A NORMATIVE APPROACH TO THE EVALUATION OF INDUSTRIALIZED BUILDING SYSTEMS

by

NADIA MEHDI ALHASANI

Bachelor of Science in Architecture
University of Baghdad
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Signature of Author ______________________________

Nadia M. Alhasani
Department of Architecture
May 10, 1984

Certified by ______________________________

Eric Dluhosch
Associate Professor of Building Technology
Thesis Supervisor

Accepted by ______________________________

N. John Habraken, Chairman
Departmental Committee on Graduate Students

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Abstract

The rapid development of the building industry within the last 10-15 years involved the adaptation of a more specialized and advanced system of construction and management. And, with the expanding alternatives of industrialized building systems developed and being developed in Europe and North America, the task of decision-making concerning the choice of the most appropriate system as a solution to a specific problem confronting us, becomes more of a burden on the decision-maker(s) than ever before.

Intuition, a non-quantitative means of judgment, cannot be solely depended upon for complex decision-making. Thus, quantitative scientific evaluation methods become more of an appropriate tool to do so.

One approach to dealing with this subject is the systems approach, focusing on systems as related to the processes of building, industrialization and evaluation. This, in a sense, exposes the notion of "systems" as a dynamic tool in the planning of complex procedures.

Understanding the theories of evaluation, weighing and aggregation, becomes crucial in order to comprehend and determine the parameters required for the problem to be evaluated.

On the one hand, we will explore the major factors directly related to the planning and generation of a building industry within a specified context. Such factors as the local market, resources and organization are considered to be among the most sensitive when weighing their importance and feasibility to a proposal. One the other hand, user's requirements and performance specifications are two aspects that a building system's typology (hardware) is based upon. It is adopted, in this case, as a rational approach to a more comprehensive method of selection.

Thesis Supervisor: Dr. Eric Dluhosch
Title: Associate Professor of Building Technology

بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ

For sharing
All the laughter and tears . . . . .
All the hopes and fears. . . . . . .
All the happiness and sadness. . . .
For helping make my dreams come true
I dedicate this work
to my Mother and Father

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"Everyone knows that it is much harder to turn word into deed than deed into word."

Maxim Gorky - 1937

This is an opportunity that I treasure; an opportunity to extend my gratitue and appreciation to too many a person that helped me through my life at M.I.T. and made it an experience that I will cherish for a long time.

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To all of you and many others, THANK YOU.

CONTENTS

INTRODUCTION

A long-standing problem of increasing urgency has been the provision of new buildings in general, housing in particular, to meet the ever increasing demand of such facilities especially in so-called "developing" countries.

In order to fulfill this rising demand for accomodations, new effective and more advanced methods of construction technology is required. Exporting such techniques may be the answer to the stated problem, yet the new context for the imported technology - in some cases - was not ready to accomodate the new techniques for various reasons.

"Approximately 400 commercial systems are now available for licensing in Europe. These manufacturers are searching for new markets to expand their profits. Certain pieces of equipment and hardware which are considered outdated or obsolete in their countries are still marketable in developing areas, which are sometimes deliberately sold and which is often one step behind the latest level of technology used in the country supplying the technology. This is done by producers in order to be able to dispose profitably of obsolete equipment." (Terner and Turner, 1972).

This leads us to seeking answers for questions such as:

1. How do we decide upon developing a scheme to adopt the erection of a new building systems plant?
2. What is the most appropriate building system to help solve our problem of building shortage?

With these questions in mind, the scope of the study is defined as "to utilize the evaluation methods, the building industry, user's requirements and performance specifications in a systematic approach for a certain project, with an emphasis on industrialized building systems.

To be able to do so, certain guidelines need to be developed based mainly on:

1. The review of a number of evaluation methods suitable for various problem-solving and decision-making situations.
2. The identification of the factors crucial to the operation of an industry in general and/or building systems plant in particular.
3. The adoption of a systematic approach towards the formulation of user's requirements and eventually performance specifications to provide guidelines for the building systems selection.

Therefore, the objectives stated for the study are as follows:

1. Seeking a rational approach to the evaluation of building systems adoption, and the factors to be taken into account when considering the procurement of a building systems plant.
2. Identifying the major and most pressing issues to study the possibility of selecting a certain type of building system for a given situation.
3. Emphasizing the importance of scientific and systematic procedures in decisions related to building systems.

CHAPTER ONE

THE SCIENCE OF DECISION-MAKING

1.1 EVALUTION AS A TOOL FOR DECISION-MAKING

Decision-making traditionally tended to depend on intuition when confronted with more than one alternative. Depending on the skills and experience of the "decision-maker", the selected solution may or may not succeed in fulfilling the requirements.

With the increasing complexity in the building industry, scientific research was adopted and the building profession was at a turning point. With this development, a new method was required to deal with the various proposals at hand.

The building industry became under greater pressure to make sure that the most appropriate solution was decided upon for a given situation.

Being a dynamic process, evaluation has been widely emphasized on during the last 10-15 years. The process itself helps with decision-making and improvement of the quality of the selected solution.

Evaluation as a scientific process is now a popular method that is introduced to the various stages of the building process. Methodologists are engaged in developing various methods to deal with evaluation as applied to the building process.

According to the IBS (Industrialized Building Systems) guide "Evaluation" is defined as follows:

Evaluation brings together two things:

1. An object to be evaluated; and
2. A judgment providing a framework in terms of which an evaluation can be made.
3. A criterion of evaluation that embodies given standards.

Evaluation in effect can be viewed as a mode of classification. The evaluation is limited to the condition of use envisaged at the time. Evaluation can only relate to the use in the manner stated or implied.

Such a broad process is of great importance, in general it:

1. Leads to a number of solutions (alternatives).
2. Gives users satisfaction (user requirements).
3. Provide feedback to evaluators.
4. Generates better data base (additional information).

Evaluation is usually a comparison process where the evaluator checks the proposals against existing conditions in order to maintain the status, or against proposed conditions in order to improve the status. That is we evaluate against (Dluhosch, 1983):[1]

1. Relative to deontic state - absolute minimum (this is a simple item evaluation procedure, e.g. "A" is good but "B" may be good too).
2. Relative to other alternatives - a relative standard (e.g. "A" is better than "B" but "B" must be acceptable too).

In some cases, it is a straight-forward process, such as applied to quantifiable subjects that may be weighted and evaluated in a direct manner, without any argument (off-hand judgment). Otherwise, more difficult situations confront the decision-maker where non-quantifiable subjects may be objectified in order to be evaluated.

That is, "non-quantifiables" may be evaluated without objectification (e.g. "A" is good), but it is more an individual statement with no clear basis of judgment. Objectification is making one's basis of judgment clear to oneself and particularly to others to establish a mutual understanding of the basis of judgment.

A means of objectification is introduced through scaling. Being able to do so, it will help the evaluator to come in terms with facts in a more accurate way.

1.2 AN INTRODUCTION TO THE PROCESS OF EVALUATION

1.2.1 Means of Objectification

An aspect of the evaluation process is "objectification;" which may be defined as follows (Rittel, 1971):

"A" succeeds in objectifying to "B", the basis of his/her judgment, if, as a result "B" can judge on "A's" behalf, without necessarily sharing "A's" beliefs or convictions.

This process does not depend on convincing the confronting party "B" but rather a learning process takes place between the participants. That is, it brings out into the open problems that occur during the process and/or conflicts between the group of evaluators that may be discussed and hopefully narrowed down. Therefore, it is a process of understanding and weighting a situation, to give a more rational basis for decision-making. In other words, it is a process of problem solving and learning.

There are some arguments on whether feelings and other issues such as quality can be measured.

Social scientists agree that man's behavior is affected by his environment, so his definition of meaning is influenced by his response to his surroundings.

Some characteristics can be responded to directly and immediately and thus are easily qualifiable such as exterior appearance, spatial comfort and performance, etc. In this case assessment criteria describing feelings are expressed through words such as safe, convenient, noise efficient, etc.

It is very often heard of, when inquiring about the merit of a suggestion or a proposal the question "On a scale from 1 to 10 how do you rate this?"

Scientific inquiries are based on a similar concept, where the aim of the inquirer is to abstract possible responses into numerical values and ask the respondents to choose among them.

Scaling is a measurement method, that conveys feelings or attitudes into quantifiable terms - usually numerical values - for statistical evaluation (Palmer, 1981).[2] In other words, scaling helps the person to rate the subject on hand and shows the relative importance to the individual or group.

On the one hand, it may identify the degree of value of a single variable as important, less important, unimportant. On the other hand, it may be used to compare the relative values of two or more alternatives, giving results as a simple choice or complex ranking.

Designers, for example, may find scaling a useful method in evaluating their own decision options, especially when complex issues are not easily judged individually or when based on detailed criteria.

There are a number of scaling methods to use, the choice depends on the nature of the object to be evaluated, user's needs, kind of information and time available. (Kim, 1983).[3]

1. <u>Nominal scale</u>: In which the numbers (or other means of presentation) have no value but are assigned merely for identification.

2. <u>Ordinal scale</u>: It is a ranking in order of the set of objects according to an arbitrary selected ordering range.

3. <u>Interval scale</u>: It is the measuring of relative differences in values among alternatives (with arbitrary origin and fixed intervals).

4. <u>Ratio scale</u>: In which a natural origin "Unique zero" exists, and a ratio scale can be created with proportionate ascending or descending increments (with a natural origin and arbitrary intervals).

5. <u>Absolute scale</u>: Here the scale has both a natural origin and natural intervals (see Fig. 1).

Grant (1982)[4] discusses two common errors associated with using numbers to represent value judgments.

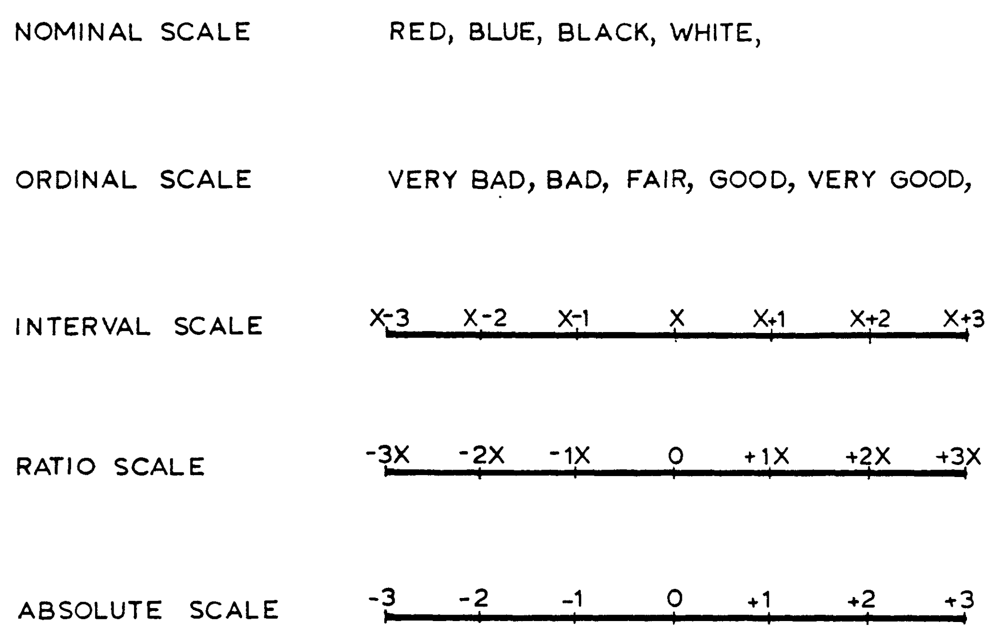

Figure 1: Methods of Scaling

The first fault in using numbers to represent abstract concepts is to assume that there is information contained in the numbers that was not present in the judgmental process of that assigned the numbers. This tendency to read unjustified information content into numbers is all the greater when some arithmetic or mathematical manipulations has taken place with the numbers. A way of guarding against this tendency is to interpret the output of numerical manipulation on a simpler scale than the input.

A second fault related the creation of information through manipulation rather than through measurement or value judgment is the assumption that numeric manipulations justify absurd degrees of perception.

As a whole, there is a great temptation to make the two errors described above when dealing with numeric weights, that is, to assume the presence of information content that has been created by manipulation rather than by measurement or judgmental input, and to assume an absurd degree of precision.

The rule of thumb that one should always interpret the output of a numeric manipulation on the next scale down in order of complexity is one way of guarding against these errors.

1.2.2 The Problem of Weighting Objectives

Decisions are required from each individual concerning criteria selection in the real-world of planning and problem solving.

The designer, for example, is faced with overall judgments related to design proposals and partial judgments about individual criteria (parameters, objectives, or aspects). He often tends to choose one or a few characteristics that he feels are the most important, disregarding others, thus oversimplifing the problem of choosing.

This does not rule out the successful intuitive decision for an experienced designer who has developed an internal, perhaps even an unconcious approach to aggregating many partial judgments into overall design decisions.

Adopting a systematic approach to the problem of weighting does not assume that the decisions generated will be superior to those generated by an intuitive designer. it only seeks to educate, and help those that have to deal with more complex problems, economize the efforts of the designer, and reduce the chances of making undesirable decisions by making the basis of their decision transparent.

The "weight" of a list of objectives is the assignment of numbers to the objectives representing the judged relative importance of each objective among all the objectivs on the list. (Grant, 1982).[5]

So the weight of each objective is the number assigned to the objective in an attempt to portray its judged relative importance.

One variation on the "weighting" response is that of the deliberation of numeric weights of relative importance, that is, the multiple parameter decision situations require the deliberation of numeric weights of importance.

A second variation on the weighting response is that of placing all partial judgments on a uniform scale, and then aggregating them without having to consider the matter of relative importance.

A similar process of dealing with partial judgments without weighting involves word pairing of the individual parameters and judgments are based on the "nearness" of a given image to a given word. Overall judgments are summed up by the total differences in nearness between two or more images for all pairs.

Arguments against the previous concepts state that the whole concept of weighting is not valid and only when precise assignment of weights is maintained that weighting as a process is conceived with giving any opportunity for conscious deliberation.

Individuals are forced to, and do, make decisions which they act upon them, whether or not the decision taken is the best.

In order to do so, they have the choice of:

1. Aggregating partial judgments with respect to each of the criteria being considered; or
2. Basing their decision on one criterion to the exclusion of all others; or
3. Make their decision based on some internally derived "Gestalt" basis in what we have come to call an intuitive process.

Two schools of thought developed from studying the problem of weighting, a general outline on this subject may be summarized as follows (Grant, 1982):[6]

1. Apples must be added to oranges:
   - 1.a Therefore, find a uniform scale for quality (or goodness, or fitness or suitability, or desirability) and then weight the quality judgments using conciously deliberated numeric weights of relative importance.
   - 1.b Therefore, find a uniform scale applicable to all partial judgmental criteria and combine all partial judgments without the necessity of weighting:
     - (1) Using a numerically understood monetary scale as an "objective" measure.
     - (2) Using some other scale, such as varying shades of grey.
     - (3) Using some other scale, such as word-pair profiles as in the semantic differential; or,
2. Apples cannot be added to oranges:
   - 2.a Therefore, find out which criterion is most important, and decide on the basis of that criterion alone; or,

2.b Consider all criteria carefully, then sit back and let the matter incubate, and an implicit, intuitively derived decision may merge; or

2.c Attempt to construct compelling patterns from the partial judgments, without deliberating weights. In some cases this overlaps 1.b:2.

Another aspect discussed by Grant (1982)[7] is decisions; decisions as to which objectives to consider, as to whether or not all objectives are judged to be of equal importance or not; and if the objectives are judged to be of unequal importance, as to how much they differ in importance, are all VALUE JUDGMENTS, not neutral facts. Like all value judgments, they are somebody's value judgments, not characteristics drawn from impersonal nature. As value judgments, they are quite specific to their judgmental context. A judgmental context is identified by:

1. The object or objects being judged.
2. The purpose for which judgment is taking place.
3. The time of judgment.
4. The judge.

The judge, is somebody who makes the value judgment whether in his own behalf or on behalf of somebody else.

A judgment that takes place in one judgmental context might never occur in any other judgmental context, even though two contexts might differ only by one or two characteristics. For example, two different people may judge the same object for the same purpose at the same time and may come up with completely different value-judgments, and the same person may judge the same object for the same purpose at two different times and many arrive to two different value-judgments.

It is important to comprehend that each individual has his own set of values, and therefore when filtering a given set of factual data through two different value-based images, it is not surprising that different judgments or decisions will result.

1.3 SELECTED METHODS OF EVALUATION

1.3.1 State of the Arts

It is by now evident that evaluation is a vital process and is the heart of decision-making. Even though many researchers have involved themselves with this subject particularly in the 50s, it was not until recent years that the word "evaluation" became a complementary part of many a dynamic process such as design, planning and policy-making.

Many methodologists have worked in the field of developing methods for evaluation and decision-making, like Ackoff (1968), Boss (1965), Churchman (1961), Rittel (1972), and others.

Four different methods are selected as means of evaluating objectives, each being appropriate for a certain set of objectives and may be applied successfully for a given condition.

1. The Alpha-Beta Value Model: This model involves the making of two kinds of value judgments, and the combining or aggregation of these partial judgments into overall judgments.

2. The Method of Paired Comparison: This method is useful for ranking when differences among the things to be ranked are not obvious or large, and when the basis for ranking is subjective judgment.

3. The Churchman-Ackoff Method: A technique for improving estimated weights of relative importance through a process of successive comparision judgments.

4. Rittel's Evaluation Procedures for Groups: This includes two procedures for non-economic evaluation which is successfully applied to group judgments.

The following sections will deal in more detail with each of the methods above separately, stating its advantages, disadvantages and process of application.

1.3.2 The Alpha-Beta Value Model for Decision-Making with Multiple Objectives

The Alpha-Beta model is a judgment of weighted desirability, where Alpha value judgments are judgments as to the relative importance of objectives in decision or policy-making problems. Beta value judgments are judgments about the relative desirability (or suitability or fitness of goodness or preferability) of the alternative courses of action being considered.

For a given proposal or course of action, like a design, planning or policy proposal or scheme, the Alpha-Beta products for the proposal for all objectives are summed in order to arrive at an overall desirability judgment about the proposal. The purpose for deliberating such an overall judgment might be to select one from among several possible courses of action or proposals, or to accept or reject a single proposal, or to evaluate the effects of some alteration in a given proposal or course of action.

