

Outsourcing Transportation Infrastructure Maintenance: a theoretical approach with application to JR East

by

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Bachelor of Engineering in Urban Engineering, University of Tokyo (1998)

Submitted to the Department of Civil and Environmental Engineering

In partial fulfillment of the requirements for the degree of

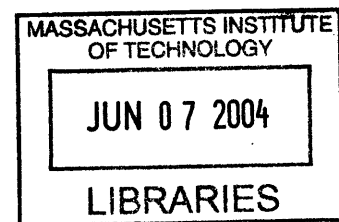
Master of Science in Civil and Environmental Engineering

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

June 2004

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Abstract

In transportation agencies, how to reduce maintenance and operation cost is one of the biggest and most common concerns, because their revenue is not expected to increase drastically in the future. One of the solutions undertaken nowadays is contracting out and utilizing contractors' efficiency for cost cutting and performance improvements. Actually, highway agencies in the US have already tried several pilot programs, employing performance-based contract, aiming at reducing their cost of maintenance and rehabilitation of their assets. It has been reported that these agencies achieved huge cost-reduction and performance improvement at the same time by implementing these strategies.

Railway infrastructure maintenance is not outsourced as much as highway maintenance in the US. However, a theoretical discussion about outsourcing and contracting shows that railway track maintenance can be outsourced to enhance operating efficiency.

Exploring the cases in several railway organizations and highway agencies, fixed-price contract with incentive schemes turn out to be mainly utilized. Evaluating maintenance contractor's performance by several comprehensive performance metrics is also a useful tool to manage and control the contractor's performance, which is linked to reward or penalty payments.

Considering the lessons learned in the discussions above, applications for railway maintenance in JR East is discussed. Its maintenance contract structure is in the midst of transition, but still imbues a traditional style. Instead, a long-term, performance-based contract with incentive scheme is suggested to improve the efficiency of infrastructure maintenance and adjust the future environmental changes JR East faces.

Thesis Supervisor: Joseph Sussman

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Acknowledgements

I am especially grateful to my thesis supervisor, Professor Joseph M. Sussman. Without his earnest support, I would never finish this work. He always encouraged me and gave me insightful advice. Some difficulties have prevented me during this work, however, he always steered me to the right direction.

I would like to express my gratitude to Mr. Carl Martland, who had advised me at the beginning. Mr. Douglas Lee at Volpe Center kindly discussed my thesis topic, even though it was not fixed at that moment. Both of the two gave me precious breakthrough to develop my thesis in the early stage.

I cannot help showing my gratitude to Anna Barry and Dan Breen at MBTA. They had welcomed my one-week visit last summer, and gave me a chance to experience a railway maintenance operation in MBCR. Actually, this experience inspired me to choose this topic. Moreover, I would like to thank all the learned people who had supported me by cordially answering my sudden questions.

I thank my financial sponsor, East Japan Railway Company, for giving me a chance to study at MIT. This two year is really exciting and full of inspiration for me.

I thank Chiho for her devoted supports throughout our stay in Boston. Her hand-made dinners and conversation always give me a relaxed time and energy through this thesis work. Ken, it is true that you always disturb me when you are awake, but your lovely smile and adorable behavior always remind me of a peace of mind and give me an extra vitality. Special thanks to them!

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Chapter 1 Introduction to the Transportation Infrastructure Management

There is no doubt that public and private transportation has been playing an important role in each country by supporting their freight movement and personal mobility, which are indispensable for economic development. It forms the backbone of local, national, and international trade and travel. Among industrialized countries, such as the US, Europe, and Japan, major highway and railway networks have already been constructed, and the attention of scholars and engineers has been shifting from constructing additional new networks to maintaining and rehabilitating existing networks in an effective manner.

In this chapter, as an introduction for this thesis, the current financial conditions of the transportation infrastructure in the US¹ are discussed. Involved problems in both highway and railway transit will be clarified, and the possible solution for solving them follows.

1-1 Shortages in Maintenance Expenditures in Highway and Transit Rail

1-1-1 Highway in the US

According to the US Federal Highway Agency's (FHWA) statistics², 57.8 billion US dollars are spent annually for routine maintenance and preservation³ of highway in the US. This is about 20 percent of the annual budget for highway agencies in the nation. In addition, the expenditures for highway maintenance are increasing year by year, because of the extending highway length itself and accelerated deterioration stemming from increased traffic load. Moreover, FHWA estimates the average annual cost to maintain highways and bridges over a 20-year period is \$75.9 billion (in 2000 US dollars), based on Highway Economic Requirements System (HERS), a simulation model that employs incremental benefit/cost analysis to evaluate highway improvement.

The results of this analysis suggest that current spending for maintenance does not reach the desired level of investment in order to retain the current condition of infrastructure. Because of the current

¹ We talk about US transportation infrastructure in this chapter, due to the availability for information about its finance and physical condition.

² US DOT, "2002 Status of the Nation's Highway, Bridge, and Transit: Conditions & Performance"

³ Preservation includes, 'reconstruction, resurfacing, pavement restoration or rehabilitation, widening of narrow lanes or

weak economic condition in the US, this means that a more effective and organized maintenance scheme is required for state agencies to sustain the highway network with limited budget.

Table 1 Annual Highway and Bridge spending versus Required Investment (billion dollars in year 2000)

| 2000 actual spending | Estimated cost to maintain | Estimated cost to improve |
|----------------------|----------------------------|---------------------------|
| 57.8 | 75.9 | 106.9 |

1-1-2 Rail Transit Infrastructure in the US

Rail transit consists of heavy rail, commuter rail, and light rail. In each category, as shown in Table 1-2, non-vehicle maintenance costs, such as track and facilities maintenance, occupy a higher percentage of expenditures as compared to the other modes.

