172	112.5032	185.7997	152.2454	247.9854	245.4843
/TRAFFIC		0.3570	0.4246	0.7011	0.0762	0.1241	0.1233
OVERHEAD & PROFIT		21.1907	27.4424	39.9615	48.4917	64.7173	68.0331
TOTAL CONSTR COSTS		127.1440	164.7746	239.7692	290.9530	388.3040	408.1935
/TRAFFIC		0.4799	0.6218	0.9049	0.1456	0.1943	0.2043
MAINT COSTS (NPV)		82.7000	113.2000	72.4000	152.9000	107.4000	67.8000
/TRAFFIC		0.3121	0.4272	0.2732	0.0765	0.0537	0.0339
EQUIV ANNUAL MAINT		14.1434	19.3595	12.3819	26.1489	18.3675	11.5952
USER COSTS (NPV)		1589.6001	1493.8999	1408.5000	8672.8984	8226.9009	7894.9008
/TRAFFIC		5.9985	5.6562	5.3151	4.3399	4.1167	3.9456
EQUIV ANNUAL USER		271.8533	256.3418	240.8816	1483.2398	1406.9470	1349.4593
TOTAL PROJECT COSTS		1799.4439	1774.8743	1720.6692	9116.7461	8722.5039	8360.7959
/TRAFFIC		6.7904	6.7052	6.4931	4.5620	4.3647	4.1837

TABLE C.5D: PROJECT COSTS IN $1000 USING THE LEAST-COST TECHNICAL PACKAGES OVER ALL TECHNOLOGY PERIODS AT THE PRICES OF A TYPICAL DEVELOPING COUNTRY.

PROJECT COST ($1000)	PROJECT NUMBER	L314	L324	L334	H315	H325	H335
SITE PREP	11	5.0103	4.9754	4.9754	6.2672	6.0926	6.0926
EXCAVATION/HAULING							
DITCH	AVE2	0.2599	0.2599	0.2599	0.2536	0.2536	0.2536
6M	AVE 2	1.1601	1.1542	1.1542	0.0	0.0	0.0
9M	AVE 2	0.0	0.0	0.0	11.8777	11.8151	11.8151
60M	5-4	0.1993	0.1993	0.1993	0.0	0.0	0.0
100M	8-7	0.0	0.0	0.0	0.0	0.0	0.0
165M	8-7	0.0	0.0	0.0	4.1327	3.2316	3.2316
L-500M	6-5	0.0	0.0	0.0	40.4325	40.4325	40.4325
P-500M	8-7	4.5150	4.1942	4.1942	0.0	0.0	0.0
800M	8-7	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL		6.1343	5.8075	5.8075	56.6964	55.7328	55.7328
SPREADING/COMPACTION							
98%	21	2.3877	0.0	0.0	11.7369	0.0	0.0
93%	21	0.0	1.3193	1.3193	0.0	6.4780	6.4780
SURFACING							
GRAVEL	21	0.8614	1.3366	0.8614	1.1485	1.6110	1.1485
WBM	AVE 3	0.0	0.0	0.0	0.0	0.0	0.0
DBST/G	AVE 4	2.6572	2.6572	2.6572	3.5579	3.5579	3.5579
DBST/W	AVE 4	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL W/O SURF MAT		17.0509	16.0959	15.6208	79.4069	73.4723	73.0098
TOTAL W/ALL MAT		199.8077	250.2777	198.3776	323.5867	367.7019	317.1895
SKILLED LABOR		1.4807	1.4932	1.4414	6.4107	6.2613	6.2109
UNSKILLED LABOR		3.3230	3.2216	3.0662	21.7744	20.8289	20.6776
/TRAFFIC		0.0181	0.0178	0.0170	0.0141	0.0136	0.0135
CAPITAL		9.2049	8.3602	8.0923	47.4163	42.6827	42.4219
/TRAFFIC		0.0347	0.0315	0.0305	0.0237	0.0214	0.0212
MATERIALS		185.7992	237.2030	185.7780	247.9854	297.9292	247.8794
/TRAFFIC		0.7011	0.8951	0.7010	0.1241	0.1491	0.1240
OVERHEAD & PROFIT		39.9615	50.0555	39.6755	64.7173	73.5404	63.4379
TOTAL CONSTR COSTS		239.7692	300.3333	238.0531	388.3040	441.2422	380.6272
/TRAFFIC		0.9048	1.1333	0.8983	0.1943	0.2208	0.1905
MAINT COSTS (NPV)		72.4000	72.4000	194.2000	107.4000	107.4000	403.8999
/TRAFFIC		0.2732	0.2732	0.7328	0.0537	0.0537	0.2021
EQUIV ANNUAL MAINT		12.3818	12.3818	33.2121	18.3675	18.3675	69.0749
USER COSTS (NPV)		1408.5000	1408.5000	1488.1001	8226.8008	8226.8008	8554.8008
/TRAFFIC		5.3151	5.3151	5.6155	4.1167	4.1167	4.2808
EQUIV ANNUAL USER		240.8816	240.8816	254.4948	1406.9470	1406.9470	1463.0417
TOTAL PROJECT COSTS		1720.6692	1781.2332	1920.3530	8722.5039	8775.4414	9339.3242
/TRAFFIC		6.4931	6.7216	7.2466	4.3647	4.3912	4.6734