The steps in using the Alpha-Beta model are summed as follows (Grant, 1976, describes the procedure in more detail):[8]

1. Decide upon the nature of the decisions to be made.
2. Decide upon the objectives to be considered.
3. Decide upon the alternatives to be evaluated.
4. Decide upon a scale for expressing Beta value judgments.

4.b Optional: Deliberate preliminary Alpha values.

5. Construct a table for each alternative proposal that is to be evaluated.
6. Make Beta value judgments about each alternative proposal with respect to each objective.

7. Decide upon the aggregation function to be used.

8. Deliberate final Alpha values.

9. Normalize Alpha values to some standard sum.

10. Aggregate Alpha and Beta value judgments.

11. Derive overall judgment about each proposal.

12. Compare the overall judgments for all proposals in order to rank them.

For the purpose of illustrating this model, two proposals for industrialized building systems will be compared (small components, vs. large panels systems), on the basis of four objectives: Easy assembly, reduce construction time, on-site production, and the use of medium-weight equipment. This is an unrealistically short list for demonstration only.

Step One: The nature of the decision is to decide which of the two proposed systems is preferable with respect to the objectives listed.

Step Two: The objectives to be considered:

O-1: Easy to assemble

O-2: Reduce construction time.

O-3: On-site production.

O-4: The use of medium-weight equipment.

Step Three: The alternative courses of action to be considered:

P-1: Small components.

P-2: Large panels system.

Step Four: The Beta-value scale is to be from 1-9, with 9=most desirable, 5=neutral, and 1=most undesirable.

Step Five: Construct a table for each proposal.

Step Six: Give Beta-value judgments for each proposal (e.g. the small components system is desirable due to ease of assembly(6), undesirable for reduction of construction time(4), and very desirable for both on-site production(8), and the use of medium-weight equipment(9). The large panels system is desirable due to ease of assembly(7), more desirable in terms of reducing construction time(8), very undesirable for on-site production(1), and undesirable for medium-weight equipment(4) (see Fig. 2).

Step Seven: The aggregation function:

$$\frac{\text{sum (Alpha-Beta Products)}}{\text{Sum (Alpha's)}} = \text{Overall Judement}$$

Step Eight: Alpha-values (relative importance weights) for objectives. 0-1=1/2, 0-2=1/2, 0-3=2, 0-4=3.

(where "A" more important than "B"=1

"A" less important than "B"=0

"A" as important as "B"=1/2

Step Nine: Standardize the Alpha-values. Assuming the sum to be 100.0, then

Objectives	Alpha-values	Rank
0-1	8	3
0-2	8	3
0-3	34	2
0-4	50	1

Step Ten: Obtain Alpha-Beta Products by multiplying (see Fig. 2).

Step Eleven: Compute overall judgment values.

Step Twelve: Compare alternative courses of action (see Fig. 2).

In our example, judging from the value judgments recorded above, proposal "A" is superior to proposal "B" with respect to the objectives listed.

A number of methodologists critisize the Alpha-Beta approach. One aspect of controversy is the weighting of objectives by their relative importance. This argument is weakened by the fact that the alternative offered is usually to weight all objectives equally, which is itself a weighting judgment.

SYSTEM (A) SMALL COMPONENTS	Beta Value	Alpha Value	Alpha-Beta
0-1	6	8	48
0-2	4	8	32
0-3	8	34	272
0-4	9	50	450
Sum	-	100	802

$$\frac{\text{Sum of Alpha-Beta}}{\text{Sum of Alpha}} = 8.02$$

SYSTEM (B) LARGE PANELS	Beta Value	Alpha Value	Alpha-Beta
0-1	7	8	56
0-2	8	8	64
0-3	1	34	34
0-4	4	50	200
Sum	-	100	354

$$\frac{\text{Sum of Alpha-Beta}}{\text{Sum of Alpha}} = 3.54$$

Figure 2: Alpha-Beta Metrix for Four Items

Another aspect being criticized is that it is difficult to impossible to insure that the objectives listed are independent of each other. This leads to over-emphasize in a chosen sub-objective.

Even so, the notion of weighting by relative importance is still excepted despite its controversies as it is the best method available to deal with the complexity of multiple-objective decision situations.

1.3.3 The Method of Paired Comparisons for Ranking Objectives

The method of Paired Comparisons is an old technique, attributed to an early pscychophysicist named Fechner (1860).

Two important kinds of ranking tasks are recognized, the ranking of alternative choices in terms of suitability or desirability, and the ranking of goals and objectives in terms of relative importance.

This method can be used by an individual or by a group and is useful in some situations in which a ranking task has to be carried out. These situations are generally those in which the differences among the things to be ranked are not large or obvious, and in which the basis for ranking is a subjective judgment rather than a simple physical measurement.

The steps to be taken in applying this method are (Grant, 1976):[9]

1. Stating the objectives to be compared.
2. Constructing a square matrix with a row and a column for each item to be ranked.
3. Carry out a judgment for each cell in the matrix, except the cells on the principal diagonal, and to enter the judgment in the cell.
4. Summing the figures in each row.
5. Determining the ranking. The item with the highest row sum is ranked first, the item with the lowest row sum is ranked last, and so on.

Let us consider the situation of a developing country planning to import high technology to the building industry. The objectives here may be: increase productivity, reduce cost of units, improve quality, reduce man-labor.

The procedure will be:

In this example, four items are to be ranked (see Fig. 3). It is seen that the first objective is the most important as it scored the highest, followed by the second, fourth and finally the third objective.

The ranking by this method does not claim to make "objective" ranking or that the results may remain the same if the judge is changed. Furthermore, value judgments are subjective by definition, therefore the same person may change his judgment as time changes.

It seems to be acceptable by most people the task of ranking from most desirable (or suitable or fit, etc.) to least desirable (etc.), and the use of the method of Paired Comparisons as a tool to carry out this task seems to get no objections.

Another kind of judgment occurs in ranking goals or objectives in terms of relative importance. Weighting the different objectives seems to be less acceptable to some people. More on this controversy may be found in Grant (1982).

As seen, the Method of Paired Comparisons has been used as a means of ranking in a systematic, thorough, and arguable way. Yet there are other alternatives to the method that may be used in the task of ranking.

1.3.4 Churchman-Ackoff Method for Weighting Objectives

The Churchman-Ackoff Method for weighting objectives can be useful in problem formulation, evaluation, and decision-making in situations in which there are several objectives, and in which the several objectives are

	0-1	0-2	0-3	0-4	Row Sum	Ranking
0-1	-	1	1	1	3	1st
0-2	0	-	1	1	2	2nd
0-3	0	0	-	0	0	4th
0-4	0	0	1	-	1	3rd

Figure 3: Paired Comparisons Matrix for Four Items

potentially of different degrees of importance. This method is described in Churchman, Ackoff, and Arnoff's (Introduction to Operations Research - 1957).

It is a technique for deliberating relative importances among several objectives by means of trade-off judgments.

This method might be useful in situations in which (Grant, 1976):[10]

1. The objectives cannot be measured on a comparable scale or scales.
2. The decision-makers find the underlying assumptions acceptable (Churchman, Ackoff, and Arnoff - 1957).
3. There are multiple objectives of potentially different degrees of importance.

The Churchman-Ackoff Method is basically a systematic check on relative importance judgments by an exhaustive sequence of successive comparisons. Churchman and Ackoff describe it as being applicable not only to the deliberation of relative weights for objectives, but also to assigning values to objects and properties of objects or events.

Two procedures are layed, the first is used for weighting up to six objectives; for seven or more objectives, a second procedure is recommended (Churchman, Ackoff, and Arnoff - 1957, pp. 142-144). The basic steps and operations are the same in both procedures; what differs is the process of staging.

For demonstration the first procedure will be described, and it may be summarized as follows: (see Fig. 4 and Fig. 5)

1. On a nominal scale, classify and label all the objectives (in this case four).
2. On an ordinal scale, rank the entire set of objectives.
3. Compare the relative importance of the leftmost objective by itself (01) with the combined relative importance of all the objectives to the right in

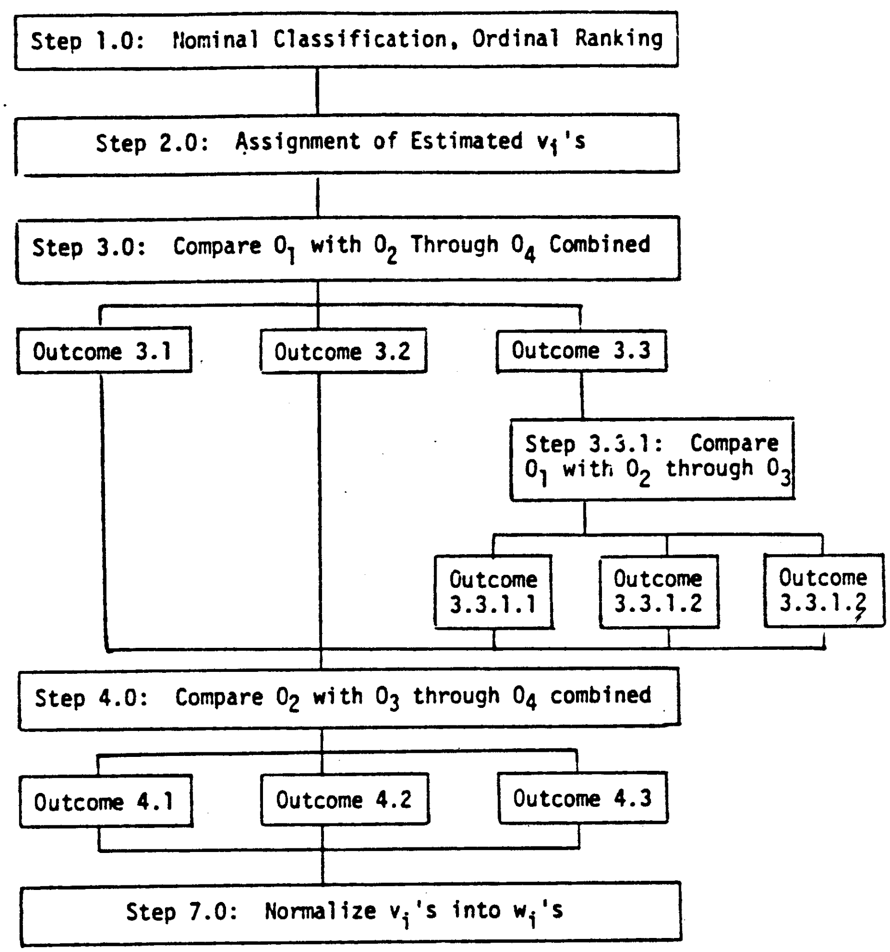

Figure 4: Churchman-Ackoff Method for Weighting Four Objectives

Source: Grant, 1982

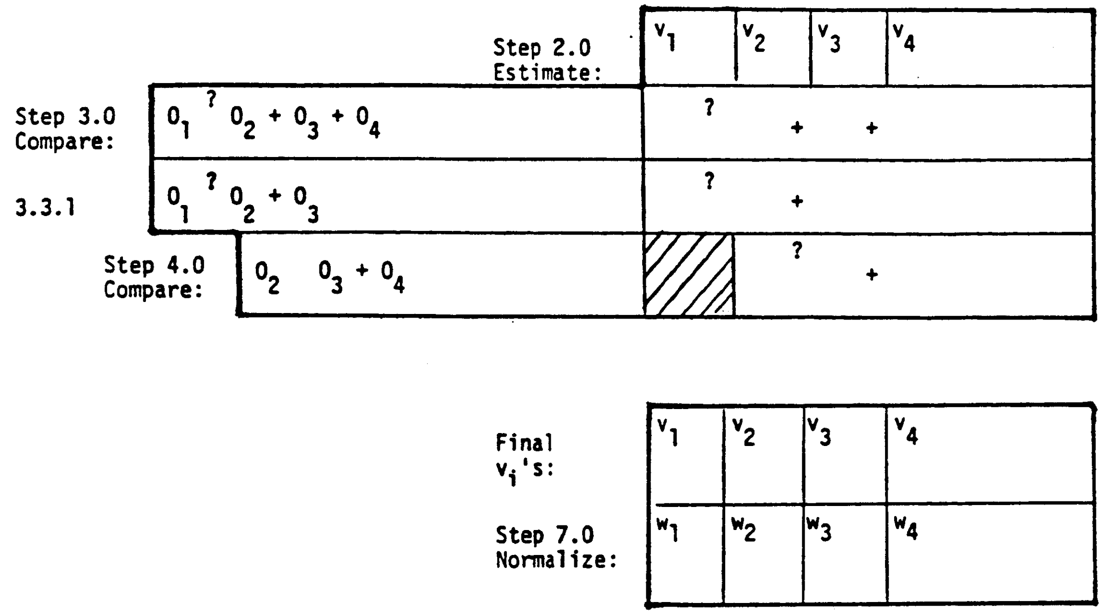

Figure 5: Tabular Form for Weighting Four Objectives
Using the Churchman-Ackoff Method

Source: Grant, 1982

combination (02,...,04). The possible outcomes are:

3.1 01 > 02 + 03 + 04

3.2 01 = 02 + 03 + 04

3.3 01 < 02 + 03 + 04

Dropping the last objective and comparing the relative importance once again, this step will be repeated until the comparison of 01 with (02 + 03) gives appropriate results (that is the outturn of the comparison is realistic).

4. Drop 01 from the comparison process and record the final value (V1) of 01 arrived at after all adjustments and repeat step 3 through all outcomes until comparison: 02 ? 03 + 04 is reached, making appropriate adjustments in the values (V2) of 2 at each step. In the case of more than four objectives this step is repeated.

5. Convert each value from objectives 01 to 04 (in this case) into a normalized value Wi by dividing each value (Vi) by the sum of all values V1 to V4. The following formula applies:

$$Wi = \frac{Vi}{V1 + V2 + V3 + V4} \text{ (where } i = 1,2,3,4)$$

The sum of all Wi's, from W1 through W4, will be 1.00.

The Churchman-Ackoff Method sounds much more complicated in a written description than it actually is in practice.

This method does not create information or values. It structures a series of trade-off judgments in succession in order to adjust and modify relative importance weights. The result is that the weights are consistent with the preference structure of the person or persons making the value judgments.

Some of the contorversial aspects of the method are based on the fact that objectives, to be relatively weighted among themselves; must be mutually indepent is the most important prob. for this method

independent, and the judgment that mutual independence among design and planning objectives is an almost impossible state.

Among arguments for weighting are that it seems to approximate the kind of thinking that actually goes into human decision-making activities, whether or not it is theoretically resolved; and that the process of deliberating relative weights, among other things, focuses one's awareness on the problem and stimulates reflection and insight.

Alternative approaches to the Churchman-Ackoff Method are listed by Churchman, Ackoff and Arnoff (1957, pp. 152-153) and by Johnsen (1968), others by Tzonis and Salamah (1974).

1.3.5 Rittel's Method for Groups Evaluation

Grant states (1982) that: "Bad" design, planning or policy-making probably results more often from forgotten factors than from malice. The process of deliberation and the use of formal decision rules among the members of an interested group of participants can help to guard against forgetfulness.

In Rittel's experience in the use of this method, he reports that the participants in such a process usually develop confidence in the procedure as a fair representation of their and the group's judgment, and that aspects that are of dubious ethical nature or honorableness seldom get mentioned.

Rittel's evaluation procedure for groups may be summarized as follows (Grant, 1982):

1. Each member of the group makes an off-hand, overall judgment.
2. Each member makes a list or the aspects of parameters that are important.
3. Each member weights the aspects/parameters to indicate their judged relative importance among themselves.

Wait one or two weeks, then repeat steps one through three.

Discard the first results and keep the second.

4. Assemble a Union List of aspects/parameters made up of all those submitted by all members of the group. Edit the Union List to eliminate repetitions.
5. Distribute the edited Union List to all members of the group and ask them to weight the aspects/parameters in accordance with their judged relative importances among themselves.

(Usually, people are willing to consider and weight items on the Union List that they did not think of the first time; that is, to learn from others in the group and adopt their aspects and parameters as well as their own).

6. Each member of the group scores each alternative against each aspect/ parameter on the Edited List.
7. Overall deliberated scores are computed from the weighting values (Step 5) and the score from (Step 6).

All the group's deliberations up to this point may have taken place without a face-to-face meeting.

8. Compare each individual's off-hand judgment from (Step 1) with his deliberated judgment from (Step 7).
9. A face-to-face meeting of the group might be convened at this point for the first time, to discuss the results of (Step 8).
10. Either decide to act upon the deliberated judgment of (Step 8) or to recycle or revise.

Some of the benefits of this approach as seen by Rittel are:

1. Maximizing the average benefits.
2. Raising or maximising the minimum; that is, choose the decision that helps the person who is worst off the most.

3. Minimize the variance between he who is best off and he who is worst off; that is choose the decision that pulls the extremes in toward the middle the most.

The above process does not help with a group that is not intelligent or does not know the problem, and does not help to deal with the considerable problem of communicating over cultural distance.

1.4 A TURNING POINT

Evaluation methods were originally researched for problem-solving and decision-making in fields such as operations research, yet scientists were able to extend and adapt these methods to use in other situations where experience and intuition became less effective in evaluating more complex problems of which the building process is one of them.

Jones (1963) consideres evaluation as a means of detecting deficiencies in the design before one is committed to it. That is "before final manufacturing drawings have been started, before production begins, before the product has been sold, before it has been installed and before it has been put to use.

In other words, evaluation is a process that would appear after every decision or stage taken by a decision-maker (see Fig. 6). What may be true for the design process, may be taken further to include the building process in general.

The building process became under greater pressure to make sure that the most appropriate solution was decided upon for a given situation.

In order to introduce evaluation to a process, it becomes necessary to develop a system in which it permits the evaluation of every stage, and gaining from the results through feedback, without interfering with the sequence of

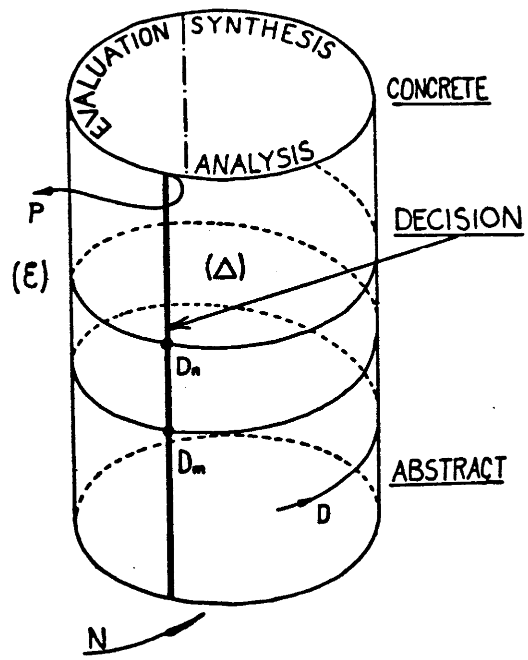

Figure 6:
Analysis, Synthesis and Evaluation in the Design Process

Source: Broadbent, 1973

events.