The Federal Railway Administration (FRA) estimated that required annual investment for maintaining condition and performance over a 20-year period is 3.8 billion dollars, whereas the actual spending for maintenance is only 1.6 billion dollars. In terms of rail transit, maintenance expenditures are not enough to retain the current condition of infrastructure.

Table 2 Operation and Maintenance Cost in US transit (2000)⁴

| Mode | Vehicle Operation | | Vehicle Maintenance | | Non-Vehicle Maintenance | | General Administration | |
|-----------------|-------------------|-------------|---------------------|-------------|-------------------------|-------------|------------------------|-------------|
| | \$ | % | \$ | % | \$ | % | \$ | % |
| Bus | 6,243 | 56.6 | 2,420 | 21.9 | 482 | 4.4 | 1,882 | 17.1 |
| Heavy Rail | 1,620 | 41.2 | 733 | 18.6 | 999 | 25.4 | 579 | 14.7 |
| Commuter Rail | 1,031 | 38.5 | 646 | 24.1 | 493 | 18.4 | 510 | 19.0 |
| Light Rail | 247 | 41.7 | 142 | 24.0 | 99 | 16.7 | 104 | 17.6 |
| Demand Response | 838 | 68.4 | 144 | 11.8 | 26 | 2.1 | 217 | 17.7 |
| Other | 341 | 62.1 | 89 | 16.2 | 41 | 7.5 | 78 | 14.2 |
| Total | 10,320 | 51.4 | 4,174 | 19.4 | 2,140 | 12.4 | 3,370 | 16.7 |

shoulders, and bridge replacement.’ In this thesis, preservation is regarded as a maintenance activity in a broad sense.

⁴ Resource: Course material in 1.259J Transit Management.

In both highway and rail transit in the US, we can find that the maintenance budget is not enough to retain its current condition. Under these circumstances, each transportation agency is strongly encouraged to perform maintenance in a cost effective manner.

This kind of problem is not unique in the US. The transportation agencies in other industrialized countries see the same problems, too.

1-2 Outsourcing Transportation Services in the US

One of the possible solutions for this problem can be outsourcing that would reduce the cost of operation and maintenance. In the US transit industry, outsourcing is relatively common among commuter rails service and demand response service, such as ferry service. On the other hand, it is the least utilized among heavy rail and light rail as is shown in table 3. Only five percent of the railway service is outsourced; therefore, it can be said that outsourcing is not widely relied upon in the railway industry in the US. Even though operation and maintenance are put together in this data, we can assume that maintenance itself is also less outsourced in the US railway.

Table 3 Outsourced transit service in the US (2000)⁵ [million dollars]

| Mode | Directly Operated | Outsourced | Total | % Purchased |
|------------------------|--------------------------|-------------------|--------------|--------------------|
| Bus | 10,468.4 | 558.0 | 11,026.4 | 5.1% |
| Heavy Rail | 3,930.8 | 0.0 | 3,930.8 | 0.0% |
| Commuter Rail | 2,316.2 | 362.8 | 2,679.0 | 13.5% |
| Light Rail | 592.1 | 4.5 | 596.6 | 0.8% |
| Demand Response | 458.6 | 766.8 | 1,225.4 | 62.6% |
| Others | 484.3 | 66.2 | 550.5 | 12.0% |
| Total | 18,250.4 | 1,758.3 | 20,008.7 | 8.8% |

On the other hand, in the highway sector, outsourcing has been wide spread and highly utilized nowadays. Table 4, which is the result of surveying each state DOT, shows the current status of private-sector utilization in each category. This table shows that maintenance is widely outsourced as compared to the other activities, such as construction and operation. Even though the ratios of

⁵ Resource: course material in 1.259J Transit Management.

outsourcing vary from lower than 20 to 100 percent, outsourcing in highway maintenance is relatively common these days.

Table 4 Percentage of activities outsourced in highway agencies (2002)⁶

| Outsourced Ratio \ Activity | 0-19% | 20-39% | 40-59% | 60-79% | 80-99% | 100% |
|-----------------------------|------------|-----------|-----------|-----------|------------|-----------|
| Construction | 10 | 4 | 4 | 4 | 4 | 2 |
| Maintenance | 29 | 14 | 15 | 15 | 25 | 11 |
| Operation | 14 | 5 | 6 | 7 | 22 | 23 |
| Others | 56 | 57 | 48 | 30 | 65 | 30 |
| Total activities | 109 | 80 | 73 | 56 | 116 | 66 |

Table 5 indicates that the number of outsourcing has been gradually increasing after the 1960's, and it has turned out to be most utilized in maintenance activities. We can understand that the importance of outsourcing has been growing since the early 1970's.

Table 5 Decade when Outsourcing begun in highway agencies in the US

| Decade \ Activity | 50's | 60's | 70's | 80's | 90's | 2000~ |
|-------------------------|-----------|-----------|-----------|------------|------------|-----------|
| Construction | 3 | 1 | 2 | 8 | 9 | 5 |
| Maintenance | 16 | 9 | 24 | 23 | 33 | 2 |
| Operation | 13 | 5 | 6 | 13 | 27 | 7 |
| Others | 15 | 24 | 47 | 67 | 97 | 35 |
| Total activities | 47 | 39 | 79 | 111 | 166 | 49 |

1-3 Innovative Contract Structure for Effective Infrastructure Management

Highway agencies have been trying to utilize outsourcing maintenance to reduce their operation cost. In practice, by this scheme, highway agencies began to reduce their maintenance cost, and it turned out to be an effective way to manage their huge asset. In particular, we can find several dramatic examples that achieved significant cost reduction. For instance, Virginia DOT had outsourced part of their interstate highways and its maintenance cost saving has been estimated to range from 16 to 23 million dollars.