TABLE C.50: PROJECT COSTS IN $1000 USING THE LEAST-COST TECHNICAL PACKAGES OVER ALL TECHNOLOGY PERIODS AT THE PRICES OF A TYPICAL DEVELOPING COUNTRY.

PROJECT COST($1000) \ PROJECT NUMBER		L311	L314	L315	H312	H313	H315	L316	L317	H317
SITE PREP	11	6.0577	5.0193	4.9754	9.8983	7.7336	5.2672	5.0103	4.9754	6.2672
EXCAVATION/HAULING										
DITCH	AVE2	0.1299	0.2599	0.2599	0.0	0.0482	0.2536	0.2599	0.2599	0.2536
6M	AVE 2	1.4471	1.1601	1.0417	0.0	0.0	0.0	1.1601	1.0417	0.0
9M	AVE 2	1.9536	0.0	0.0	22.4331	14.2563	11.8777	0.0	0.0	11.8777
60M	5-4	0.1993	0.1993	0.0	1.7519	0.0	0.0	0.1993	0.0	0.0
100M	9-7	0.0	0.0	0.0	0.0	1.4216	0.0	0.0	0.0	0.0
165M	8-7	0.0	0.0	0.0	9.8546	0.0	4.1327	0.0	0.0	0.0
L-500M	6-5	0.0	0.0	1.2442	0.0	40.4325	40.4325	0.0	1.2442	40.4325
P-500M	8-7	0.0	4.5150	4.2177	0.0	0.0	0.0	0.0	0.0	7.2051
800M	8-7	0.0	0.0	0.0	0.0	0.0	0.0	6.2691	5.8562	0.0
TOTAL		3.7303	6.1.43	6.7634	34.0416	56.1587	55.6964	7.9884	8.402	59.4484
SPREADING/COMPACTION										
98%	21	2.3877	2.3877	2.3877	11.7369	11.7369	11.7369	2.3877	2.3877	11.7369
93%	21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SURFACING										
GRAVEL	21	0.8614	0.8614	0.8614	1.1485	1.1485	1.1495	0.8614	0.8614	1.1495
WBM	AVE 3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DBST/G	AVE 4	2.6572	2.6572	2.6572	3.5579	3.5579	3.5579	2.6572	2.6572	3.5579
DBST/W	AVE 4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL W/O SURF MAT		15.6940	17.0509	17.6451	60.3832	80.3356	77.4069	18.9049	19.2837	82.5591
TOTAL W/ALL MAT		198.4508	199.8077	200.4019	304.5610	324.5151	323.5867	201.5618	202.0435	326.7291
SKILLED LABOR		1.7126	1.4807	1.5000	6.4876	6.7039	6.4157	1.4807	1.500	6.4157
UNSKILLED LABOR		3.2103	3.3230	3.5872	13.4655	22.2497	21.7744	3.7789	4.613	22.5991
/TRAFFIC		0.0186	0.0181	0.0192	0.0100	0.0145	0.0141	0.0199	0.0205	0.0145
CAPITAL		7.0929	9.2049	9.5369	34.4203	46.6861	47.4163	10.5032	10.7497	49.7430
/TRAFFIC		0.0268	0.0347	0.0360	0.0172	0.0234	0.0237	0.0396	0.0406	0.0247
MATERIALS		186.4352	185.7992	185.7780	250.1902	248.8758	247.9854	185.7992	165.778	247.9856
/TRAFFIC		0.7035	0.7011	0.7010	0.1252	0.1245	0.1241	0.7011	0.7011	0.1241
OVERHEAD & PROFIT		39.6902	39.9615	40.0804	60.9126	64.9030	64.7173	40.3123	40.4061	65.3478
TOTAL CONSTR COSTS		238.1410	239.7692	240.4823	365.4753	389.4183	388.3040	241.8741	242.4496	392.0867