Many methodologists here refer to the systems approach. The systems approach may be thought of as a possible method of tackling intricate problems generated by the evolution of a more complex society that is subject to rapid change.

From the previous sections, it was seen that in order to make an evaluation or weigh a statement we must first identify the objectives and parameters related to the subject to be evaluated.

In the building systems' industry, the major subject of this study, many a factor contributes to its success or failure. In order to achieve success it becomes necessary to identify, weigh and evaluate all major factors that effect decisions throughout the building process.

Decisions that are identified at this point at two separate levels:

1. Deciding upon initiating a building industry: Here it is more of a planning process which deals with factors such as resources (labor, equipment, finance) and market conditions.
2. Deciding upon the choice of a specific building system for the industry: This level deals directly with the user's requirements and performance specifications of the system.

With too many a factor to be considered, it is evident that a rational approach is necessary to adopt, to ensure that no major factor was missed or overlooked.

Therefore, it is important to understand systems as an approach to building generally, and to the building industry specifically.

Chapter 1

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CHAPTER TWO

SYSTEMS, SYSTEMS APPROACH, AND SYSTEMS BUILDING

2.1 INTRODUCTION

> The systems Approach was the flame of inspiration that propelled the white-head technology of the 60s.

In an attempt to better comprehend the more complex problems of today's building process, professionals - specifically architects - sought to expand the amount and kind of information at their command. As a result, it was found that many a factor has never been considered before, must be taken into account in the present building process.

With the increasing number of factors considered, and the growing complexity of interrelations among them, the product is evolving into a system with multi-parameters, thus intuition becomes somewhat "unreliable" in dealing with a solution for the problem confronting us. That is, observation and experience alone are not enough for a decision-maker to depend on when considering all factors.

Today, the building process finds itself concerned with a great number of problems ranging from the need and demand for building, programmatic requirements, etc., to construction processes, operating costs and benefits.

Due to this sense of totality in the building profession, it can only be grasped and comprehended by analysing and understanding its components (or sub-systems) in relation to each other and to the system as a whole.

2.2 SYSTEMS THINKING

2.2.1 Background

Today, the word "system" is widely used in day-to-day vocabulary. Commonly used, it means the grouping of parts with the help of a set of regulations to make it work as a whole. Yet for the methodologists and scientists, "systems" is a much deeper notion.

> Systems is a set of parts coordinated to accomplish a set of goals. (Churchman, C.).
>
> System is a kit of parts with a set of rules to yield some desired behavior. (Brill, M.).
>
> A System as a Whole is not an object but a way of looking at an object. It focuses on some holistic phenomenon which can only be understood as a product of interaction among parts. (Alexander, C.).

Systems therefore represent a way of thinking and coordination, and help develop a sense of wholeness and equilibrium. The systems approach has been adopted in the early 70s, associated with processes and products related to technology and its development.

E.D. Ehrenkrantz defines the systems approach as "a process which is used in viewing a problem as a set of interrelated, interdependent parts which "work together for the overall objective(s) of the whole."

The definitions above are examples representing the various ways that systems are looked upon. There notions are reflected in systems as hardware with their integrated parts functioning as a goal-oriented whole or systems as a combination of hardware and rules to serve a requirement; and the views of a system not as an object but as an image or profile of coordinated hardware elements or sub-systems. The purpose of the above definitions is to introduce the idea of systems and examples of how it is explained and understood by various people. No attempt is made here as to which concept is the most appropriate, if any.

2.2.2 Basic Considerations of a System

Systems are not independent or isolated. They are often embeded in a larger system and always have systems within them (i.e., each system is the sub-system of a larger system). That is, what is a system for one, is a sub-system for another.

In order to understand the exact meaning of a system, five basic considerations are outlined by Churchman (1968).[1] When utilized together we can visualize the meaning of a system.

1. The total System Objectives and the Performance Measure.

Here we must state that it is the "real objectives" we are seeking rather than those that are sometimes advanced as obvious. We can test the system's objectives by determining whether the system will knowingly sacrifice other goals in order to attain the objectives. Measuring the systems' performance is a test of how well the system is doing.

2. The System's Environment: The Fixed Constraints.

The environment of a system is what lies outside the system. It includes the things and people that are fixed or given, from the system's point of view. These can not be changed, yet they are sometimes determining how the system performs.

3. The Resources of a System.

These lie inside the system and are the tools required to make the system function. Resources, as opposed to the environment, are changable and can be manipulated to the systems' advantage. Therefore, it is essential to seek the possibilities of increasing the resources through technological advances.

4. The Components of the System, Their Activities, Goals and Measures of Performance.

Here again we turn to basic activities rather than traditional and obvious components, rationally breaking down the tasks the system must perform.

The act of breaking down the tasks helps analyze the activity and weight it in terms of its worth to the system as a whole. The division of a system into components leads to a better understanding of a system, and its "future" operation.

5. The Management of the System.

The management deals with the planning of the system, considering the overall goals, environment, the allocation and utilization of the resources and components and the control of the systems performance, thus making sure that the plans are carried out in accordance with its original ideas and evaluating the final result.

So when talking about a system, we should know its position with respect to other systems and the environment, and what one can manipulate or wants to manipulate within the system and what is out of one's power of control.

The above five considerations are compatible for any generated system, whether related to buildings or other forms of systems. Their application to building systems will be discussed in further detail as we proceed.

2.2.3 The Influence of Systems Approach on Today's Thinking

In the early 60s, with the rise of aerospace programs, the issue of systems approach was greatly publicized and clearly demonstrated to the world (i.e., man landed on the moon, etc.). Systems were the logical approach to solving problems surrounded by uncertainties.

This approach enabled scientists to better understand and comprehend the nature of the problem facing them, and give a more determinate environment to deal with the system as a whole.

With today's changing world, many old concepts are no longer valid, and it becomes essential to further investigate in depth the possibilities of old solutions, in a more advanced context to serve in today's framework rather than using past methods to try and solve the present problems we face.

One issue to be considered in this respect, is the problem of rate and speed of change. The later is so fast that periods of adaption are often outpaced by change, and learning curves to adapt to change do not keep pace with the effects of change.

Even if it is recommended by methodologists, the systems approach is easier to apply to "tame" problems rather than "wicked" ones. The problems that scientists and engineers face are usually "tame" ones. For example, solving a mathematical equation is a clear mission whether or not the problem would be solved. "Wicked" problems, in contrast, have no clear characteristics, public policy-making is an example of such problems.

Rittel (1973)[2] states that "for any given tame problem, an exhaustive formulation can be stated containing all the information the problem - solver needs for understanding and solving the problem-provided he knows his "art", of course. This is not possible with wicked problems. The informaton needed to understand the problem depends upon one's idea for solving it. That is to say: In order to describe a wicked problem in sufficient detail, one has to develop an exhaustive inventory of all conceivable solutions ahead of time."

With this concept in mind, the building process involves many human factors which depend to a lesser or larger degree on predictions, therefore building may be considered as a wicked problem.

In the case of building technology, construction is made to be permanent; designers today recognize the user's requirements in terms of change as time passes to adapt to their social changes.

Predictions in general are either short- or long-term. Short-term predictions are usually more specific and made more frequently (see Fig. 7).

This brings us to accept a conceptual change in our way of thinking about a building in which we must worry about what a building is, and how we go about

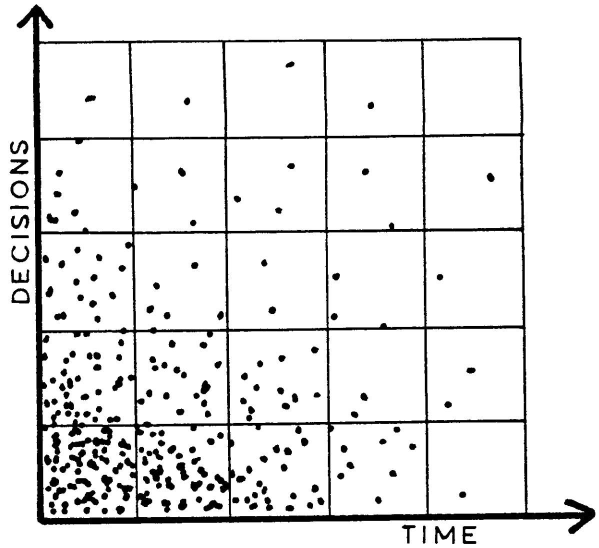


Figure 7: Frequency of Decision-Making

Source: Dluhosch, 1983

building it taking into account a design system that is adaptive and flexible with a technology that permits both anticipated and unanticipated changes as time passes by.

2.3 SYSTEMS APPROACH TO BUILDING

2.3.1 Systems in Design

It may be assumed as valid that "good" designers are in general consciously or unconsciously adapting a systematic approach in solving their design problems, and are often able to produce flexible buildings that can be adapted without having to make difficult compromises.

In aerospace, the systems approach meant high technology. Yet, alternative appropriate technology can also be subject to the systems approach, whether one refers to it as "high", "medium" or "low" technology. The important thing is to understand the processes of the technology chosen, its scope of application and possibilities.

Subsequently, the systems approach does apply to the architectural profession, even though it may not be universally and explicitly acknowledged as such (see Fig. 8).

Other professions, such as engineering and to some extent behavior science, introduced scientific notions into areas previously dealt with "intuitively" by architects. This has led to a "loss of innocense" by architects and the need to absorb "scientific procedures" into design.

The systems approach has the following advantages compared to conventional design process:

1. It permits completeness of problem definition.

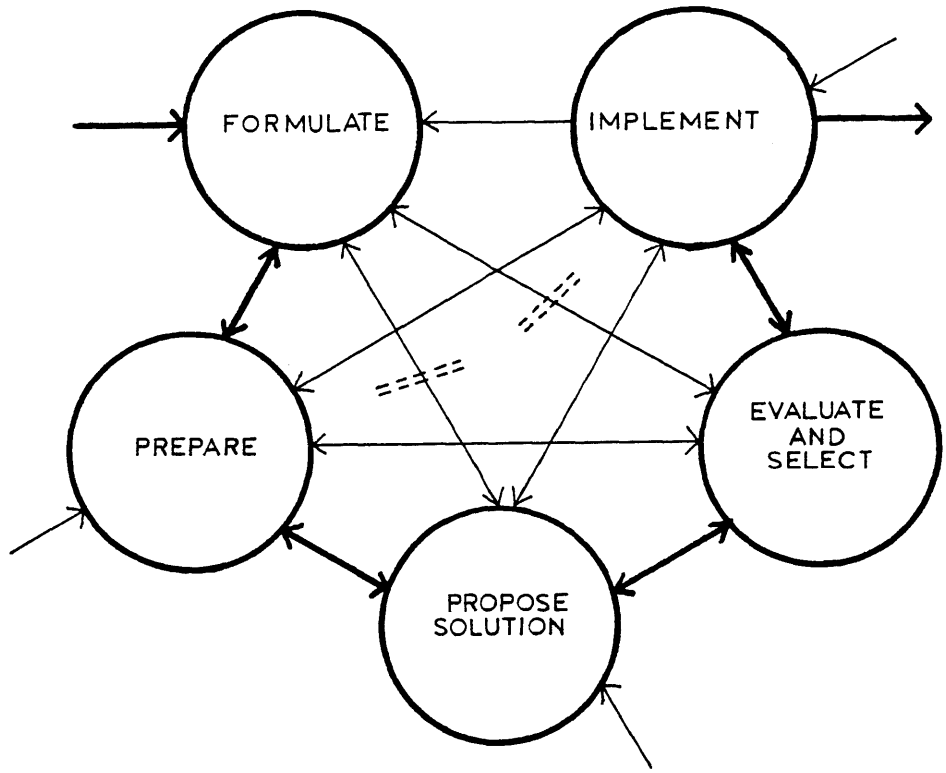


Figure 8: The Total Interaction of the Design Process

Source: Gerischer, 1971

2. It results in an earlier and more reliable prediction of the eventual cost and user acceptance of the product.
3. It enables one to utilize the concept of performance more effectively.
4. It provides a means by which one can continually evaluate solutions generated against rationally defined objectives and criteria throughout the design process.

Many may argue that the conventional design process is similar to this approach, which may be true to a certain extent. The conventional method on the other hand, can not be applied in all cases, especially generic buildings, repetitous units, etc.

Building systems are one field in the building process that the systems approach is applied to. However, it is important to understand that building systems may or may not be the result of applying the systems approach to their design.

2.3.2 Systems Building and the Building Process

In a broader sense of the word, when the systems approach is applied to buildings, we are searching for a process that deals with a comprehensive overview of the complex processes of building.

There are five basic resources which one deals with in building: Land, Financing, Management, Technology and Labor.

A number of general steps as stated by Ehrenkrantz (1970),[3] are developed to resolve building problems. These steps are:

1. Statement of objectives.
2. Problem analysis and base line data gathering: Analysis of:
   a. The state of the art, to benefit from past work in dealing with meaningful and organized progress.

b. All parts of the problem and the relationship(s) between the parts.

c. The variables and constraints which will affect attainment of the objectives (labor unions, building codes, etc.).

d. Identification of the needs of the potential uses of the building through surveys, interviews, etc.

3. Development of performance criteria based on identified user's needs.

4. Generating alternative solutions.

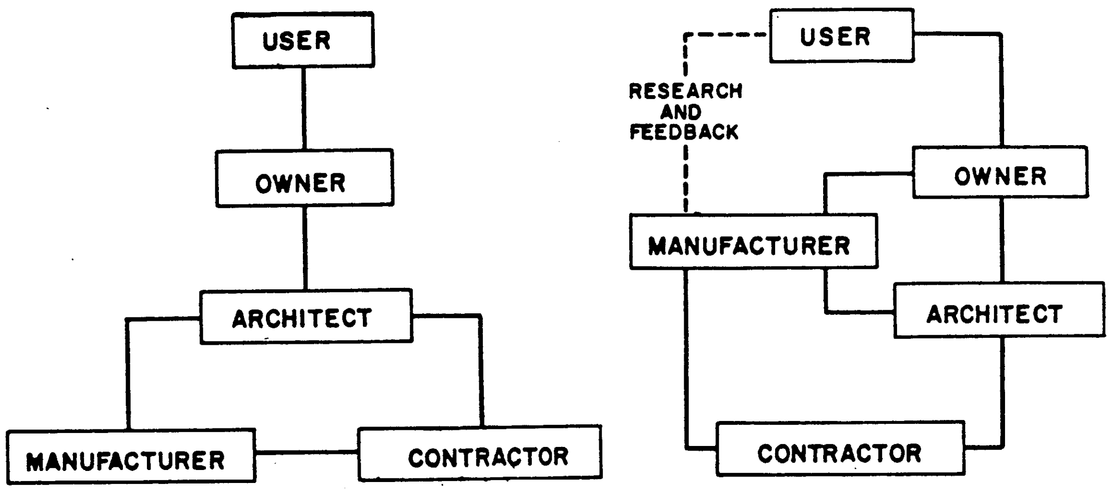
5. Evaluation and selection of alternatives.

The sequence of the five steps may change in terms of priorities depending on the problem in hand.

The most dynamic of the steps is the evaluation processes in which we are dealing with the assessment of the actual performance to enable a rational selection of alternatives. "Rational" in the sense is seen as the most appropriate solution and the additional possibility of improvement.

Given today's building complexities, the systems approach helps with the allocation of available resources to match user's requirements within a given budget, with the air of creating a balance between allocated resoures and returns.

We manipulate the program so as to satisfy the requirements stated within the context. User's requirements must not be compromised. If, however, it is impossible to achieve our goals with the available, then it becomes necessary to review the total context, to come up with alternative procedures, the way resources may be supplied or altered (see Fig. 9).



Traditional Relationships in the Building Process

Evolving Relationships in the Building Process

Figure 9: Relationships in the Building Process

Source: Bender, 1973

2.3.3 The Process of Building Systems

> A "Building System" may be defined as a set of interrelated building parts with a base of information which defines the relationships between the parts and may work together to accomodate the varying needs and objectives of a variety of building programs. (Ehrenkrantz, 1970).

Building systems may be classified in two major categories:

1. Closed Systems: A system in which components or sub-systems are peculiar to that system and cannot be combined with those of another system.

2. Open Systems: A system in which components or sub-systems are interchangeable with those of other systems.

"Open Systems", therefore, have longer effective lives as systems, and the designer does not have to look for alternative sub-systems to maintain the continued performance of the system as a whole.

"Closed Systems", however, must use specific products for the better part of the sub-systems, yet they may provide a more highly organized total delivery system for the construction of specific buildings (see Fig. 10).

The systems approach is used in many aspects of a given building system. For example one aspect is where attempts are made to use conventional materials as opposed to specially developed components. This consists of detailing the various building elements and organizing the construction process so that unskilled as well as semi-skilled labor are more productive and makes fewer errors, and so that the physical performance of buildings is improved. With more building systems being developed, it becomes easier to work with known performances for specific groups of materials that work together.

It is more evident that with the increase in the number of new products, capabilities and requirements in new projects, a more orderly form of information is needed, whether the designer is using conventional methods or building systems.