Moreover, there are some outstanding examples in terms of innovative maintenance frameworks. In the state of New Mexico, a construction firm, Koch industries Inc., had reached a highway reconstruction and maintenance contract, which was called as 'Design-Bid-Build-CM-Maintain'. This

⁶ Table 1-2 and 1-3 are cited from NCHRP Synthesis 313, 'State DOT Outsourcing and Private-Sector Utilization', 2003, TRB. Each number represented in the table is a reflection of the total number of activities reported.

type of contract included a warranty, since the company built this highway and guaranteed the quality of pavement and structures that they constructed by this long-term, 20 years and 10 years, for pavement and structures respectively. This framework is so innovative that the construction company is encouraged to minimize the total construction and maintenance cost over the long term. Conversely, traditional Design-Bid-Build contract does not drive contractors to reduce the life cycle cost, but just focuses on only cutting construction costs. (Table 6)

Table 6 Examples of Construction and Maintenance Projects with innovative Contracting Approaches⁷

| Project Name | Description | Contract Award | Maintenance Warranty period / | Cost Saving |
|------------------------------|---|----------------|--|-------------------------------|
| Virginia Interstate Projects | Maintain 1,250 lane miles on I95, I77, I81, I381 | \$131.6 mil | 5.5 years | \$16-23 mil |
| New Mexico Route 44 | Reconstruction and widening 120 miles of two-lane state highway | \$314 mil | 20 years (pavement) 10 years (structures) | \$89 mil (over life cycle) |

In those projects, one of the characteristics that drove significant cost savings is performance-based contract (PBC) in highway construction and maintenance. Among the US highway agencies, the usage of this method had been limited due to a lack of experience and knowledge; however, several DOTs have begun employing this and implementing maintenance contract successfully.

1-4 Research Objectives and Methodology

1-4-1 Approach

Highway and railway are both transportation infrastructure, and possess both similarities and differences. Both are running short of funding for maintenance, but one employs outsourcing intensively, while the other does not. Based on these successful examples in highway maintenance, in this thesis, we will explore the usefulness of outsourcing for railway infrastructure maintenance.

Key Questions are;

- Is it feasible for the railway to apply maintenance outsourcing?
- If so, what kind of contracting method is appropriate?
- What is the actual Make-Buy decision making procedure in railway infrastructure maintenance?
- During the contract period, what kind of management is required for the railway to maximize the efficiency of the outsourcing strategy?

After employing outsourcing, how a railway firm can control the maintenance contractor is also

emphasized in this thesis. Overall, practical and managerial issues about maintenance outsourcing are mainly discussed.

1-4-2 Outline of Chapters

Chapter 2 reviews fundamental and general issues about maintenance, which includes proactive maintenance, inspection, condition assessment, and the measurement of the maintenance contractor's performance measurement.

The overall framework about outsourcing and contracting is reviewed based on the literature on business and public management in Chapter 3. Outsourcing is a common tool in management for both the private and public sectors; thus its theory has been well established. Moreover, contracting is also studied mainly by public sectors, in which performance-based contracting is utilized and proved to be effective in some areas. Framework about make-buy decisions and inter-firm relations will be presented.

Based on these discussions so far, ideal contracting structure on railway infrastructure management will be discussed in Chapter 4. First, characteristics of track maintenance are given. Discussions about complexity and uncertainty in track maintenance, and the inter-firm relationship between the railway and the contractor will be the focus in order to determine the appropriate contracting structure.

Chapter 5 presents several brief case studies about highway and railway maintenance outsourcing, in which each of them involves some outstanding points on how to improve the efficiency of maintenance. In concrete, highway maintenance in the US and Argentina will be scrutinized, and railway infrastructure maintenance in Australian freight corporation and commuter rail service in greater Boston area will be mentioned.

Finally, in Chapter 6, we will analyze the contracting structure currently being undertaken in East Japan Railway Company (EJR), the largest passenger railway company in Japan. EJR is facing dramatic environmental transition nowadays, and they are in the midst of restructuring their infrastructure maintenance. Several suggestions for adjusting and developing their future maintenance structure will be given based on the discussion given in this research.

⁷ Battelle, 2003, "Performance-based Contracting for the highway construction and industry"

Chapter 7 discusses conclusions drawn from this research. In addition, several suggestions for future research will be given.

Chapter 2 Maintenance Theory and Infrastructure Deterioration Process

2-1 Definitions of Maintenance and its Categories

Maintenance can be defined as a “combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function”.⁸ In terms of railway tracks, rails, sleepers, ballasts, and fastenings should be maintained carefully to function in order to support smooth movements of rolling stocks, in a cost effective manner. Maintenance is complex work, and is prerequisite for simultaneous technical and economical performance.

On the other hand, “operation” refers to activities involved in the actual delivery of service to users. In other words, operation is the use of infrastructure for its intended purpose, while maintenance is a set of activities to keep the infrastructure in such a state that it can be operated correctly with cost effectiveness.

Maintenance activities can be categorized into two kinds, proactive and reactive maintenance. Moreover, rehabilitation is usually regarded as maintenance, but the magnitude of it is much larger than other kinds of maintenance.

a. Proactive Maintenance

Proactive maintenance is said to be the most cost effective way to maintain infrastructure that is exposed to heavy use. Proactive maintenance are systematic pre-scheduled activities or programs of inspection and maintenance activities aimed at the early detection of defects and implementation of actions to avoid breakdowns or infrastructure deterioration. Inspection data will be utilized to build the deterioration model and predict the future deterioration of infrastructure. Based on this modeling framework, maintenance engineers will make a maintenance plan to organize cost effective maintenance. Often the costs of preventive maintenance activities are lower compared with reactive maintenance or rehabilitation. Generally, in terms of maintenance of highway pavement or railway track, proactive maintenance is the most preferred practice.