/TRAFFIC		0.8986	0.9048	0.9075	0.1829	0.1949	0.1943	0.9127	0.9149	0.1962
MAINT COSTS (NPV)		72.4000	72.4000	72.4000	107.4000	107.4000	107.4000	72.4000	72.4000	107.400
/TRAFFIC		0.2732	0.2732	0.2732	0.0537	0.0537	0.0537	0.2732	0.2732	0.0537
EQUIV ANNUAL MAINT		12.3818	12.3818	12.3818	18.3675	18.3675	18.3675	12.3818	12.3818	18.3675
USER COSTS (NPV)		1408.5000	1408.5000	1408.5000	8226.8008	8226.8008	8226.8008	1408.5000	1408.5000	8226.8008
/TRAFFIC		5.3151	5.3151	5.3151	4.1167	4.1167	4.1167	5.3151	5.3151	4.1167
EQUIV ANNUAL USER		240.8816	240.8816	240.8816	1406.9470	1406.9470	1406.9470	240.8816	240.8816	1406.9470
TOTAL PROJECT COSTS		1719.0408	1720.6692	1721.3023	8699.6758	8723.6172	8722.5039	1722.7739	1723.3495	8726.2852
/TRAFFIC		6.4869	6.4931	6.4958	4.3533	4.3653	4.3647	6.5010	6.5032	4.3665

BIOGRAPHICAL SKETCH

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M.I.T., Civil Engineering and Management, Ph.D., February 1977

Positions: Postdoctoral Fellow
Civil Engineering Department
Massachusetts Institute of Technology
January 1977 - present

Doctoral Candidate and Graduate Research Assistant
Civil Engineering Department
Massachusetts Institute of Technology
September 1971 - January 1977

Undergraduate Research Assistant
Civil Engineering Department
Massachusetts Institute of Technology
June 1970 - August 1971, and
October 1968 - May 1969

Student Engineering Assistant
Barton-Aschman Associates, Inc.
Chicago, Illinois
June 1969 - August 1969

Honors and Awards: Mellon Foundation Postdoctoral Fellowship
January 1977 - present

Sloan Research Traineeship
September 1974 - August 1975

Tucker-Voss Award - 1974

NSF Graduate Traineeship
September 1971 - August 1972

M.I.T. National Scholar - 1967

Letter of Commendation,
National Merit Scholar - 1967

Societies: Society of Sigma Xi

Tau Beta Pi

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M.I.T. Chapter Vice President
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M.I.T. Civil Engineering Departmental
Committee on Graduate Students
1972 - 1973

Associate Advisor for Freshmen at M.I.T.
1970 - 1971

Committee to Review Undergraduate Curriculum
in Civil Engineering at M.I.T. - 1969

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