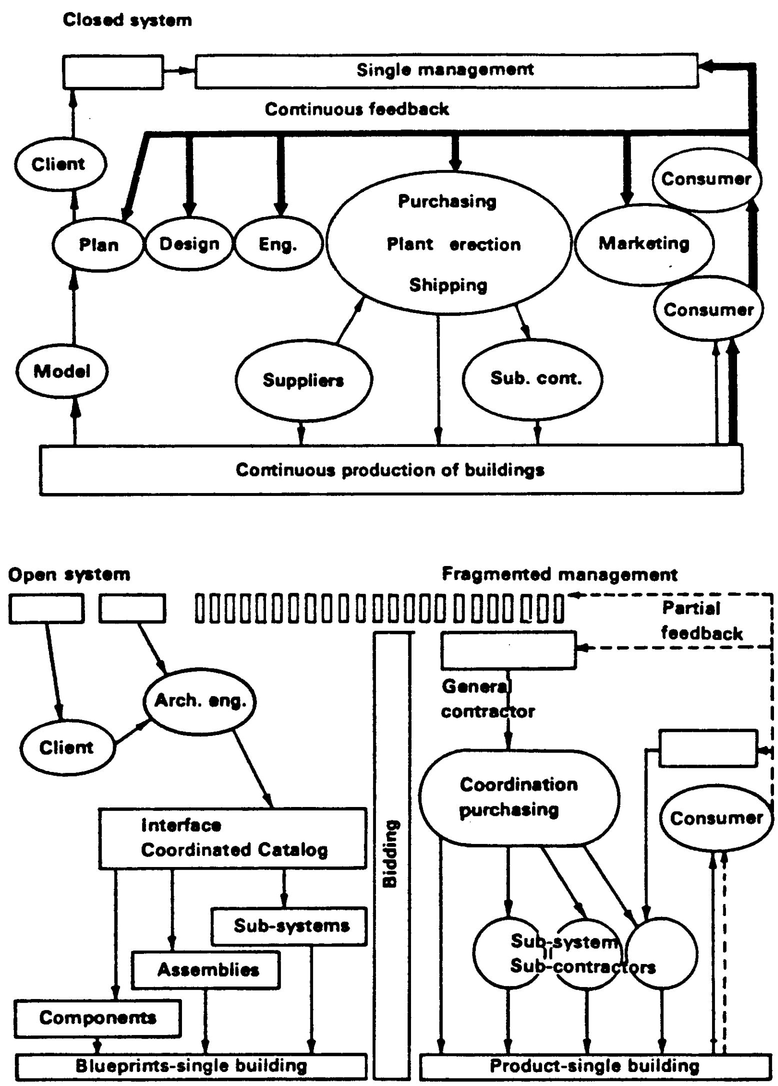


Figure 10: Closed and Open Systems

Source: Dietz and Cutler, 1971

Another aspect of the use of systems approach in building systems is the building industry. If one considers the building industry as a large system, it consists also of a set of components (or sub-systems) with an overall objective of the whole. The systems approach helps to operate the total system and its components, in this case.

Moreover, there are a number of common factors that appear in the various "systems approaches" to building systems as related to their performance:

1. Determination of performance desired for some aggregation of components of a building.
2. Establishment of a minimum dollar volume of building deemed necessary to attract manufacturers and the technical-legal-managerial effort required to make possible procurement of components by performance specifications.

Performance in the sense of (Gerischer, 1971):[4]

1. Identification and definition of the user's needs.
2. Transformation of these needs into performance specifications for a set of interrelated building components.

> The difference between building systems and systems approach is that building systems deal with man, energy, and procedural rules to develop a defined objective entity, while systems approach is a way of dealing with the problems of integration, organization, and control. (Gerischer, 1971).

The systems approach, in this case, points the finger towards industrialization with its wide range. It may be applied both to conventional, on-site construction which is highly organized, as well as to off-site production of e.g., prefinished building panels and components.

Industrialization at one extreme involves the careful planning of manual on-site building operations, which may be partially mechanized. On the other extreme, it may involve a high level of off-site prefabricated components with a minimum of on-site building activities.

2.3.4 Industrialization of Building

Industrialization of building is

> The organization of building industrially by applying best methods and techniques to the integrated process of demand and design, manufacturing and construction. (RIBA - 1965).
>
> Applying methods and techniques to the integrated process of demand and design, manufacture and construction which will give the highest level of productivity. (SEF - 1968).

Once the replacement of handicarft by machines has been accepted by the profession, the repetitiveness in the building process becomes prime candidate for industrialization (see Fig. 11).

Buildings are more or less permanent, offering a life span of thirty to fifty years, therefore the building process is hesitant in accepting innovative ideas and others that are not tested for their permanence.

Nonetheless, the building process if dependant on a number of so-called "second hand" mechanizations, i.e., products developed in other branches of the industry. One example is the introduction of electrical motors to the powering of cranes which can lift heavy building components in highrise construction.

Another aspect adapted by the building industry from other advanced industries, was the implementation of automated assembly lines based on the model of automobile industry. It has been used sparsely in the production of light-weight facade and partition wall components, and in the manufacturing of mobile homes.

Thus, industrialization may refer to anything from a carefully organized, traditional, semi-mechanized, on-site trade operation which requires considerable on-site labor, to the production and installation of large, complex, prefinished building components.

Thus, industrialization of the building process requires a deep understanding of both the methods of building industrialization and properties

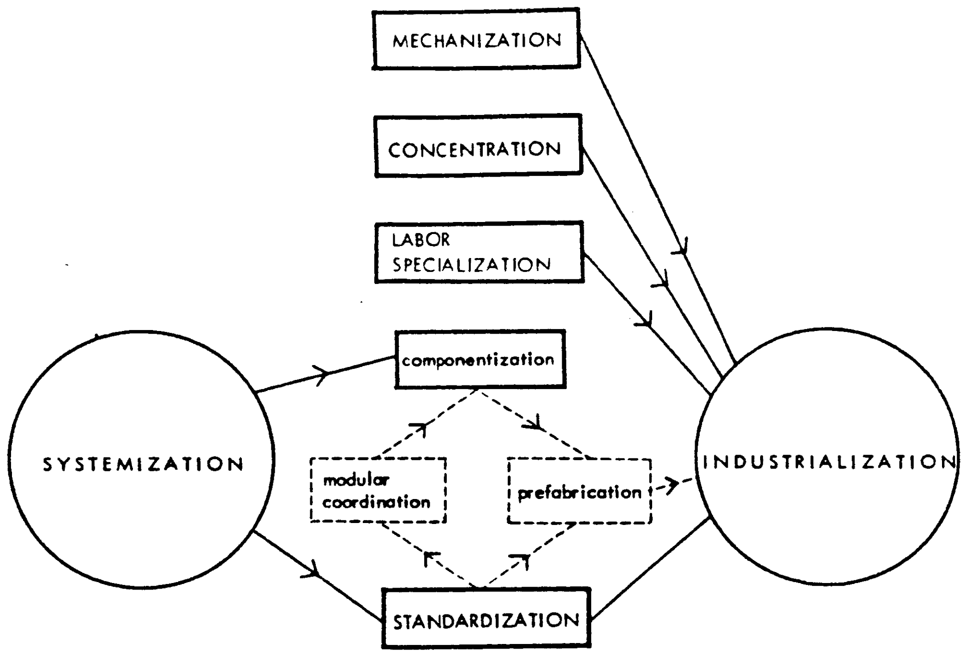


Figure 11: A Fully Industrialized Building System; Its Relation to Standardization

Source: Terner and Turner, 1972

of materials.

The introduction of mechanization in the building process began with the rationalization of traditional materials by means of more sophisticated tools and machines. Later on, new materials such as steel and concrete were partially introduced. Not only did they yield to larger spans or heights of buildings, but lent themselves together with new means of transportation and hoisting, to mass production on and off-site.

Then the metric system came along during the French revolution, with the development of systems of dimensional coordination, graphic representation and new modes of communication between architects and engineers, were yet another evolutionary factor in the industry's development. (Brandle, 1976).[5]

Finally, from this overview, one can visualize the interaction of both soft-and-hardware systems that are working side by side to bring together system building.

On the one hand, we have the theoretical procedures of search, organization, coordination, decision-making, feedback loops, etc., that make up the "software" part of system building.

On the other hand, the execution and operation by technical means, such as industrialized production, integrated assembly, automated operational controls, etc., make up the "hardware" parts.

As stated by Brandle (1974), this distinction between generative and operational systems helps in understanding systems with regard to their purpose (what they outght to do), and with regard to their procedures (how they accomplish it).

2.4 EVALUATION IN SYSTEMS ANALYSIS

> "Though the systematic method leads to the identification of facts, it is still necessary to set up a framework for value-judgements; then it becomes possible to establish a hierarchy of priorities and of consequences." (Paris, 1970).

Paris (1970)[6] discusses a model comprising of five steps that is a systematic analysis technique used to help choose a well-structured framework for a certain research project (see Fig. 12).

Four of the five steps are arranged in series, whereas the fifth represents the feedback loops, allowing for the modification of earlier steps.

A project begins with a phase of preplanning in which we determine all the functional criteria which the solution must satisfy.

The next phase involves the project planning as such; the study is developed in depth (in building, this is equivalent to the design phase).

Field application follows; in building, this is the actual on-site construction phase.

The next two steps: Evaluation and Feedback are nearly always overlooked (see Fig. 12).

Evaluation of products from consumer-durables industries differs from those of the building industry. Firstly, the life-cycle and the rhythm of use of the products are different; it is easier to evaluate the performance of a new automobile than a house, over a period of a few months. Secondly, diversity - which is characteristic of the building industry - increases the complexity of evaluation; e.g., no two hospitals are alike, and they are not built as mass production.

Therefore, it is not surprising that evaluation and furthermore, feedback, have not found a place in the traditions of the building industry.

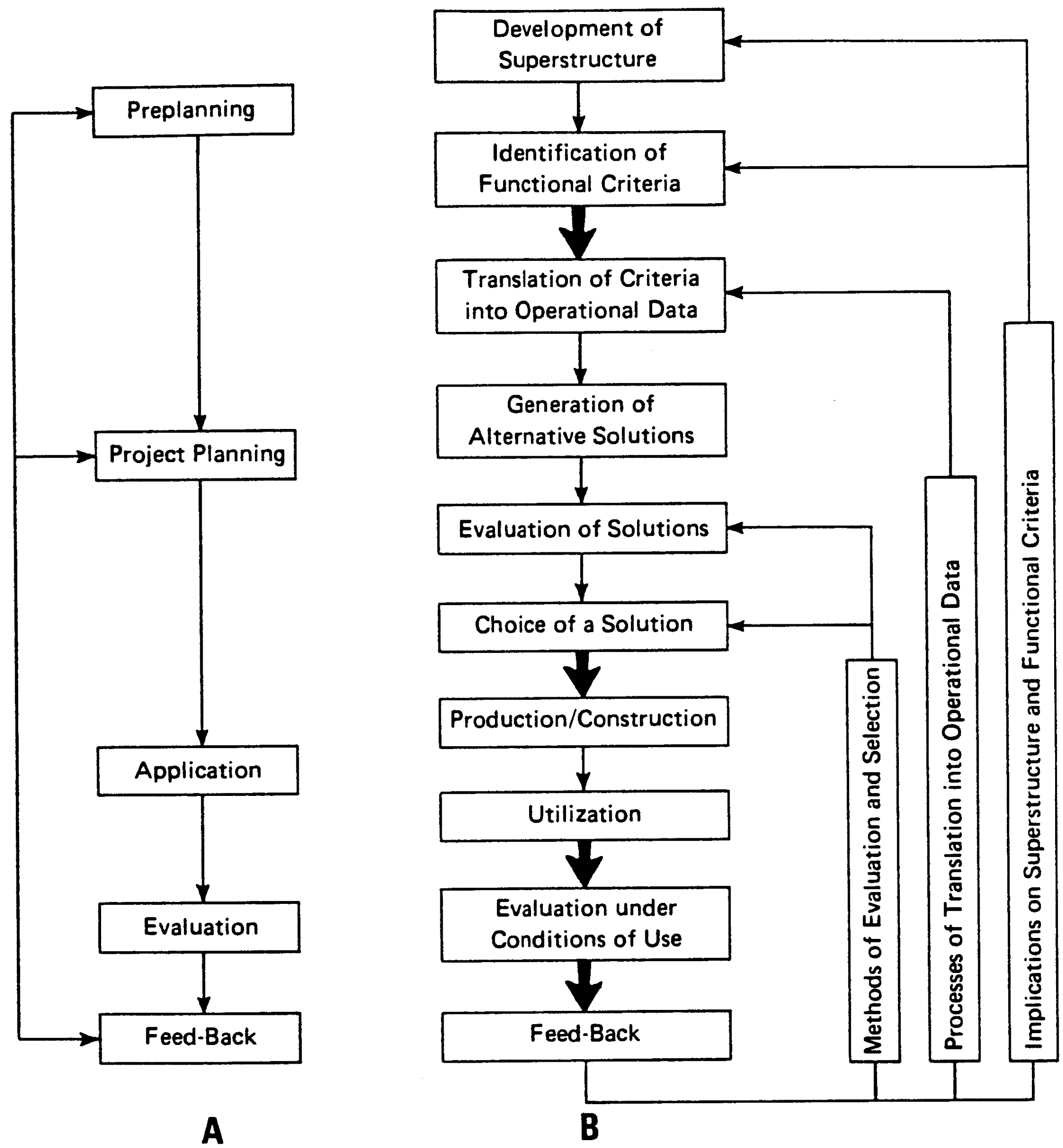


Figure 12: A Process of Carrying Out a Project

Source: Paris, 1970

Nevertheless, the use of feedback is increasing in the sector of catalog-products manufacture.

According to Paris (1970),[7] the feedback of experience regarding finished buildings is still conducted very unsystematically, because the designing architect uses his accumulated experience in an unstructured and unanalytical way.

The emphasis here is on the two stages related to identifying the best proposal. Firstly, the objective measurements of the performances of the alternative solutions are evaluated by comparison with the original statement of the operational data. Secondly, all the performances are weighted against each other to arrive at the selection of a single solution.

The solution selected may have to satisfy all the criteria, in which we look for a series of "yes" or "no" answers; or its performance is measured by continuous variables, in which case we have to trade off the different solutions offering differing performance profiles.

Chapter 2

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CHAPTER THREE

THE EVOLUTION OF AN INDUSTRIALIZED BUILDING SYSTEM

3.1 INTRODUCING ADVANCED TECHNOLOGY TO THE CONSTRUCTION INDUSTRY

In the previous chapter, the term "industrialization" was presented based on the notion of building systems of which can be classified based on two main factors (see Fig. 13):

1- Amount of industrialization (minimizing of reproduction efforts).

2- Distribution of work between site and factory.

Based on the later, building systems can be identified within 13 types, grouped as follows (see Fig. 14):

I KIT OF PARTS
1: Post and Beam
2: Slab and Column
3: Panels
4: Integrated Joint

II FACTORY MADE 3-D MODULES
5: Sectional Module
6: Box

III HYBRID
7: Load Bearing Service Core
8: Megastructure
9: Mechanization

IV OPEN SUB-SYSTEMS
10: Envelope
11: Partitions
12: Equipment
13: Services

The amount of industrialization in each varies when implemented. Some were successful, while others were not depending on the context in which the system was implemented. The idea here is not studying the system within the context it was developed for, but rather the potentials of the chosen system elsewhere.

For example, in Africa, a few high level technology plants were established in the 60s, producing buildings of heavy load-bearing reinforced concrete components. They proved to be economically unfeasable, mainly because the local markets were inadequate for their production capacity, and the low level of

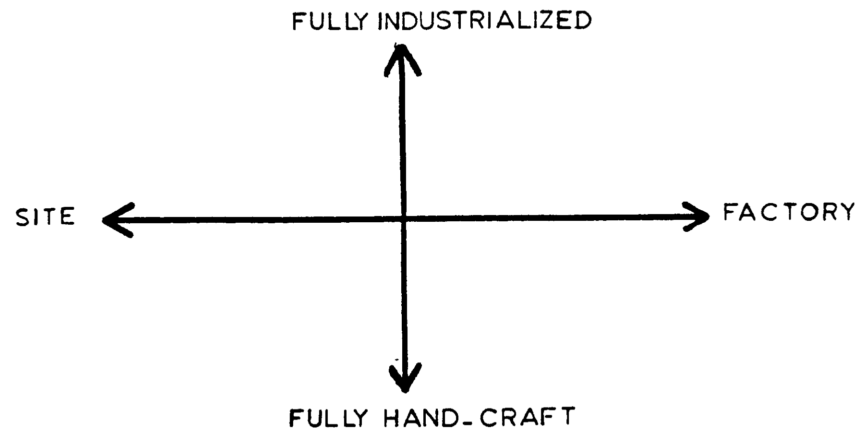


Figure 13: Reference Grid
Source: Richard, 1978

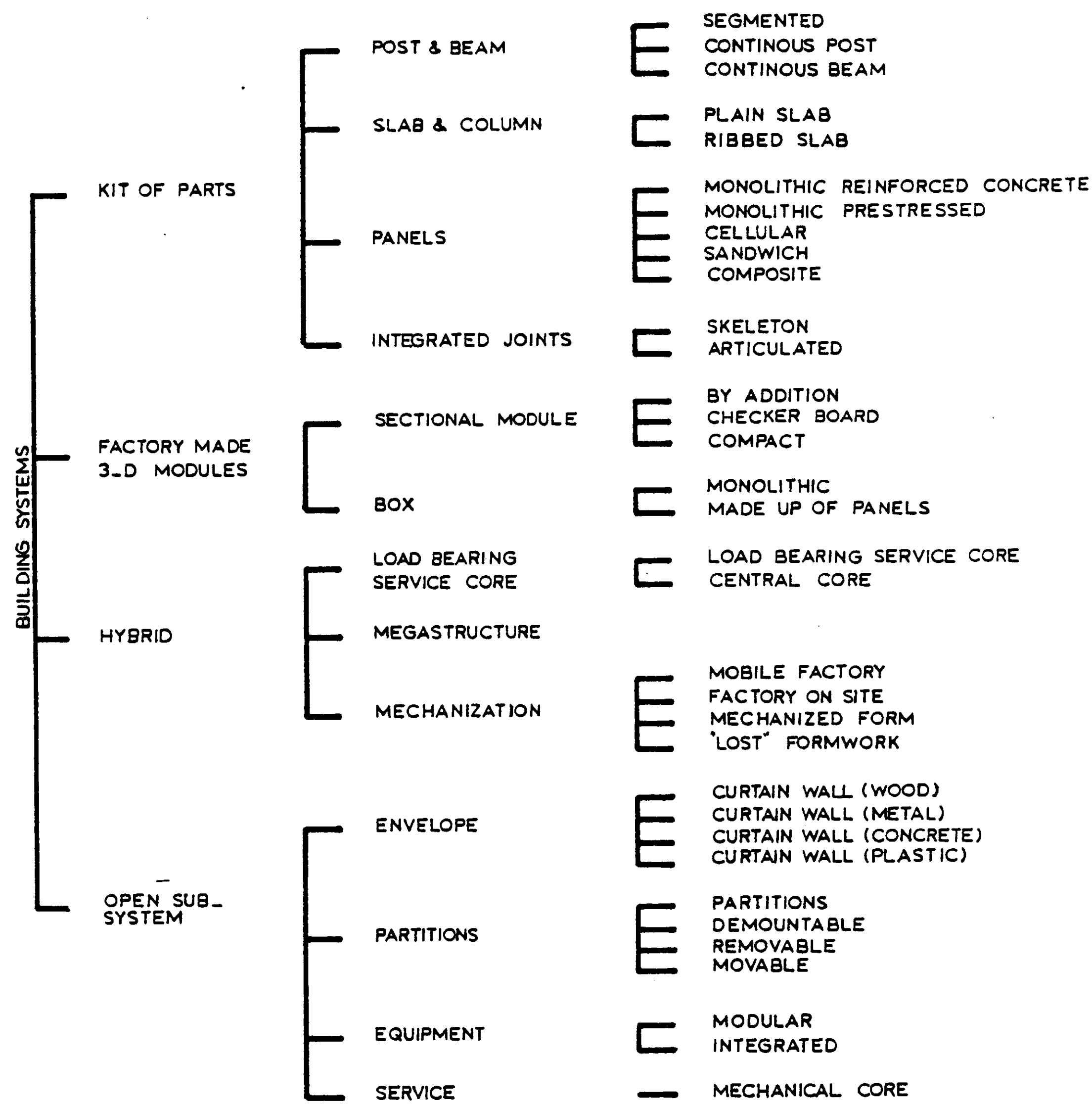


Figure 14: Building Systems Classification

productivity kept costs of the units higher than the reach of their average user.