⁸ European Standard in SIS (2001)

b. Reactive Maintenance

Reactive maintenance is an activity that takes place as a result of breakdown or noticeable infrastructure deterioration. Of course, it is intended to put an item back into a state in which it can again perform its required function. If an emergency is so critical that the operation is interrupted, the breakdown should be repaired immediately, but otherwise, it could be repaired later. This policy is appropriate to employ for the less important components that have slow deterioration rate.

c. Rehabilitation

Rehabilitation is an activity to correct major defects in order to restore a facility to its intended operational status and capacity, without significantly expanding it beyond its originally planned or designed function or extent. It should be distinguished from construction which refers to the initial creation of the infrastructure, as well as from expansion or extension which refer to the increasing of the capacity or geographical extent of a system of infrastructure.

d. Replacement

After experiencing proactive maintenance and rehabilitation several times, a component will reach the limitation of its service life, and then it will be replaced with a totally new component which will usually be the same grade as the previous one. If it is replaced with higher grade components, it is considered beyond the area of pure maintenance; instead, it is an issue of capital budgeting. One of the important expected roles for maintenance is extending the service life of each component by improving the way in which maintenance is performed.

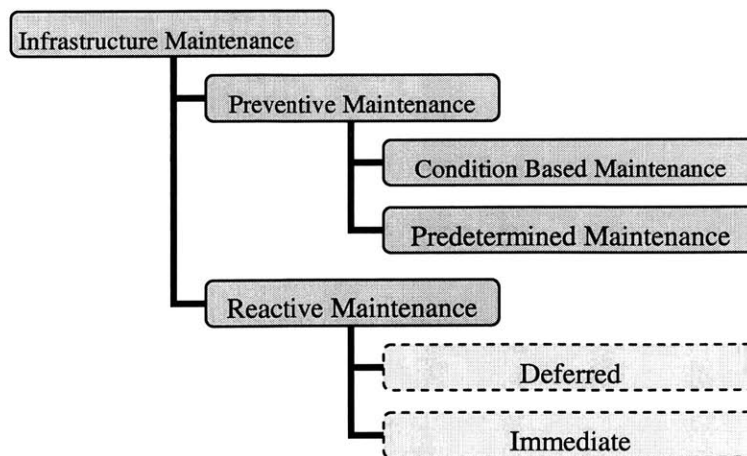


Figure 1 Categories of Infrastructure Maintenance

There are some more categorizations in terms of maintenance policy. Planned and unplanned maintenance is one of the ways to distinguish maintenance⁹.

2-2 Economic Impact of Proactive Maintenance and Poor Maintenance

To express the chronological change in the condition of infrastructure, a graph being shaped like a saw is usually used. Fig 2 indicates the periodic change, driven by gradual deterioration and maintenance work.

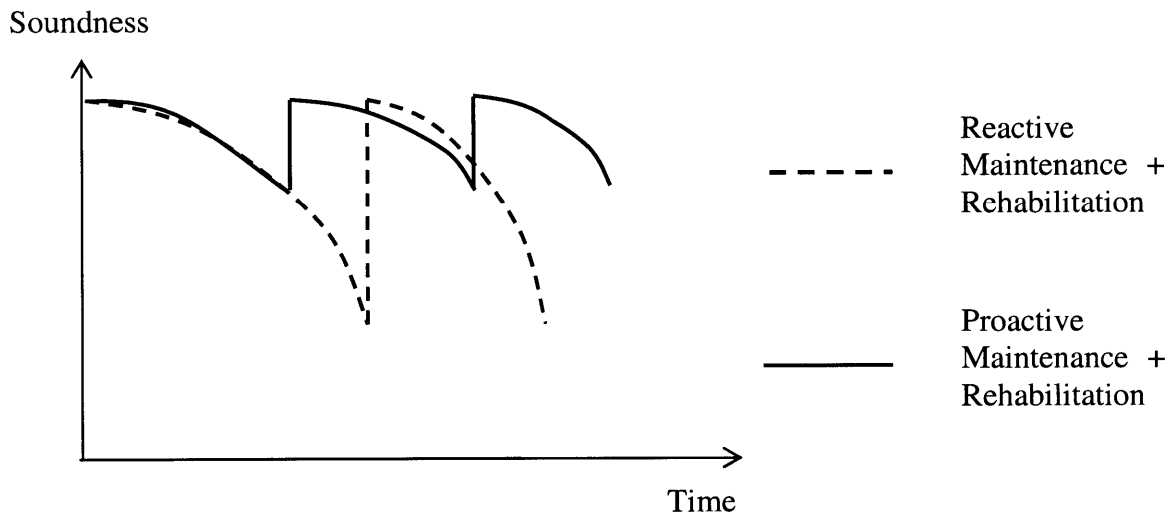


Figure 2 Conceptual deterioration and maintenance relationship during infrastructure's extended service life by proactive and reactive maintenance

A construction project will usually take years to finish, but maintenance must be continued until the time when the useful life of infrastructure terminates; the infrastructure on a railroad can last longer than a century. However, public attention tends to focus on the construction phase only due to its significant impact and cost, but the operation and maintenance (O&M) phase also deserves some attention in terms of its impact on the total lifecycle cost, which should be a big concern for stakeholders, too. If operation and maintenance is not well organized, consequently, stakeholders would need to pay more in the long term than in the case where they are maintained effectively.

There are many significant economic and financial repercussions of inadequate maintenance. First of

⁹ Romps(1993)

all, direct economic inefficiencies and financial loss due to poor maintenance is important. Infrastructure systems which are not maintained will deteriorate faster, shortening their service life, which in turn ends up wasting scarce funds and resources. If water-supply networks, for example, are not maintained well and there are heavy leakages, we will suffer from the direct loss of water itself and the economic damage for the repair of pipelines. In addition, several side effects, such as epidemics stemming from water contamination, might be widely spread in the urban area, which will bring wider impacts on the society. Like this case, the cost of failure in infrastructure service, such as the railway and highway, is generally very high; thus poor maintenance for infrastructure can lead to unnecessary expensive investment in rehabilitation, new facilities, or alternative solutions. It is clear that continuous proactive maintenance is, in the long run, costs much less than poor maintenance in any kind of infrastructure.

Once infrastructure deteriorates, obviously, it will never improve by itself. This irreversibility in infrastructure quality refers to the fact that today's maintenance policy is influential for the infrastructure condition in the future. The length of useful lives in infrastructure is usually longer than one year; thus, in discussing maintenance, we need to consider the total effectiveness in the long run.

2-3 Inspections and Condition Assessment

Inspections, which are considered part of maintenance, are driven both by safety and maintenance. The objective of a safety inspection is to assure the lack of any faults that might lead to accidents, derailments or collisions, or safety related incidents. Another objective is to monitor the continuous degradation of the infrastructure in order to prevent faults that might lead to accident or incidents. The objective of a maintenance inspection is to provide the infrastructure maintenance manager with information for short and long term planning of maintenance activities. Current trends in the progress of deterioration are analyzed and will be utilized for foreseeing the future condition of infrastructure.

In general, technologies related to inspection have been developing recently in the transportation infrastructure fields, which enable more and more accurate inspections than those by manual work. Moreover, the recent development of computer technology enables large amounts of data accumulation on inspection data, which provides engineers with an opportunity to analyze it. Due to these large-scale databases, such as Highway Economic Requirements System (HERS) developed by the US Federal Highway Administration, transportation assets maintenance is becoming a more technology-oriented field, rather than a labor-oriented one. HERS is a useful database system that provides key information about maintenance decision making. Figure 3 illustrates the flowchart of

inspection and repair work.

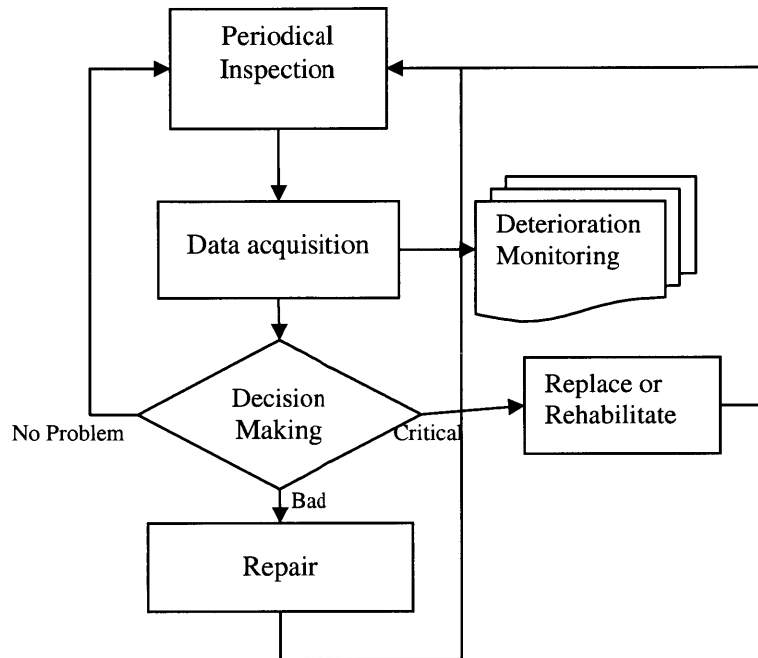


Figure 3 Inspection and Repair Flow

2-4 Deterioration Process and Condition assessment in Transportation Infrastructure

Every infrastructure begins deteriorating little by little just after the beginning of operation. The rate of deterioration mainly depends on the relation between the strength of the infrastructure and the intensity of traffic loads. If the structure was designed to be very strong considering the total traffic load, infrastructure would not deteriorate and keep functioning without major maintenance. Conversely, if the structure was too weak, it would deteriorate at a higher rate, which would require frequent maintenance and rehabilitation.

In any case, employing suitable measurement scales to express the condition of infrastructure is very important in the evaluation of the current condition and prediction for future deterioration. In this section, three measurement scales; continuous measures, discrete or continuous interval scale, and binominal scale, will be introduced.

2-4-1 Continuous Measures

Continuous measures are strongly recommended wherever it is possible to apply them. Examples of continuous scales are a roughness measured according to the International Roughness Index (IRI) in

highway maintenance, and P-index which shows the irregularity in railway track maintenance. In both modes, mean response time to fix a problem, and mean time between failures can be applied to evaluate the reliability and stability of transportation services.

These indices are beneficial because of their objectivity and the clarification of defining the meaning of scale intervals. If maintenance is outsourced, there are at least two parties, an owner and a contractor, that are related to the results of condition assessment; thus the objectivity is the most important issue in that case to avoid potential disputes among them. Even in the case of in-house maintenance, objectivity is indispensable for keeping its consistency in chronological data analysis.

2-4-2 Discrete Measures

In the event that it is unrealistic to choose continuous scale, the next best type of scale is a discrete scale with constant intervals between steps, otherwise known as a continuous interval scale. The measurement scale is likely to be a discrete scale such as 1,2,3,4, and 5. Probabilistic condition states are used to identify the probability that a maintainable element will deteriorate from one condition state to another. The distance between steps on the scale are not necessarily even, but are defined by alternative actions that may be considered for maintaining a maintenance element in a particular condition state.