With due consideration given to the socio-economic conditions, the technological level and the labor characteristics of a country, better results can be achieved as is the case in some areas of South-East Asia and the Pacific region where the use of light-weight precast elements for roofing and flooring proved to be economically competitive in some housing programs.

In 1970s, prefabrication was introduced to some West-Asian countries. It was not met with much success. The reason here was that innovations were completely induced from outside and had very little positive effect on the structure of construction activities and on the level of research in related fields.

And last but not least, countries in Latin America had various experiences in this area. Venezuela, being a special case, combined potential demand, supporting government policies and available capital, favored the introduction of prefabrication.

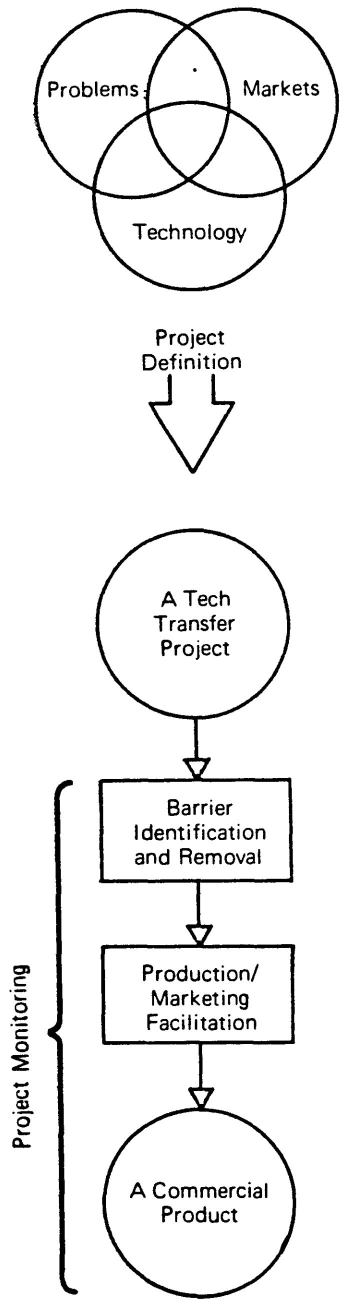
> "Technology transfer is the application of products or techniques developed for special purposes in one context to needs or opportunities perceived in another." (MacFadyen, 1972).

The process of technology transfer brings together (see Fig. 15):

1. A Problem
2. A Relevant Technology
3. A Marketing mechanism for implementing the technology to meet the need.

The lack of a systematic method for matching the need with available solutions is behind the inefficieny of technology transfer (MacFadyen, 1972).[1]

The basic goals of technology transfer are to reduce cost, improve quality and increase quantity by the utilization of existing technology.



Functional Activities.

Development to the stage at which a product or service can be offered successfully includes:

1. Market Feasibility Testing;
2. Technical Feasibility Investigation;
3. Engineering Specification Development;
4. Applications Engineering;
5. Field Testing and Demonstrations;
6. Commercial Offering.

The five areas of functional activity are:

1. Problem Definition;
2. Market Description and Market Planning;
3. Technology Search;
4. Planning a Project to Accomplish each Potential Transfer;
5. Monitoring Project Activity.

Figure 15: Functional Areas of Technology Transfer

Source: MacFadyen, 1972

One method of approaching this notion systematically is:

1. Identifying and specifying the problem.
2. Searching for and evaluating technology.
3. Estimating the scope and impact of solutions.
4. Implementing the most promising solution technologies.

The problem to be identified in this case may be:

1. Those that have commercially available solutions, but which are unfamiliar to the problem specifier.
2. Those that require an adaption of an existing technology.

This procedure was worked out by the Urban Development Applications Project (UDAP) to find applications for NASA's advanced technology in the urban sector (see Fig. 16).

3.2 IS INDUSTRILIZATION THE ANSWER TO BUILDING PROBLEMS?

3.2.1 Industrialization vs. Conventional Systems in the Construction Industry.

Industrialization has led to increase in production and consumption of most goods: automobiles, appliances, etc. Yet construction may be the only industry that did not demand expansion, even though the construction industry may be one of the largest industries in many countries (see Fig. 17).

Industrialization at the moment in many cases has not outperformed the traditional systems of building due to the special nature of building. In general, the conventional contractor offers better and cheaper products due to:

1. The use of local materials.
2. "Off-the-shelf" components.
3. Less dependent on imports.

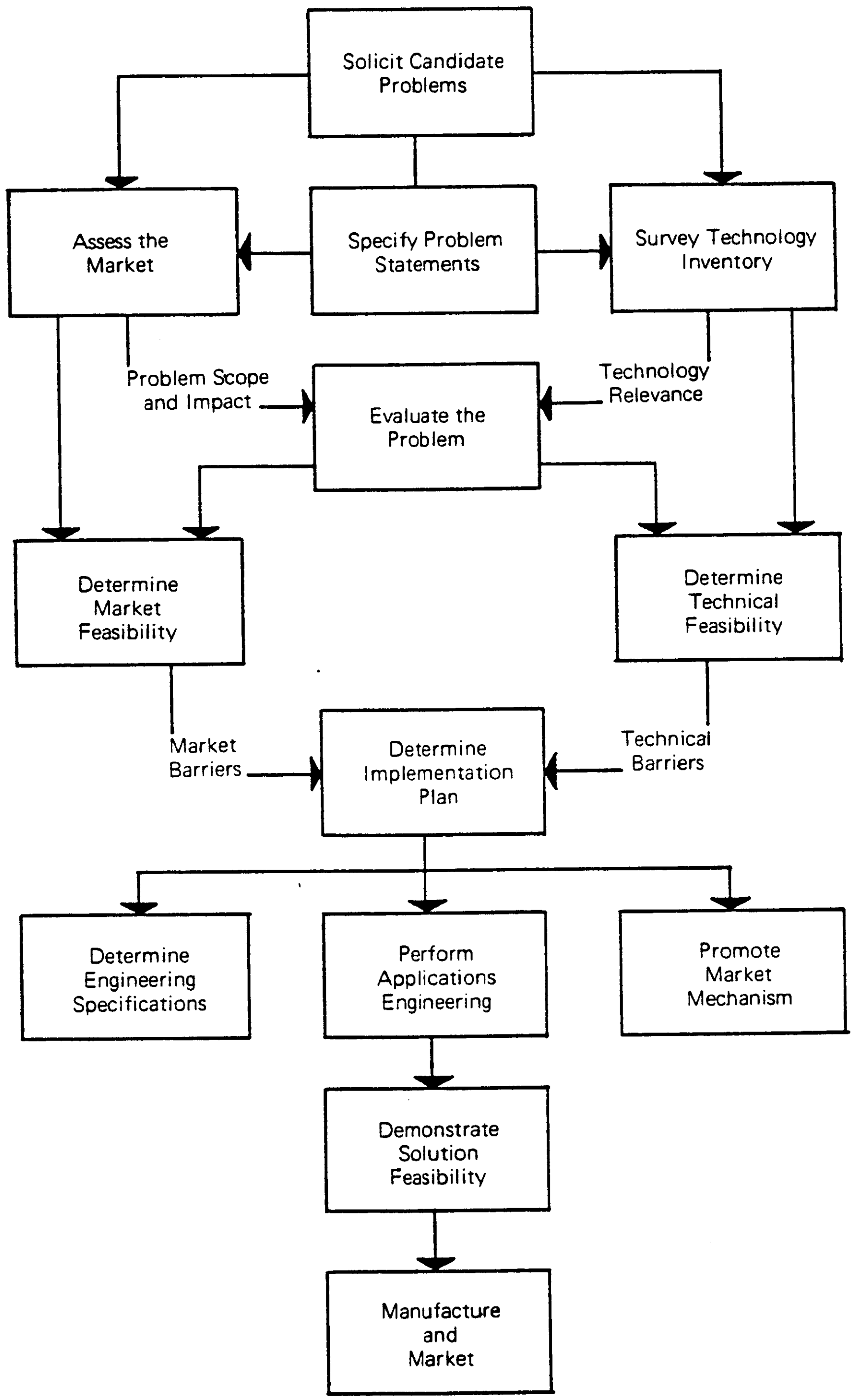


Figure 16: Discovering Solution Technologies

Source: MacFadyen, 1972

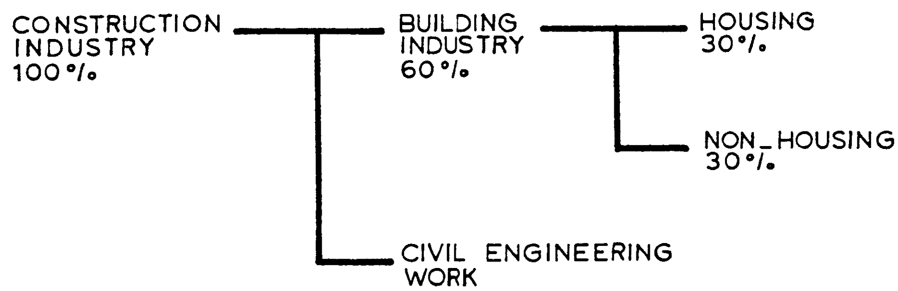


Figure 17: Breakdown of the Construction Industry

Source: Schmitz, 1981

4. Can integrate various brands and systems.

5. Can deliver custom-made products made of standard elements.

A successful attempt was made in production of standardized elements or sub-systems on the open market (concrete blocks, T-sections, windows, doors, etc.). These products proved to be a success for the following reasons:

1. Product sold in open market to everybody.
2. Inventory turns over more rapidly.
3. Sales outlets dispersed over larger territory.
4. Investment capitalized over long-term.
5. Financing dependent on conventional commercial transactions.
6. Production not solely dependent on large projects.
7. Product change easier to accomplish.
8. Technological breakthrough can be "tested" by selective marketing.
9. Relationship to other manufacturing branches closer.

This emphasizes that it is what we consider for industrialization that is important and the degree of industrialization for the situation in hand (see Fig. 18).

3.2.2 An Experience that Failed

Bringing industrialization to a society must be considered seriously if chosen as a means of improving the construction industry. A number of factors must be considered, they include: level of national/regional development, desired quality of life, official construction policies, cultural diversity of user groups, distribution on income levels in population, utilization of national/regional resources, availability of infrastructure, type of transportation systems, availability of financing capital, credit mechanisms, organizational pattern of the construction market, etc.

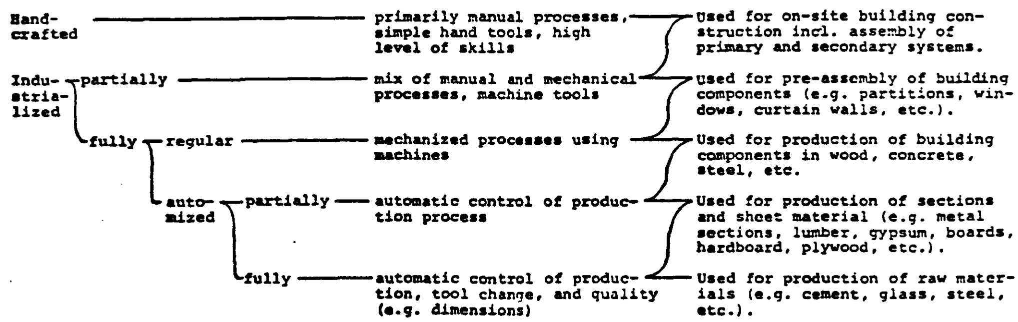


Figure 18: Steps in the Industrialization of Building

Source: Schmitz, 1981

Other aspects should also be considered, such as the social consequences of industrialization. Here, we must encourage the individuality of the users through their choice of building typology. Social benefits should be gained from industrialization such as the creation of jobs through the selection of not too high technology, or the introduction of a capital intensive rather labor intensive technology if employment is not the issue.

In a Latin American country, (a case study introduced by Terner, 1971),[2] a highly sophisticated system was imported from a European industrialized housing manufacturer.

Problems started from the beginning when the company tried to narrow the "down-time". A 14 months start-up delay occured due to bureaucratic snarls that lead to a 50% increase in both time and cost estimates. The foreign technical assistance were not able to establish good working relationships with the plant management and personnel.

A major issue for the success of any industrialized plant is a qualified management team. This was a serious negative issue in this case, as no local personnel were capable of managing the plant due to the lack of specialization in terms of the positions of general manager, plant manager, and sales/technical service manager.

New problems arose when breakdowns in the plant occured. Delays while waiting for critical spare parts were inevitable, and the owner allocated some of his working capital to invest in supporting machine and metal-workshop at the plant.

Being a "developing" country, the lack of essential public works greatly effected the smooth running of the plant. Among those were electricity and power failures, poor road conditions and the lack of telephone services between the office headquarters and the plant.

Labor was another issue. Low productivity, strikes, and high wages were among the labor problems facing the management.

As the nation's currency devalued, the company went bankrupt and had to seel its assets at a tremendous loss. As a private owner, the loss was minimized and did not include large amount of public funds (similar to government enterprises).

Selecting this example was on the hope that it states the point this tudy tries to establish. It is not the decision of whether industrialization is the answer or not to the building construction problems but rather the appropriateness of the selected solution to the context and problem confronting us.

3.2.3 The Promises of Building Industrilization

Upon deciding on accepting the concept of industrialization by a sector, a number of issues are expected. The decision would have been based on weighting the various factors involved, assessing the availability vs. lack of resources. The decision means that the choice made was feasible.

The first promise of industrialization is cost reduction. Unless there are national emergency situations, cost remains the most important factor to be considered when determining the feasibility of a building industry.

The cost reduction may be achieved through:

1. Savings in Interm Financing:

Early occupancy is achieved by increased construction speed. In the United States, a six-month's saving in construction time, for example, would mean a 6-9% overall project saving.

2. Savings in Labor and Management:

A conservative estimate of savings of on-site labor 15-50% in total man hours compared with traditional construction, 30-65% building time saved on-site, and 15-35% savings in cost of transportation and handling.

3. Savings in Materials:

Industrialized building promises savings in costs for construction materials. Integration of the various components reduces material waste during on-site construction where all parts are manufactured to fit in place.

4. Savings in Overhead and Profits:

It is the nature of mass production that reduces overhead and profit factors per unit of production. To maintain cost savings, it is essential to keep volume of production and sales high in order to realize the benefits of low overhead and profit factors per single unit.

The second promise of industrialization is improvements in quantity and quality.

In terms of quantity improvement, it is important to adopt "qualified" management of the plant in order to achieve steady production. In order to do so, a number of difficulties must be overcomed, some of which are (Schmitz, 1981):[3]

1. Excessive start-up time.
2. Bottlenecks in production due to down-time.
3. Transportation problems.
4. Sales problems.
5. Problems in the management structure itself.
6. Labor problems.
7. Monetary problems.

8. Experience of occasional bad luck.

The above problems, if remained unsolved will have a negative affect on the full production of the plant.

In general, machines as opposed to humans are less exposed to variability and error. Quality improvements and control in industrialization is also achieved through the repetitive character of specialized human work, where workers concentrate their efforts on a specific task that leads to their mastering it.

The picture of industrialization may not always be so bright as seen previously. If for any reason faulty products leak out into the market, any failure in its performance will have a negative effect on the plant's production. And because of its large-scale production, any fault or defect will be multiplied.

Nevertheless, quality improvement may be achieved if the industrialized building system is conceived well, technically developed thoroughly, and designed with user's benefits in mind. Moreover, proper standardization of components, strict adherance to performance requirements, fewer joints, simplification of assembly, flexibility in actual configuration of components will increase the quality of the building systems' end result and make it more compatible to traditional construction.

The observations mentioned are the optimum requirements of building industrialization. The success of the process is measured by the degree of which these may be achieved. This again depends on how close the selected solution is to the existing problem. An accurate solution should be extracted from an in-depth study of the various factors both participating and effecting the building industry, of which the following sections will deal with.

3.3 FACTORS AFFECTING THE EMERGING OF BUILDING INDUSTRY

3.3.1 Local Market (Demand Vs. Supply)

When considering the introduction of innovation to the market, we must test the product for safety and effectiveness, and search for a market large enough to facilitate mass production that leads to lower prices.

It is essential to study the market's condition to make a rational decision on its expected acceptance of the new product. This study should include the following (MacFadyen, 1972):[4]

1. Market demand (total no. of units):

This is a crucial and difficult aspect to consider, especially when no directly comparable products are available in the market which brings us back to the need of new products.

2. Value of each unit:

The value of the product to the consumer and its effectiveness of filling his needs are behind establishing its selling price.

3. Competitive Products:

This includes the study of all products that are produced using similar technology, regardless of the market they currently serve.

Demand and supply are two basic factors that effect the market's mechanism, in which "Demand" refers to the quantity of a commodity that an individual is willing to purchase over a specific time period, while "Supply" refers to the quantity of a commodity that a single producer is willing to sell over a specific time period. (Salvatore, 1974).[5] These in affect are related to the price of the commodity. The price system is one of the major aspects that result in shortage and surplus of a commodity in the market (see Fig. 19).