As a way of expressing the transition among each scale in discrete scale, a semi-Markov process is frequently utilized. Bridge deck and pavement surface deteriorations are well established to be described in the Semi-Markov process.

A semi-Markov process is a Markovian process with sojourn times in any given states that are independently distributed random variables. Characteristics of it are as follows;

- A state space S (usually finite or countably infinite)
- A transition matrix P , where P_{ij} is the probability that the next transaction will be from state $i \in S$ to state $j \in S$.

$$P = \begin{bmatrix} P_{11} & P_{12} & 0 & \cdots & 0 \\ 0 & P_{22} & P_{23} & \cdots & 0 \\ 0 & 0 & P_{33} & \cdots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \cdots & P_{ss} \end{bmatrix}$$

Table 7 Description about Deterioration States

| State | Explanation |
|---------|---|
| State 5 | Brand new, excellent condition |
| State 4 | Used. Still sound enough |
| State 3 | Used for a certain duration. Some deficits found. |
| State 2 | Deteriorated. Need some fixing for service |
| State 1 | Critical condition. Failure |

Table 7 shows the example of discrete measures and qualitative explanation for each state¹⁰.

Based on this categorization, we can build a diagram that shows the relation between the destructive factors, such as traffic load, and infrastructure deterioration. Figure 4 is the diagram illustrated by System Dynamics in which the amounts of infrastructure that belong to each state are defined as stocks, and deterioration rates as flows. In this model, several assumptions are set as follows;

- Deteriorate only by one state at a time.
- Deterioration is proportional to the traffic load.
- From a safety point of view, any parts of infrastructure should not belong to State 1 at any time.

This model effectively shows the irreversibility of infrastructure deterioration, literally ‘cascading’ from one state to another.

We can add the contribution of maintenance activity in this diagram. This figure illustrates the effects that maintenance activities bring, which prevents the further progress of infrastructure deterioration.

¹⁰ Please refer to the appendix A for more information.

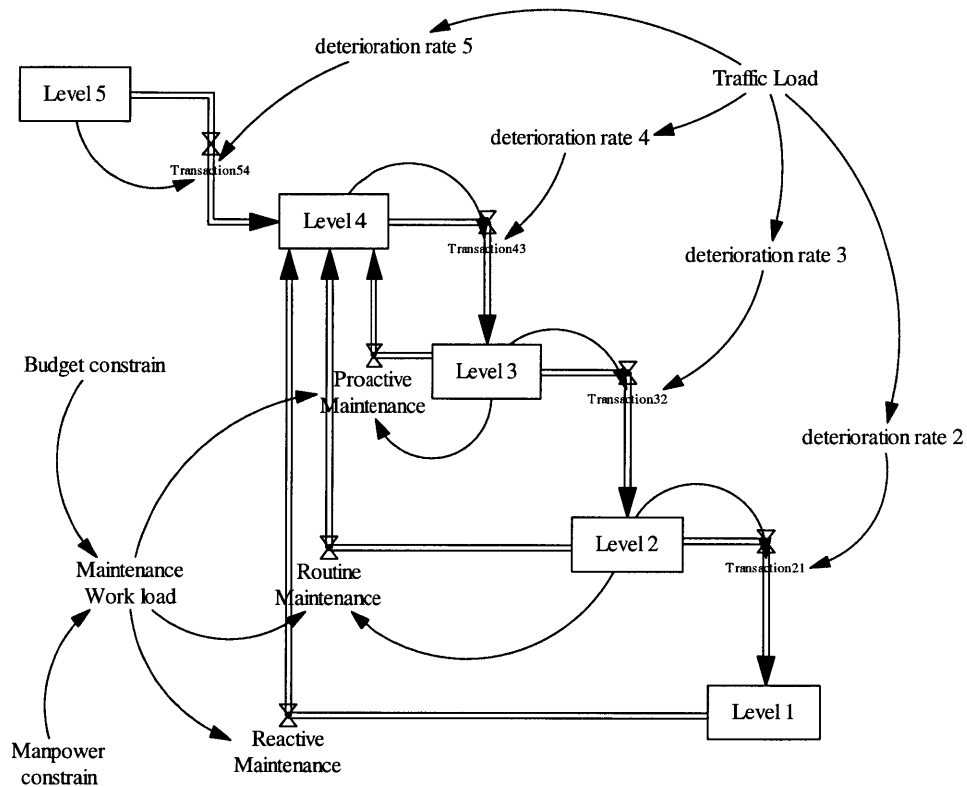


Figure 4 Model of Transportation Infrastructure Deterioration with Maintenance

2-4-3 Binary Measures

Binary measures take on just two values such as “0 or 1” or “yes or no”. This way of measurement is quite simple, and is not recommended. The main downside of binary measures is subjectivity in defining the value, which will be a cause of dispute among the related parties. Therefore, binary measurement should be avoided: it should be employed only when there are no alternatives.

In any case, periodic condition assessments which are measured by scales are an important process from both the engineering and management perspectives. Maintenance engineers will be concerned with the results of inspection data to scrutinize the effects of maintenance work they are currently doing, while maintenance managers will be interested in it to understand the current trend of infrastructure deterioration and foresee the required budget to maintain it in the future.

Chapter 3 Theoretical discussion about Outsourcing and Contracting

There are a lot of industries that are utilizing outsourcing as a tool to solve their problems. In this chapter, first, we will confirm the essence of outsourcing; and then, analyze the pros and cons of several kinds of contracting methods that have been applied in practice.

3-1 Outsourcing Strategy

Among the useful management tools private and public sectors are utilizing nowadays, outsourcing is one of the well-established methods which is getting nearly ubiquitous. It may be hard to find a firm which does not employ this common tool at all aiming at achieving higher efficiency. In this section, we review the theory and some practical applications of outsourcing.