"Shortage" is referred to a situation in which some nonmarket agency, such as government, fixes the price below the equilibrium price. "Surplus" refers to

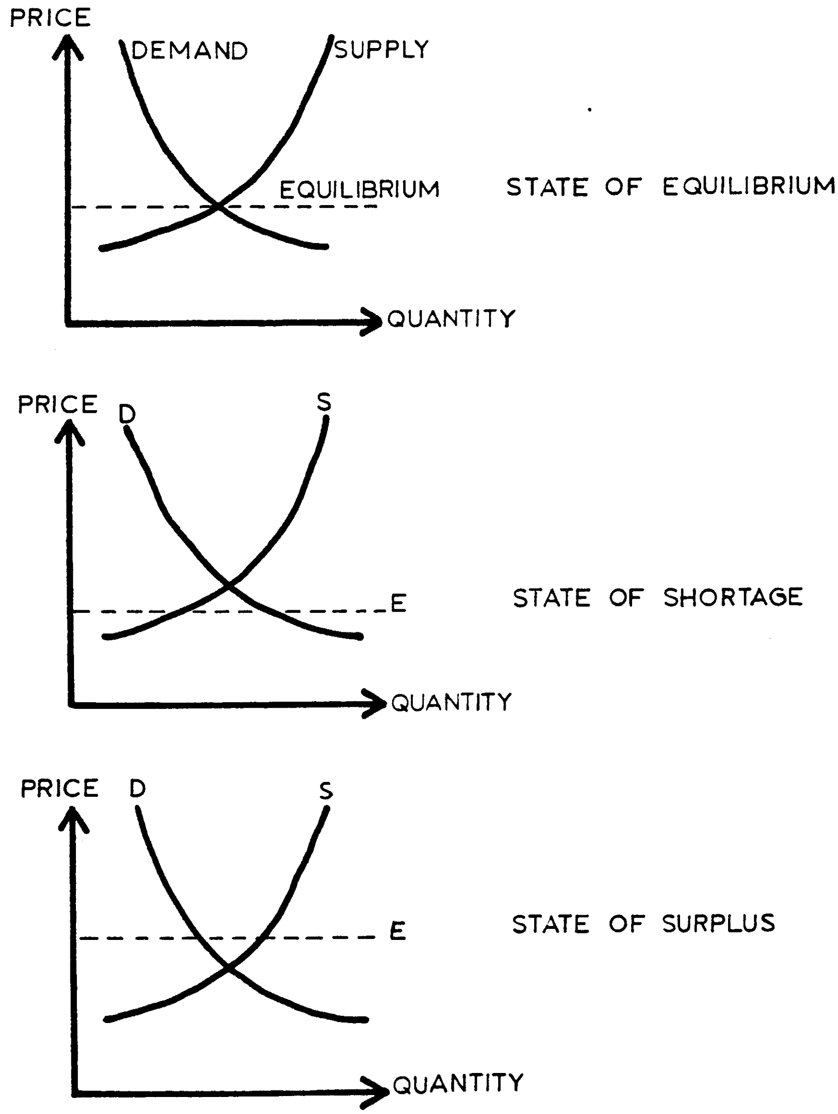


Figure 19: Demand and Supply in the Market

Source: Heilbrouer and Thurow, 1978

the opposite situation where the price is fixed above the equilibrium level.

In more realistic terms, the housing shortage for low-income groups, for example, is due to this group not affording the available housing stock in the market rather than the everyday meaning that low-income groups cannot find enough housing.

A closer look at Fig. 20 shows the relationship between consumers and products, in which it varies in a great extent between closed and open systems. Closed systems are seeking for a market while open systems are seeking for a product.

3.3.2 Resources

3.3.2.1 Land

As a resource, land cannot be utilized until it has emerged from its raw state by having something done to it.

One of the main issues to be considered when choosing a land to establish an industry on, is its location to the market place and other resouces. It should be accessible where roads, other transporation and service facilities are provided. Location may be the overriding factor in land price.

Electricity, water, and telephone lines on the site are essential for the smooth running of the plant. The provision of these facilities are essential to run a smooth operation.

Transportation to and from the site is of great importance. A smooth flow of materials into the plant is crucial to prevent breakdowns in the production line, and even more important is the transportation of the products to the market without delay or damage.

Land may be considered as an investment with a long-run return, for unless it is placed outside the market mechanism, it is difficult to see how a

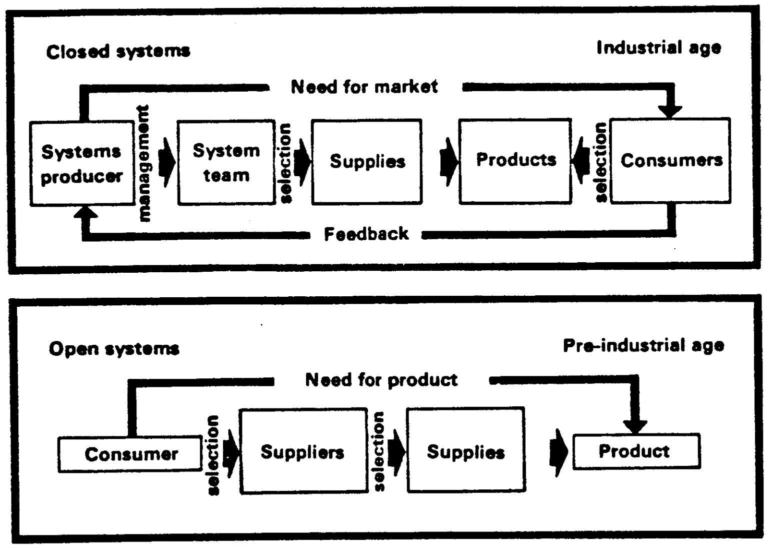


Figure 20: Closed and Open Systems: The Relationship Between Consumers and Products

Source: Dietz and Cutler, 1971

reduction in price can occur under the pressure of growth and development.

3.3.2.2 Labor

Labor is a critical consideration that must be studied carefully. It is divided into unskilled, semi-skilled, and skilled labor, of whom they may be union and non-union members.

The French industrialized system reduces labor by up to 75%. In 1965, Soviet economists estimated the savings in labor due to prefabricated residential building method as much as 23 million man-days (Terner and Turner, 1972).[6]

Labor-saving industrialized techniques is the solution when there is a labor shortage or labor is expensive. In developing areas, with the availability of cheap labor, a less sophisticated industry is more appropriate.

For example, in the United States, construction wages exceed manufacturing wages, and the later the more productive. This is a combination that suggests a successful industrialized construction practice (see Fig. 21).

High wages in construction industry are due to a number of reasons. The main reason is the great uncertainty of employment compared to other industries. In general, the construction activity is higher in the summer than winter. Another reason is the high skills required in construction. The building trades require a considerable period of training. Moreover, high wage rates in construcion is due to the higher risk in work injuries. And last but not least, is the fewer fringe benefits the construction industry has compared with other industries. Therefore, the high hourly rates to some extent compensate for the lack of such benefits.

It is important to study the trade-offs between capital equipment and machinery for labor. Construction has the highest unskilled labor compared to other industries. The use of machinery brings the need of skilled labor, the

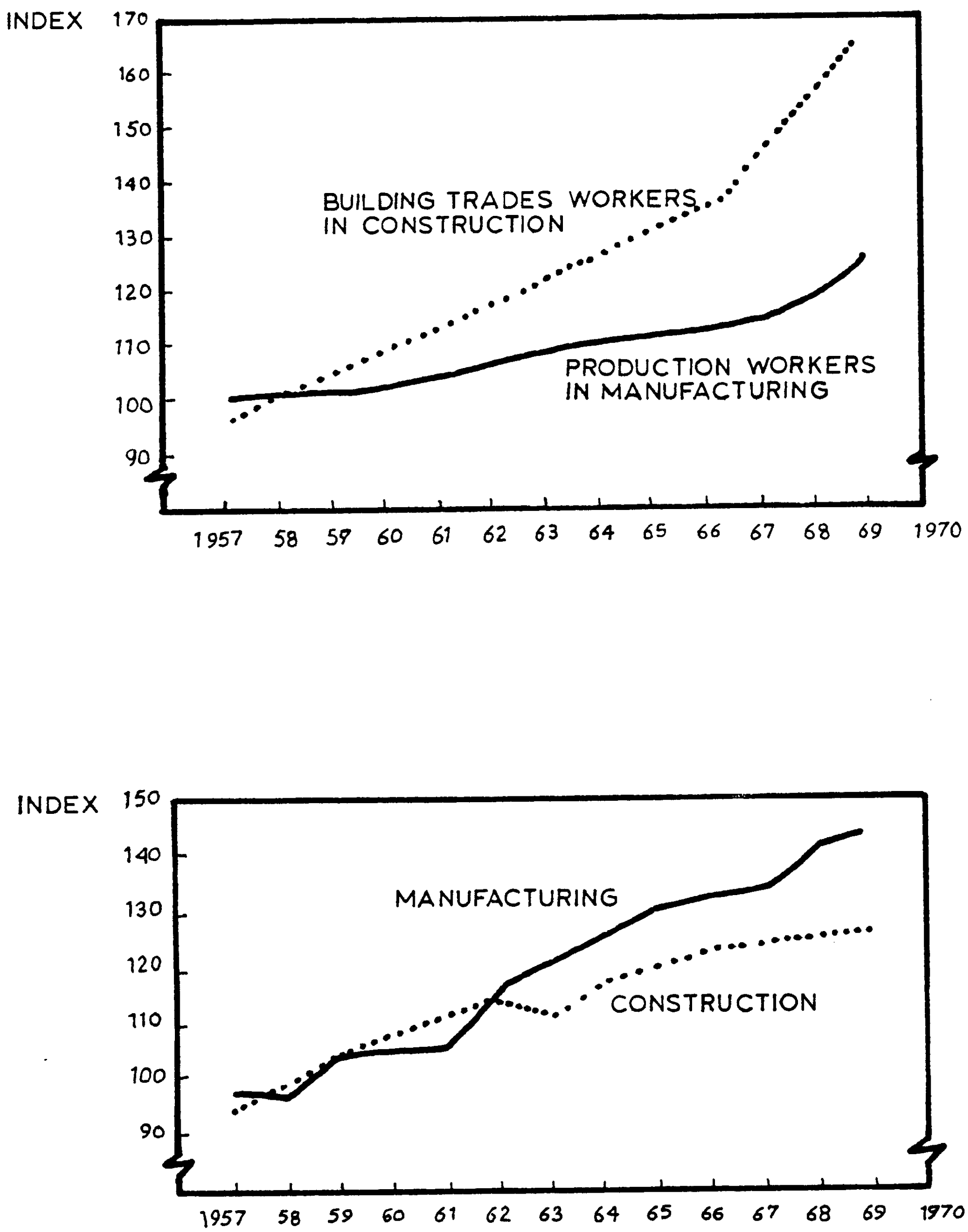


Figure 21: Manufacturing and Construction Wage Differential and Productivity in the U.S.

Source: Terner and Turner, 1972

higher the technology, the more skilled is the labor required (see Fig. 22).

Finally, we are weighting industry-building vs. labor-saving. This does not include technology that helps develop the industry and cuts cost without laying out labor (a man with a tractor vs. a man with a shovel).

How has the introduction of machines influence the supply of labor? In general, it was introduced to increase productivity of labor. Yet, the increased output in some areas of the industry was not absorbed and not all workers were able to keep their jobs, this led to a shift in labor from one sector to another (see Fig. 23).

Here, it is evident the impact of technology in the distribution of employment. In the secondary sector, even though demand has increased. Yet technology improvements entered the sector, increasing the productivity of labor in this area, thus smaller portions of the labor force can satisfy the larger protions of demand for this sector.

3.3.2.3 Raw Materials

One of the important factors that should be studied carefully is the availability of raw materials to be provided for the plant. Local materials, if available, are easier to handle in terms of procurement and transportation. Imported materials on the other hand are more difficult to obtain, there are extra charges for importing, storing and handling them, yet that does not rule out it being cheaper in some cases than the locally produced materials.

In general, aside from the actual cost of the material itself, the total cost includes the following:

1. Warehousing: Storage at the plant, at the site, and at intermediate points, all require shelter of some sort.

2. Handling: Loading and unloading of materials as it is being conveyed from one local to another. This includes both labor and equipment costs, the more

TYPE OF MACHINE	NO. OF LABORERS REPLACED
EXCAVATORS, 0.15-3m^3	20-160
MOTOR-SCRAPERS, FROM 6 m^3	50-120
DOZERS, FROM 80 kg.	70-90
MOTOR-GRADERS, 50-120 kg.	30-50
MACHINES FOR EARTH COMPACTION, 4-25 tons	20-50
BUILDING CRANES, 30-80 metric tons	30-40
DUMP-CARS, 3-5 m^3	20-30
MOTOR-CRANES, 5 tons	10-20
MIXERS, 250-750 tons	5-20
CONVEYORS, 4-15 m	3-5

Figure 22: Replacement of Human Labor by Machines

Source: Terner and Turner, 1972

DOMESTIC DEMAND FOR OUTPUT

	DISTRIBUTION OF DEMAND	
	1899-1908	1976
PRIMARY SECTOR (AGRICULTURE).	16.7	3.2
SECONDARY SECTOR (MINING, CONSTRUCTION, MFG.)	26.0	32.3
TERTIARY SECTOR (TRANSPORTATION, COMMUNICATION, GOVT., OTHER SERVICES)	57.2	64.5

DISTRIBUTION OF EMPLOYMENT

	DISTRIBUTION OF ALL EMPLOYED WORKERS (%)	
	1900	1976
PRIMARY SECTOR	38.1	3.8
SECONDARY SECTOR	37.7	29.7
TERTIARY SECTOR	24.2	66.5

Figure 23: Distribution of Output and Labor in the U.S.

Source: Heilbroner and Thurow, 1978

breaks there are in transportation and moving the higher is the cost of handling.

3. Transportation: From source of material, local distributors and import storages to the plant.

4. Partial Fabrication: Some materials may be treated or fabricated (such as reinforced steel, window and door frames, etc.) in other locations before delivering it to the plant.

In general, raw material should be accessible to the plant throughout its production period to prevent slow-downs or stops in production despite other factors.

3.3.2.4 Equipment

The sophistication of the plant in general and the machinery used in particular depend on the level of technology implemented within, whether low, medium, or high tech.

Upon deciding on the level of technology to be adapted (taking into consideration levels of management and labor available, type of product and market demand), appropriate machinery will be installed whether bought locally or imported.

The emphasis here is on imported equipment that is usually expensive, draining foreign exchange, requiring royalty payments (based on volume of production) or buying patent licenses (Dluhosch, 1983).[7]

Moreover, sophisticated equipment requires expensive experts' advice, training of labor and special management.

All machinery demand maintenance regardless of its level of complexity. Once workers are trained, the issue of regular (weekly or monthly) maintenance seems not to be the problem. Yet it becomes a dilemma when major repairs are necessary. Expensive expertise is needed, spare parts may have to be imported (if an excessive stock is not kept) or a secondary industry to support the plant would have to be established.

Without proper care of the machinery, "breakdowns" are liable to cause delays in the process of production leading to great losses in both time and capital.

3.3.3 Organization

3.3.3.1 Capital

3.3.3.1.1 Short-Run Costs

Initial heavy investment in plant and equipment is required when thinking of establishing an industry, on the hope of a gradual amortization leading to "long-run" savings.

Capital, as a factor of production includes producer's capital goods that takes two forms (Handler, 1970):[8]

1. Fixed Capital

This comprises plant and equipment, those that enter indirectly into the final products through the services they provide over their useful lives.

The plant used for production may have a useful life of 50 years or more, while equipment may last no longer than 15 years or so. This capital cost is allocated as a cost to each year's product and each unit produced.

The industries which have increased efficiency and reduced costs most markedly are those which have made the greatest use of fixed capital. In the construction industry, the use of fixed capital is exceptionally low compared with that of other industries. In other words, the construction industry does not utilize its capital when measuring the extent of use of plant and equipment in relation to output.

2. Circulation Capital:

This comprises inventories or stocks of raw materials, goods in process, and products awaiting sale. The function of circulation capital is to maintain a continuous flow of materials and products through the productive and distributive process. Therefore, it is an aspect of flow of goods to users.

3.3.3.1.2 Long-Run Costs

While the short-run costs deal with the initial cost of facilities, their construction and installation, the long-run cost deals with their lifetime cost. Therefore, it consists of capital costs, financing costs, maintenance, operation, and replacement of components. Consequently, the better the quality and higher the initial cost, the less is the cost of maintenance, operating costs and thus extend the life of the facility.

Interest is one of the cost problems that effects the long-run funds invested in the facility. If the funds are borrowed, interest changes are incurred; if funds are in the possession of the investor, then interest is foregone on funds which could have been invested elsewhere. Therefore, the investor in a facility must not only include interest as part of his long-run costs; he must also receive an adequate return on his investment in that facility, i.e. interest on invested capital. (Handler, 1970).[9]

In general, long- and short-run cost may have to be balanced against the availability of funds and revenue possibilities.

3.3.3.2 Management

"The function of management is to bring together the various factors of production in order to create a product. This is achieved by combining the factors in some manner through some sort of process." (Handler, 1970).[10]

With the increase in labor skills and specialization, it becomes important to provide relatively high-priced management and coordinating skills. Tasks and labor distribution along the production lines must be balanced and well-orchestrated, in a sense that lengthy operations are lightly man-loaded.

"To be successful, management must establish and maintain a smooth production rythm, despite the inevitable contingencies and disruptions." (Terner and Turner, 1972.[11]

It is of great importance to understand that new production processes bring along new methods and techniques that in fact require new management concepts. These concepts include engineering, production, sales and distribution. (Dluhosch, 1983).[12]

A successful industrial system is that system which is both well-managed and organized. Its management helps reduce cost not by the use of low-cost materials, but rather by achieving efficiency and speed. The later requires careful coordination and control that can only be dealt with through qualified management.

3.4 AN OVERVIEW

When building industrialization was first adopted in Europe after World War II, there was a desperate need for hundreds of thousands of new units in war-destroyed cities, the important factors for this solution of the problem were shortage of man power and large quantities of units in the shortest possible time. Cost was not the issue. The same situation was obvious in the U.S.S.R. Therefore, the decision was made to industrialize all building operations.

It is important to make the distinction between technology process and product. They are interrelated but can, for a given product, occur on different levels of complexity and expense.

In the following (Fig. 24), manufacturing technology (on the vertical axis) is divided into 3 production categories: handcrafted, partially industrialized, and fully industrialized. Product technology (on the horizontal axis) is also divided into 3 categories: traditional, intermediate, and high technology. The center cell represents a balance between the process and product that is mostly needed in developing areas.