3-1-1 Definition of Strategic Outsourcing

The most comprehensive definition of outsourcing is, “the act of transferring some of an organization’s recurring internal activities and decision rights to outside providers, as set forth in a contract.”¹¹ In practice, not only activities, but also resources such as employees, facilities, equipment, and technology are often transferred simultaneously.

Outsourcing is a quite familiar term nowadays, but we tend to misunderstand the exact meaning of it. First of all, we need to clarify the distinction between ‘strategic outsourcing’ and conventional ‘contracting out’. These two words are similar, but the difference is whether contractors own responsibilities in their work or not. In general, in case of strategic outsourcing, the responsibilities that contractors own range from management to practical work, while limited responsibilities are allocated to contractor in a conventional contract out. Table 8 shows the comparison between the two.

3-1-2 The Essence of Core Competencies

What is the definition of a core competency? There are no exact answers to this question, but Quinn (1994) defined the essence of core competencies as follows;

- Skill or knowledge sets, not products or functions,
- Flexible, long-term platform; capable of adaptation or evolution,

¹¹ Citation from Maurice(1999)

- Limited in number (not one but rarely more than five),
- Unique sources of leverage in the value chain,
- Area where the company can dominate,
- Elements important to customers in the long run, and
- Embedded in the organization's systems.

Identifying the core competencies the firm possesses itself requires high skills, which indicates that a lot of firms actually missed specifying them in the past. However, this identification is extremely important for Chief Executive Officers to make decision about an outsourcing strategy. Visible results of the firm's activity, such as specific products and services, are likely to be regarded as one of their core competencies; instead, skill and knowledge sets, invisible matters, should be core.

3-1-3 Brief History of Outsourcing in the Public and Private Sectors

Private sectors case-- from tactic outsourcing to strategic outsourcing

Outsourcing has been employed by industry as a useful tool to improve their efficiency for some time. However, the main reason why organizations employed outsourcing was less strategic, and more tactical, in the 1980's. According to a survey conducted by Boston Consulting Group (BCG) in 1991, the biggest benefit that organizations expected by introducing outsourcing was a reduction of overhead and short-term costs. Such a simple task as the cleaning of office buildings, distributing internal mail and so forth had been outsourced. This result implied that outsourcing was regarded as a tool to cope with the fluctuation of workload.

However, in the middle of the 90's, firms in some areas moved toward 'strategic outsourcing' and reaped considerable benefits. Strategic outsourcing is completely different from conventional outsourcing, because it is aligned with the organization's long-term strategies; therefore the positive or negative impact on the organization is significant. It is not just a simple and useful tool, but in fact a complex one. Management should carefully consider their future core competencies, organization structure, cost structure, performance level, and competitive advantages, before making any decisions about 'strategic outsourcing'. (See Table 8)

For example, Nike is one of the most successful companies that implemented strategic outsourcing and end up maximizing the value of the firm. They outsourced almost all of their manufacturing processes, and instead focused on the design, marketing, and research of sports shoes. As a result, Nike has built an excellent reputation as a fashionable shoe, supported by its suppliers which produced

Nike shoes in Southeast Asia. Nike’s strategic scheme to utilize outsourcing was much different from those in the 1980’s in terms of the scope, intensity, and duration of it. Hereafter, ‘strategic outsourcing’ will be referred to as outsourcing in this thesis.

Table 8 Comparison Between Tactical and Strategic Outsourcing

| | Tactical Outsourcing | Strategic Outsourcing |
|------------------------|----------------------|----------------------------|
| Main purpose | Problem-solving | Restructuring organization |
| Duration | Short term | Long term |
| Decision rights | Not transferred | Transferred to providers |
| Impact on organization | Small | Large |

Public sector case-- making use of private sectors’ efficiency

Public sector organizations also started employing this tool. Public-Private Partnership (PPP) and Public Finance Initiative (PFI) are two good examples in which the public sector organizations are trying to utilize the potential efficiency that private sectors inherently have.

In the UK, outsourcing was introduced by the Conservative government in the early 1980s as a way to neutralize strikes, downsize blue-collar council, and cut costs. It was seen as a means of rolling back the "bureaucratic" state, and injecting into supposedly moribund services the competition that was needed to drive up quality and make them more responsive. In the public sector, it is interesting that the main purposes of outsourcing was not only cost saving, but reducing the power of the labor union.

Nowadays, also in the US, we can find a lot of attempts to introduce outsourcing in the public sector, such as highways, schools, prisons, and so forth. Due to the budgetary restriction these days, state governments need to reduce their operating costs. As a result, they tried to improve the productivity in the public by introducing competition with private sectors. One of the most successful local governments, in terms of cost reduction, is the City of Indianapolis. It is a well-known story that the former Mayor utilized Activity-Based -Costing to analyze their operating costs in each category, and exposed public sectors to a rigorous competition with private sectors through an open bidding process. As a result, their operating costs dropped drastically, and the financial health of the city has improved.

3-1-4 Cost and Benefit of Outsourcing

Outsourcing brings a certain amount of benefit to the organization; otherwise they would never employ it intensively. However, as is often the case with useful tools, outsourcing also involves both pros and cons. Thus, careful consideration is required before making decisions about introducing outsourcing.

a. Pros

Operating cost saving

The first benefit we should mention is cost saving. Needless to say, operating costs will never drop if the service providers' productivities are exactly the same as that of an organization. It is a prerequisite that a contractor has a higher efficiency and productivity than the organization that decides to execute outsourcing. In practice, the provider will apply a superior package of resources, such as cutting edge technology, state-of-the-art equipment, experience, and well-trained highly motivated personnel. Moreover, if the economy of scale works in service provider's activities, operating cost will drop even more.