Four variables characterize the process of industrialization, namely: standardization, labor specialization, concentration, and mechanization. (Terner and Turner, 1972).[13] In relating risk levels of these variable to the degree of economic development, investment in mechanization is greater at all levels (see Fig. 25).

In general, industrialization of the construction process aims to achieve a number of expectations that may be summerized as follows (Terner and Turner, 1972):[14]

1. Speed of Construction: A 25-50% reduction in construction time may be expected, which leads to quicker turnover of capital employed and savings from capitalization of interest if the project was financed by a load.

2. Cost Reduction: A 10-25% reduction in cost in the long-run can be achieved due to savings in building materials and skilled labor. This saving results from the repetitive process and building site, and the gradual amortization of the initial heavy investment in factory, plant and equipment.

3. Quality Control: the quality of output from the plant is unified due to close supervision of the manufacturing process. This is mainly because of the consistency of the machine's accuracy that defeats hand-made products. The products will contribute to the soundness of the structure and building which in turn reduces maintenance cost in the future.

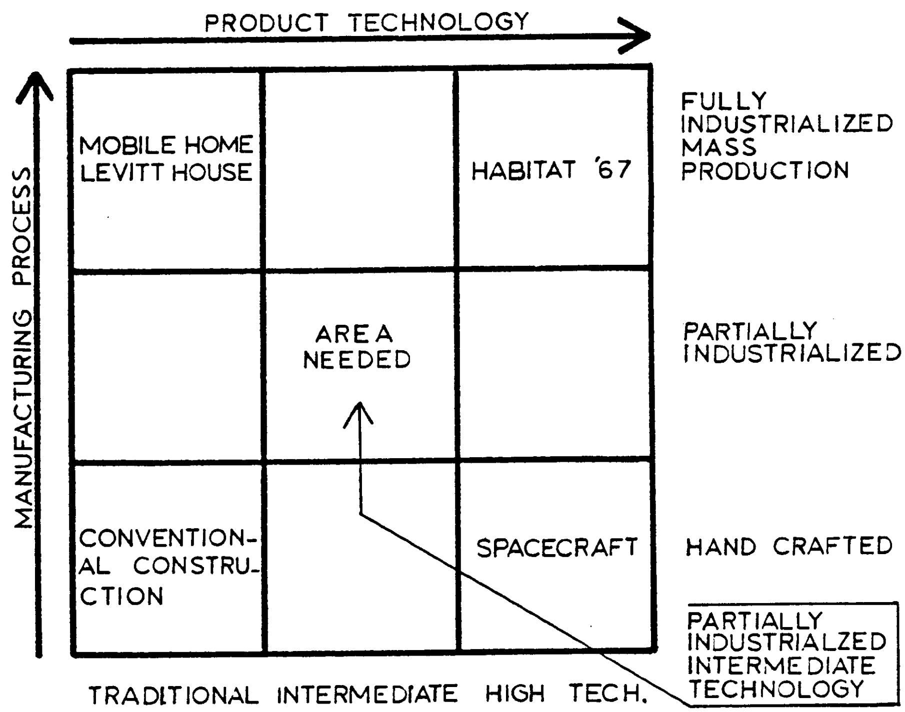


Figure 24: Industrialization of Process Compared to Product Technology

Source: Terner and Turner, 1972

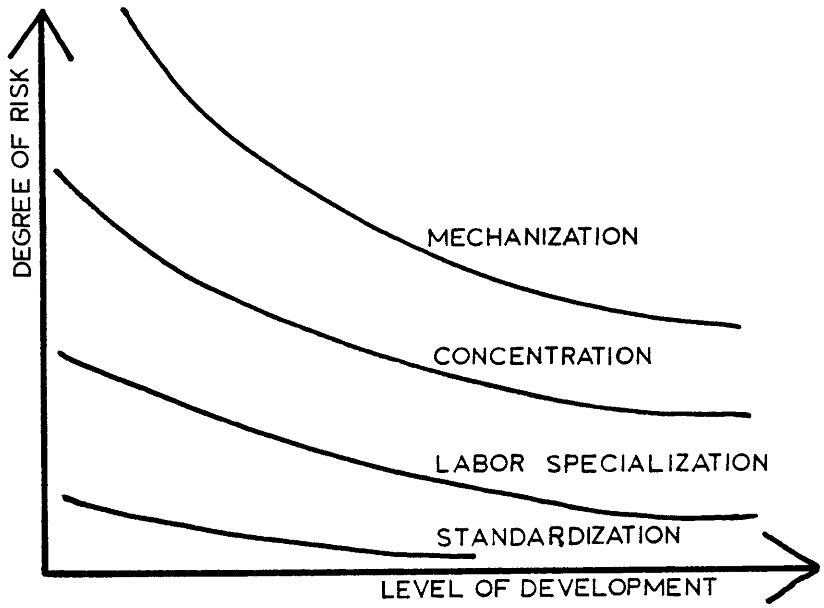


Figure 25: The Relationship Between Risk and Economic Development for the Four Elements of Industrialization

Source: Terner and Turner, 1972

4. Organization and Supervision: A smoother operation and higher supervision is evident. Less risk of accidents is expected in the plant than on site, and weather conditions will not interrupt with the production process. Moreover, sites will have less workers so on-site supervision will be easier and more effective.

It is concluded from the previous review that industrializatoin is an important step to adopt especially in the construction process. Its effectiveness, benefits and drawbacks depend more or less on the appropriateness of the level of technology implemented and type of product produced within a given context, taking into consideration the various factors discussed previously .

There are a number of situations in which building industrialization failed, yet it is not inevitable that these instances may turn into a success once dealing with their weak points.

In order to reduce possible failures it becomes important to identify the major objectives that we are hoping to achieve with initiating a building industry.

The main factors that directly contribute to the building of an industry were discussed in this chapter such as labor, finance, level of technology, etc.

In section 3.2.2, an experience that failed was reviewed, it was evident that even though the owners of the plant had high hopes for the chosen system to succeed in their country, they were faced with many unforeseen problems. Some of these problems were overcomed, while others were impossible to solve due to the nature of the environment.

For a similar situation, a systematic approach is recommended to state the main objectives of the project. A group evaluation seems an appropriate choice at this point, selecting individuals to provide leadership, expertise on responsiveness, policy guidance, overviews based on knowledge of other industrialized building systems projects). This process will help provide a wide range of parameters to consider thus giving a fair representation of the project's most critical factors and furthermore reduces the possibility of disregarding major parameters. Weighting the groups' findings against the alternative solutions available, will evidently reduce the risk of failure.

Chapter 3

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CHAPTER FOUR

TOWARDS A RATIONAL SELECTION OF BUILDING SYSTEMS TYPOLOGY

4.1 THE NEED FOR USER AND PERFORMANCE REQUIREMENTS

Once a level of industrialization is established, it becomes necessary to select the appropriate system to produce. Various technical systems may be well developed from the technical point of view, yet it does not necessarily fulfill the user's needs. Therefore, it becomes important to acknowledge the relation between the user's needs and the more technical requirements for the subsystems of a building. Here we are referring to user and performance requirements.

It is crucial to adopt a rational approach to the translation of user requirements to requirements of building parts, therefore, searching for an answer to the questions: How to identify and formulate user requirements for a buiulding in a systematic way, and how to formulate the performance requirements for a building and its parts?

With the continuous change in user's functional requirements, and in order to maintain the average functional life of buildings, it is essential to construct flexible spaces that can be adapted to the frequent changes in use.

Discussed in the previous chapter was the importance of economics in industry, and in order to maintain its position in the market it should delay reaching its technological and social obsolescence.

Technological or physical obsolescence, as referred to by Brandle (1976), is concerned with the decay of a material or component whose performance and durability can not be easily predetermined. On a wider range, this term also refers to the degree of interdependence among the subsystem of a building system.

Social or functional obsolescence, as viewed by Rabaneck, Sheppard and Town (B.S.D. 1974) is a situation created by social, political and economic change in which "an object is no longer valued as most appropriate for its particular function." This kind of obsolescence becomes more difficult to predict with the increasing rate of technological innovations.

Because of its sensitivity and direct effect on the industry's future, the need for flexibility, variability and adaptability was chosen to be discussed in further detail.

4.2 IDENTIFICATION OF USER REQUIREMENTS

4.2.1 User's Activities as a Basis of Identification of User Requirements

In order to make the concept of user requirements operational (both in theory and practice), these requirements have to be identified in a uniform and operational way. To be able to do so, a basic unit of analysis is needed which is applicable both when identifying the problem and when verifying the solution.

In a study conducted by Cronberg (1975),[1] a criteria was constructed on the basis stated below:

1. The unit should be relevant to the problem area.
2. The unit should be applicable for the systematic identification of all user requirements (within the problem area).
3. The unit should be oriented to the individual but also indicate variables of the physical environment.
4. One should be able to isolate the unit and it should be empirically accessible.
5. The unit should allow for the verification of the final solution.

User activities, as a choice for a basic unit for the identificaton and formulation of user requirements for buildings, was based on the following factors:

- Activities constitute a link between the user and his physical environment.
- Information on activities can be collected.
- Activities were considered as a relevant starting point to define user requirements of buildings.

> "Activity is what the user does or should be able to do in the dwelling." (Nilson et al., 1971).
>
> "Activity is a goal-oriented process of both the actor and his environment." (Dalgrenet et al., 1973).

A more expanded concept of the notion "activity" is stated by the definition in Webster's New Collegiate Dictionary (1967):

> Activity is 1) the quality or state of being active; 2) natural or normal functions as: a. a process that an organism carries on or participates in by virtue of being alive, b. any similar process actually or potentially involving a mental function.

The later definition includes the traditional goal-oriented activities which can be observed in addition to process-related activities of the user (physiological and mental). (See Fig. 26).

The selection of activities to be analysed must in each case be determined by the problem area in question.

The dimension of activity analysis must include the following questions:

- Which activities are going on?
- Who performs the activity?
- What is needed to perform the activity?
- Where is the activity performed?
- When, for how long, and how often is the activity performed?
- What movements are necessary for the activity?
- What is the objective of the activity?
- What side-effects may result from the activity?

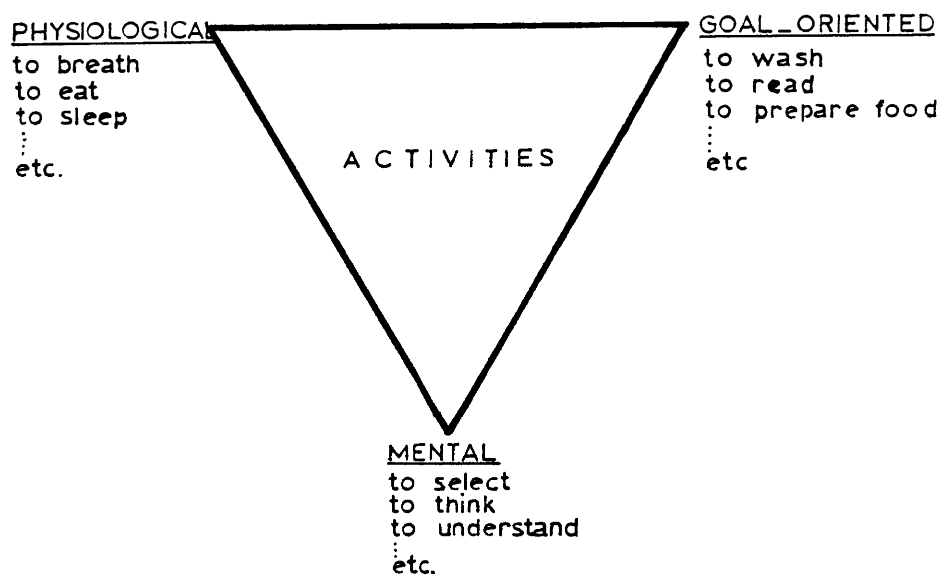

Figure 26: Examples of Different Kinds of Activities

- What does the user think of the activity?

Several methods are available for data collection on user activities, a number of which are:

1. Surveys: Face to face interviews, telephone interviews and mailed questionnaires can be used for data gathering on a chosen activity.

2. Observations: Provided that the activity may be observed and recorded, this method is usually combined with surveys, and can be used to select critical activities once the problem is identified.

3. Methods to measure physiological processes and responses: Only in a few cases have these methods been used for identifying user requirements for buildings. Examples of these include studies with the objective of relating the user's subjective evaluation to a physiological response or climatological studies on the impact of climate on the performance of an individual.

4. Measurement of mental processes and responses: This method studies the perception of the environment by the user. The majority of these measure the user's subjective judgement without including variables of the physical environment (e.g. semantic scales).

The selection of a method for collecting data on user activities will depend, on the type of activity being studied and on the kind of contact which can be established with the user and the resources available for the study.

To what extent are data on user activities already available? (Conberg, 1975).[2]

In the non-project-oriented planning process (codes, standards, etc.), detailed data on the users and their characteristics are limited, while general data are available to a certain extent. The most important sources of information to identify important critical activities are statistics. From these data are derived directly or indirectly, and can be complemented by a review of available literature and research studies, feedback from buildings in use, etc.

Within the project-oriented planning process there are more opportunities for contact with the user. In some cases the user is known personally; therefore, interviews are employed, in others his characteristics are known so data on similar user groups may be used to study user activities. No systematic data collection on user activities is generally carried out in this phase of the planning process.

In general, there exists methods of data gathering on user activities that could be systematically used to collect the data. Problems are evident in both gathering and data processing. The extent of these problems vary depending on the resources available, the data gathering method employed, the activity being studied and the type of contact which can be established with the end user.

4.2.2 Formulating User Requirements

Three dimensions have been derived from the activity model in (Fig. 27) by Cronberg as the basis for formulating user requirements for building. They are:

1. Which activities are performed by the user (or which activities should he be able to perform)?
2. Who performs the activity (who is the user)?
3. Which of the consequences caused by the characteristics of the building when performing the activity, are important or critical to the user?

A user requirement is defined by the answers to the three questions above:

1. User activities.
2. User characteristic(s).
3. Consequence(s) for the user.

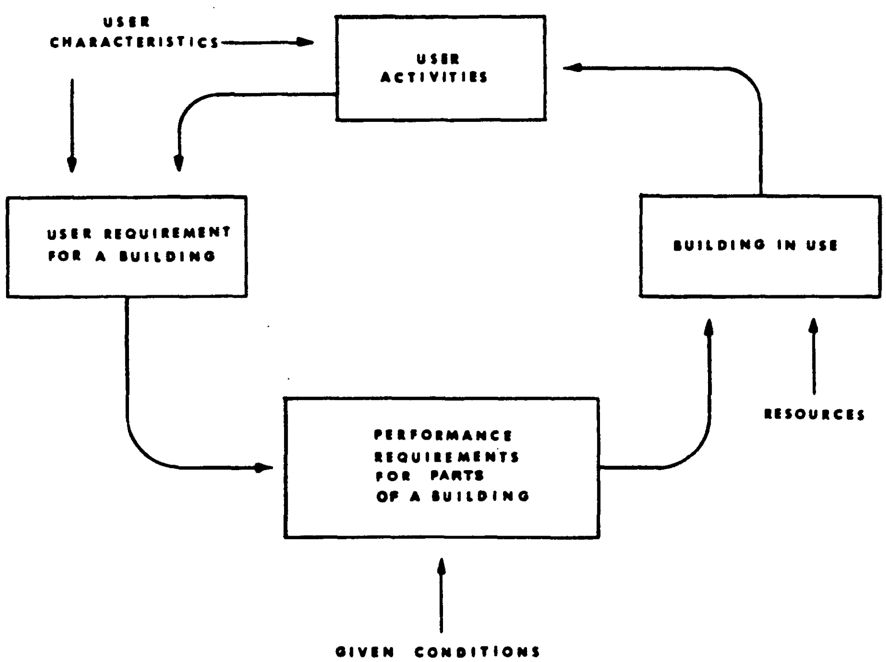

Figure 27: User Activities as a Basis for the Design of a Building

Source: Cronberg, 1975

Integrated into a statement they explicitly formulate the user requirements.

What becomes interesting is the transformation of user requirements into parts of a building. For each problem a different set of activities will be identified in various degrees of detail. It is possible to set up a list of subsystems for a specific problem or problem area (e.g. a list of subsystems for accessibility in buildings). The characteristics of a subsystem can be related to several subsystems. (A window, for example, possesses a number of properties, therefore may belong to the subsystems: to light, ventilate, to see, etc.).

A technical solution is then the next step to determine. Here, physical units are proposed in which they combine certain characteristics of one or more of the subsystems mentioned.

Finally, once technical solutions are listed, it can then be subdivided into smaller units.

This next level includes:

- Material(s): this refers to the substance of which the technical solution is made of and the properties of this substance.
- Form: or the combination of the materials above and the work necessary for the production of a technical solution.

Once user requirements for a building are identified and formulated, and a description system for the transformation of these requirements to requirements for parts of the building has been proposed, the next step would be identifying and formulating requirements for subsystems, technical solutions and materials previously extracted from user activities. This leads to the introduction of performance requirements.

Yet, the author would like to pause a moment and study what is considered an important user requirement in more detail, hereby referring to the flexibility and adaptability of the technical solution.

4.2.3 Flexibility (Variability vs. Adaptability)

4.2.3.1 Definitions

> "Variability achieved through varied combinations of repetitive parts is a strategy characteristic of industries in which the performance requirements of the product are diverse and a variety of models must be provided for marketing reasons." (Oxman, 1977).

It is essential to plan for change in a system to maintain its "suitability" under various conditions. The need for flexibility is a major factor in building industrialization where it aims for economic rationale through providing maximum variety and application of its components.

According to Dluhosch (1974), flexibility may be defined as the ability to achieve a change of conditions, without changing the basic system as such.

In a similar manner, Oxman (1977) refers to flexibility as the ability to adjust to change, thus the term "flexibililty" describes two attributes:

- The inherent ability to modify shape or organization while maintaining stability in other qualities, and
- The ability to adjust to change.

These attributes are frequently defined separately by other basic terms:

- Variability: "Apt to change or vary; to make different from one another." (This is the intrinsic ability to make different or vary while otherwise maintaining stability).
- Adaptability: "To make suitable by changing; to adjust to new circumstances." (this emphasizes the maintenance of stability through the exercising of an inherent ability to adjust to changes in external conditions).

Thus referring to the definitions of the term "system" in Chapter 1, variability in a system would be the ability to make different by a varied interaction of the parts, and adaptability in a system would be the ability to modify the interaction of parts in such a way that stability is maintained in the face of changing conditions. These notions contribute to the phenomenon known as flexibility in systems which determine its limits or constraints.

Flexibility is achieved through its own specific set of operational rules, and within its defined limits. That is each aspect considered for change must be linked to its own properties through a set of manipulating rules within the overall hierarchy of decision-making and of direct manipulation (see Fig. 28).

Therefore, components on the market place differ in their degree of flexibility and mode of manipulation.

4.2.3.2 Scope of Application

Considering dwelling types as an example, there are two basic classes of need which are linked to the concept of flexibililty (Dluhosch, 1974):[3]

1. Changing needs: This includes family cycle, social mobility, location mobility, change in world view, and change in dwelling culture.

2. Differing needs: Refers to differing dwelling types, consumption and production influences, income distribution and societal allocation policies.

Changing needs is largely dependent on time and therefore one must consider short- and long-term flexibility.

While differing needs are mainly dependent on space, so alternative approaches must be considered to obtain variability (see Fig. 29).

Planning for change may be achieved through two levels (Pietroforte, 1984):[4]

1. Technical requirements: In this case we begin with technical requirements in order to achieve flexibility, and is based on principles of construction and

Type of Object	Mode of Manipulation
Small use objects, including hand tools, gadgets and implements	Easily manipulated by hand by a single person (note difference levels by age and health)
Non-attached medium size objects, furniture, tools, implements, etc.	Capable of manipulation by exertion of a whole body
Semi-attached and detachable objects, components, or sub-assemblies, including partitions	Require two or more persons to move or manipulate, or minor mechanical aid
Units, assemblies, etc.	Capable of manipulation by mechanical means only

Figure 28: Hierarchy of Flexibility/Variability

Source: Dluhosch, 1974

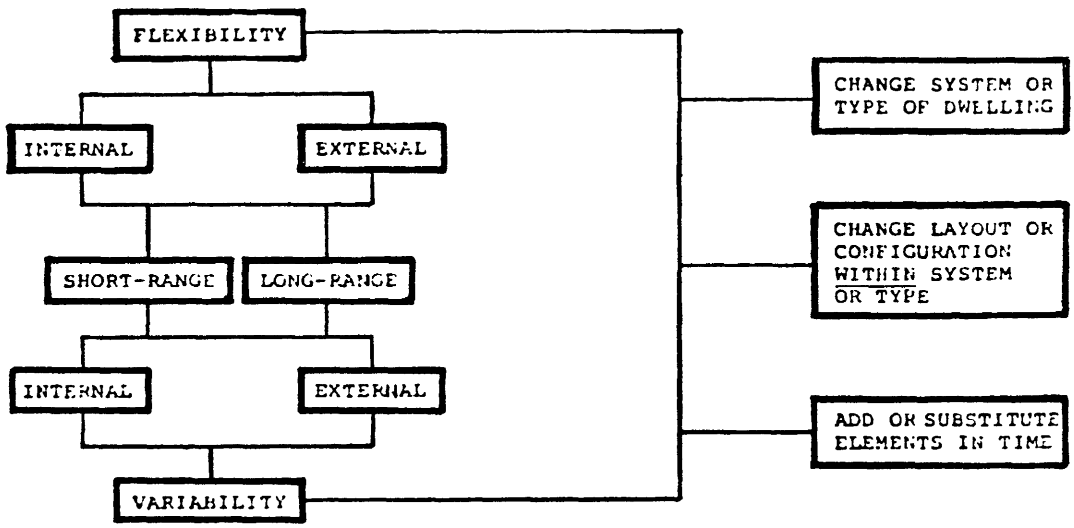

Figure 29: User's Requirements and Change

Source: Dluhosch, 1974

service distribution.

2. Functional requirements: Here we are designing for adaptability, adjusting to functional (spatial) requirements. In contrast to the technical requirements, it emphasizes on planning and layout.

Considering the two classes of user need stated and refering to Fig. 28, it becomes possible to formulate user requirements based on his activities in the areas of flexibility as shown in Fig. 30.

4.3 PERFORMANCE REQUIREMENTS AND STANDARDS

4.3.1 The Concept of Performance

> "Performance provides the means for guiding and evaluating the accelerating growth of building technology while imposing none of the constraints of the prescriptive approach." (Wright, 1972).

The performance concept is not new to the building profession. The first project to use performance requirements in the United States was the SCSD project that begun in 1961 by Ezra Ehrenkrantz, yet Europe has an older experience in the field.

The performance concept may be brought down to two main approaches (Karlen, 1972):[5]

1. Behavior in use: referring to the behavior of a thing in its environment under its exposure to different agents.

2. The output of a process (transformation by activities or by function): For example, the function of a building is related to the functions of the parts of the building.

Either approach does not alter the notion of performance approach as an organized procedure within which it is possible to state the desired attributes

ACTIVITY	USER CHARACTERISTIC(S)	CONSEQUENCE(S) FOR THE USER	USER REQUIREMENT
to expand	-Changing needs a) Family cycle b) Social mobility c) Locational mobility d) Change in world view e) Change in dwelling culture -Differing needs a) Differing dwelling types b) Consumption and production influences c) Income distribution d) Social allocation policies	satisfaction of need to have more space	The building should be designed in a way which enables the user to expand his own unit to meet his needs.
to select		satisfaction of need to select any planning arrangement	The building should be designed in a way that the user is able to select any planning arrangement that he desires.
to adapt		satisfaction of need to adapt the unit	The building should be designed in a way that the user is able to adapt his dwelling to meet his needs.

Figure 30: Formulation of User Requirements

Source: Rojanavanich, 1983

of a material, component, or system in order to satisfy the requirements of the user without regard to the specific means employed in achieving the results. (Wright, 1972).[6]

A thorough statement on the performance concept was made by the Building Research Division of the Bureau of Standards called the Performance Concept - A Study of its Application to Housing. It explains the performance hierarchy, from performance requirements to codes (see Fig. 31).

There are five important reasons for the development and application of performance specifications in the building industry which are outlined by Brill (1972),[7] namely:

1. Performance specifications, based on user's needs, are a means of retaining and amplifying "the voice of the user" in this complex building process.
2. They permit design decisions to be made when more information is available to the designer, therefore one is richer in information at the decision point.
3. By permitting any solution which meets the performance required, the building industry is permitted to explore alternative solutions to those now seen as "models".
4. Performance information makes it possible for the industry to bring the costs of their products within the demand of the market by focusing on the basic performance characteristics of such products.
5. Stating the desired performance explicitly forms the necessary information base for a system of formal evaluation and feedback, both now missing from building industry.

Even though it has its advantages, performance approach has uncertainties that may be pointed out such as the possibility of the performance standards being poor and restrictive, the still-required cost/quality decisions and the

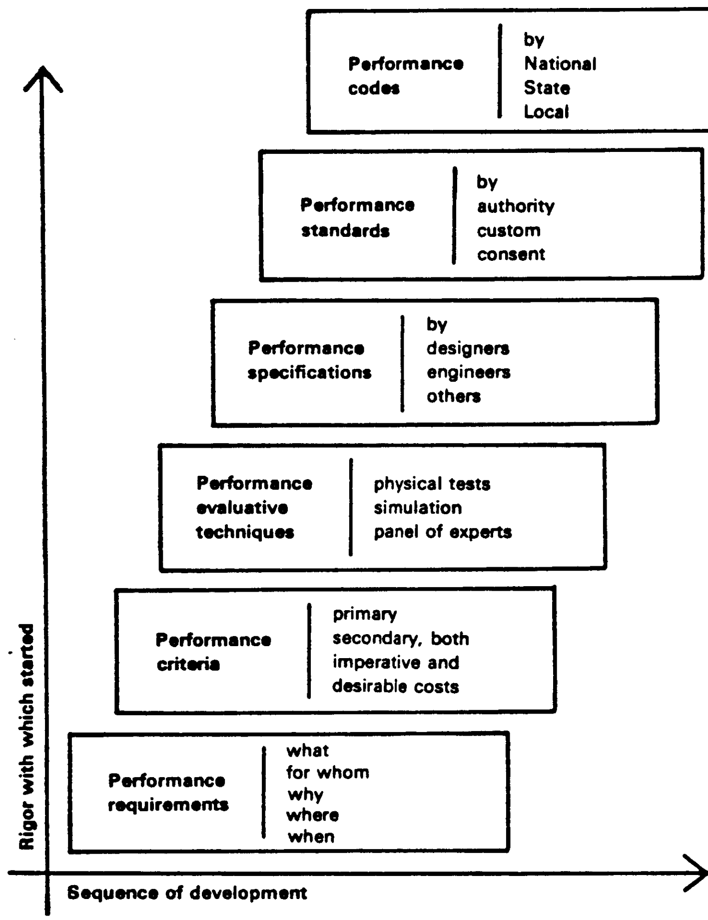

Figure 31: The Performance Hierarchy

Source: Building Research Division - N.B.S.

necessity for quality trade-off decisions.

4.3.2 The Development of Performance Requirements

In 4.1.2 the formulation of user requirements was discussed based on user activities. Taking a step further, is the formulation of performance requirements.

In other words, we are first to identify the performance requirements for subsystems, technical solutions and materials on the basis of the user requirements, and secondly formulate the performance requirements in a way which will enable the control of the requirements, both in the building process and in the building in use.

In a sense, we are searching for a statement of what is expected from the material, component or system in terms of performance itself.

A performance requirement does not prescribe a solution, (Cronberg, 1975),[8] and can be formulated with two components (see Fig. 32):

1. The goal component, identifying what is to be achieved.
2. The criteria component, describing how the goal satisfaction can be controlled.

Performance requirements are formulated independently of the solution and/or material which is applied to meet the requirements. When formulating the requirements, the solution is left open. Instead, the goals for the end result are given. At the same time, one must specify how to evaluate the degree to which alternative solutions fulfill these requirements.

4.3.3 An Example of a Performance Statement

The National Bureau of Standards (Guide Criteria-1971) states the essential parts of a preformance statement to be:

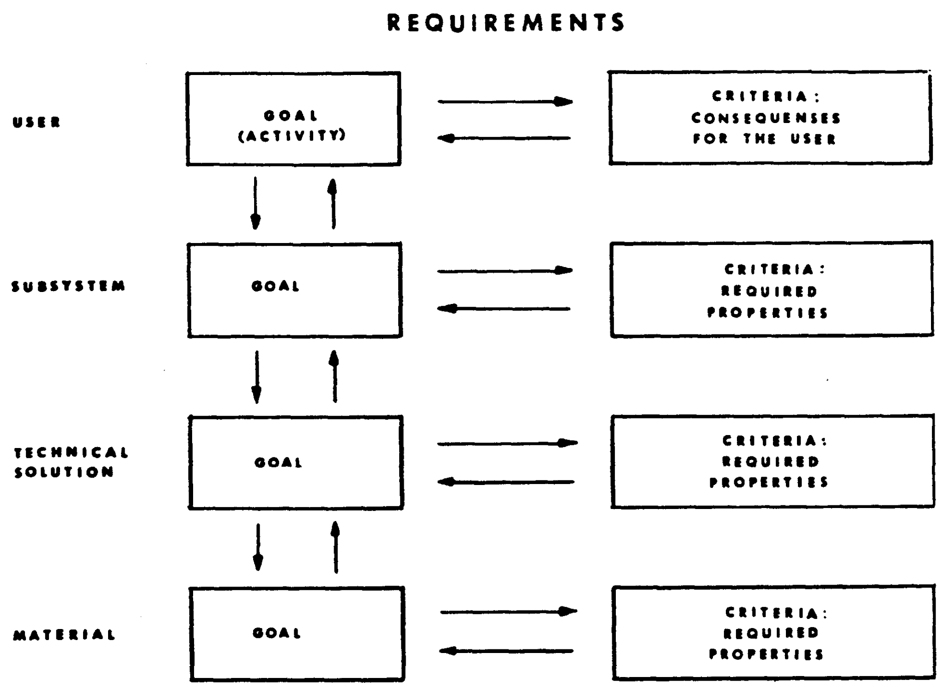

Figure 32: Formulating Performance Requirements

Source: Cronberg, 1975

1. The requirement: A qualitative statement about the important aspects of product quality.

2. The criterion: A quantitative statement providing specific minimum levels for attaining compliance with the intent of the requirement.

3. The test: A statement indicating the specific method of assessment.

4. Commentary: A statement of the origin of the criteria, their intent, and the degree of confidence in the performance level and evaluation methods indicated.

Fig. 33 is an example illustrated by the NBS, it presents a performance statement. The goal is given in qualitative terms: "The evacuation of the occupants" and the "fire fighters being able to bring the fire under control." As a criterion to determine that the qualitative "requirement" is being met, a property of the built element, its fire resistance (defined by the test method ASTM E 119-67), is given.

On the whole, the goal component in each stage (subsystem, technical solution and material) is derived from the user requirement, and the criteria provide a means for evaluating alternative solutions in terms of their goal satisfaction.

4.4 THE NEED FOR WEIGHTING REQUIREMENTS

One of the aims of a designer is usually to transform user's needs into performance criteria as accurate as possible. It is not in the designer's capacity to fulfill all user's needs; on the one hand, such needs as happiness and health are examples of human needs that cannot be fulfilled by a designer; on the other hand, illumination, fresh air, etc. are examples of needs that are within the designers capacity to provide for the user.

BUILT ELEMENT: EXTERIOR ENVELOPE; ROOF-CEILING, GROUND FLOOR

ATTRIBUTE: FIRE SAFETY

- Requirement

  The roof ceiling assembly should contain the fire for a period long enough to permit evacuation of occupants and to allow fire fighters to bring the fire under control.

- Criterion

  The assembly should have a fire resistance of 3/4 hour.

- Test

  ASTM E 119-67

- Commentary on F.4.1.1

  ASTM E 119-67 is the only accepted test for rating the fire resistance of structural components.

Figure 33: Example of a Performance Statement

Source: N.B.S. (Guide Criteria, 1971)

It may be considered an ideal situation when one component fulfills all the performance specifications layed by the designer. In practice this is not usually the case. The component selected does not usually meet all the specifications; here a decision should be made about the most crucial specifications that must be satisfied.

In order to do so, a task of weighting user's requirements will help rank and identify the most important requirements that should be met through the performance requirements of a component.

This is a process that aids the designer in reaching a rational solution and eventually meet the minimum performance requirements - at least.

With the increased varieties of technical solutions through the components available in the market, the designer will have to go through the process of a preliminary identification of possible solutions, then evaluate each chosen component against the stated objectives; the component meeting the most objectives and ranking the highest would be the most appropriate choice, given the situation at hand.

Chapter 4

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CONCLUSION

> "Architectural criticism - debatable at best - must stop its verbal jousting; each project must be under-written by scientific certainty, so that its arrangement can be justified in a way that is logically convincing."
> (Gerard Blachere - 1966).

The rapid development in almost every aspect of today's society has indirectly affected building activity. The increasing demand for new buildings and accomodations has reached a level where the "conventional/traditional" methods of building and constructing are struggling way behind to meet these new demands (this is true for housing, offices, health and education facilities, etc.).

Industrialized building, whether the answer to the problem of building shortage or not, has been adopted by many an authority, public or private, to help narrow down the expanding gap between demand and supply of buildings.

The building process has changed immensely throughout the years. The process nowadays is more complex and involves a number of issues. Seen as a large-scale organization, the building industry demands an efficient flow of both "soft-and-hardware" components to ensure the proper execution of the project.

Given the complex processes on hand, it is necessary to ensure the appropriateness of each stage before proceeding to the following. Moreover, with the size of investments (men, equipment, finance) in the building process, it becomes an even more pressing issue of making sure that resources are allocated in the best possible way.

Evaluation is one of the means appropriate for such situations. Lately, it has become a major issue and was applied to almost every stage of building construction. Post-construction evaluation is also applied in cases where a building is evaluated by the users to judge a possible repetition of the building elsewhere and improve, whenever possible, on less successful solutions.

In general, we are evaluating either the software of the building process which includes: user's requirements, the program, design schemes, etc., or the hardware, which represents the physical part of the building itself, this can be by means of:

1. Parts of the building; such as building components, the various building systems, etc.
2. The building as a whole; such as the total building performance throughout its life-cycle.

Coming back to the issue of industrialized building systems, it has been evident that it is necessary to identify the factors directly related to the running of any industry in general, the building industry in particular, whether in terms of manpower, finance, or resources.

In order to do so, we must first specify and expand on the main objectives of the project (e.g., create new job opportunities to reduce unemployment, supply local markets with badly needed dwellings, etc.). This may be considered a major step towards the weighing of the above mentioned factors, in the sense of ranking priorities. An intensive data-gathering and analysis process is required to assure making as accurate a judgment as possible at this stage.

Establishing and clarifying the project's objectives leads to outlining the industry's parameters in terms of labor skills, level of technology acquired, amount of investments and more important, type of product.

Emphasizing the latter, the type of product will be greatly affected by the process of demand and supply in a local market. Once a typology is established, we turn to another issue to be considered, i.e., one that may be defined by the term "building systems" typology in the broadest sense of the word.

Given the market's analysis to begin with, we then focus our attention on the user's needs and requirements. Analysing and evaluating user requirements will help us identify the quality, quantity and economy of the "product" to be manufactured.

This eventually leads to the final stage of this study, that is the determination of performance specifications. In a sense, performance specifications represent the link between these specifications within a given environmental context reduces the chances of failure in terms of choosing the most appropriate building system in the light of a given situation.

The process of evaluation and other related processes such as weigh ing, aggregating and ranking are tools available to decision-makers and policy-planners to assist them with their judgment and decisions on a more scientific, comprehensive and rational basis.

This study represents a general overview of industrialized building systems and hopefully achieves to demonstrate the logic behind introducing "evaluation" to the building process; with an emphasis on the processes of implementation of evaluation as an independent process in the selection of industrialized building systems.

Yet, many questions arise and others remain unanswered. Two topics must be dealt with; the first with which concerns the decision-maker(s):

1. Who should the decision-maker be?
2. Is his or their decision final?
3. Who should evaluate the final decision?

The second topic concerns the method of evaluation:

1. Which method should be selected for a certain situation?
2. What parameters are important to evaluate?

3. How do we deal with pressing issues that cannot be argued (Trade-Offs)?

Furthermore, it must be mentioned that "evaluation of evaluation" is an important process that was not discussed in this study. It deals with evaluating evaluation itself, that is to make sure that our choice or decision is worthwhile.

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