Enhancing organization's core competencies

Making use of cost savings, organizations can focus on their core competencies and allocate their resources to it intensively. By saving money and resources, organizations can reallocate their resources in order to enhance their core competencies, which is the desired outcome of a successful outsourcing strategy. In order to survive the rigorous competition in business nowadays, it is indispensable for firms to differentiate themselves from other competitors and build a competitive advantage. Outsourcing can accomplish that.

Improve performance and quality

If service providers have high skills, organizations can expect not only cost reduction, but improvement of performance and service quality. If an organization has only limited experience and skills, it would be worth considering outsourcing to utilize the expertise of outside providers in order to compensate for their weakness.

Risk sharing

Outsourcers have responsibility for their work, which means that they own risks related to their activities. Transferred risk is proportional with the span of the outsourced area. From the organization's perspective, this is a significant advantage, especially in an industry that involves relatively high risk. This point will be discussed more precisely in the next section.

Reinforcing Flexibility

Outsourcing enables the organization to downsize; thus it is much easier to alter or modify its business

policies without the administrative work that would usually emerge when such kind of restructuring takes place. In an industry in which flexibility and agility matter, being surrounded by unpredictable environments, this advantage is essential.

b. Cons

On the other hand, there are several downsides that accompany outsourcing. It is true that outsourcing is quite a useful device, however, once misused, or abused, it could cause irreversible fatal damage to the sustainability of an organization.

Loss of key market

There is the danger that service providers would acquire an organization's skills by working together, and they could enter the same market that the organization currently participates in. Consequently, the organization can lose its market share.

Loss of competencies

It is a highly possible situation that the organization has the competencies they should possess, but they end up being transferred unexpectedly to the providers. The main reason of this tragedy is the misunderstanding of their core competencies. In particular, the organization should be careful on this point, because, fundamentally, non-core competencies area should be outsourced.

Loss of cross-functional synergies

Even if a section that is considered to be a non-core part of the organization, is going to be outsourced, additional careful verification should be made before the final decision. What they should check is the cross-functional synergy that the section's interaction with the core competencies brings.

Transaction cost

The transaction costs must be considered before concluding that cost reduction will be achieved just by the simple cost comparison. Generally speaking, outsourcing involves a lot of administrative work in the transaction phase, because plenty of resources such as employees, facilities, and equipment are transferred to providers. If the power of the labor union is strong and influential, organizations will be required to pour a certain degree of effort to negotiate with them. These processes are time consuming and extensive, making them far from simple tasks.

Uncertainty

It is quite important for the organization to assure the performance level of providers; inferior providers may ruin the customer perception for the organization, from which it is so hard to recover.

Employees' unhappiness

Outsourcing often transfers a number of employees to other existing firms or organizations, which

may affect the morale of both leaving and remaining employees. Managers should pay attention to this point to prevent the deterioration of productivity.

Difficulties in reversing

Once outsourced, it is very hard to reverse and operate it in-house. Managers in organization should think that reversing is the last countermeasure even if the outsourcing has failed.

3-1-5 Buy or Make? Decision Making Framework

We have discussed the pros and cons of outsourcing; then, how should managers make decisions about 'buy or make' and the choice of their sections to be outsourced? As a summary of the theoretical discussion about outsourcing, four sets of factors to make decisions are introduced; strategic factors, market factors, service and technology factors, and economic factors¹². Candidates of outsourcing should pass all the screening factors so that they are finally determined to be outsourced in practice.

Strategic Factors

First of all, identification of core or non-core business should be clarified, as noted before. The failure in identifying the core competencies would be critical to the establishment of a successful outsourcing strategy. Again, core competencies should be kept in-house; otherwise, the firm will lose its competitiveness in the future. Non-core business should be chosen as work for outsourcing.

Market Factors

Market reliability is a key issue in considering outsourcing. Attention should be paid to the condition of the market in which service providers exist. If healthy competition exists and it improves the service providers' performance, then it might be advisable to outsource. In contrast, if the service provider market for a particular capability is continually at risk of failing, then it is advisable to maintain it internally. If a service provider has a strong customer base for the needed service, the service provider will be able to provide services more cheaply than the owner's in-house department due to the economies of scale.

Service and Technology Factors

If the service is highly modular, it enables the owner to more simply outsource portions of the service. Conversely, if the service is highly integrated, it is much more difficult to outsource portions of the service. In addition, if technology associated with service provision is integrated, it is hard to be

¹² Beckman, 2004

outsourced, while if it stands alone, it can easily be replaced.

Economic Factors

As a final step, economic factors should be mentioned. Cost reduction is one of the biggest benefits that the owner is supposed to enjoy by introducing outsourcing; thus this point should be carefully verified before making a final decision. Table 9 shows the comparison between cost of owning and outsourcing an activity. Of course, the outsourcing plan should be approved only when the total estimated cost of outsourcing is lower than that of owning it.

Table 9 Comparison of Costs for Internal Ownership Versus Outsourcing [Beckman, 2004]

| Type of Cost for Owner | Cost of Owning an Activity | Cost of Outsourcing an Activity |
|------------------------|---|--|
| Service delivery costs | Raw Materials Direct Labor Machine Overhead | Purchase cost including; Labor Materials Machine Overhead Contractor's profit |
| Investment costs | Capital People resource(hiring, education) System Development | N/A |
| Transaction costs | N/A | Contracting costs including; Purchasing, sales, marketing, taxes, legal, restructuring Coordination costs including; Engineering, forecasting, service scheduling |
| Surveillance cost | N/A | Cost of quality assurance(QA) |

3-1-6 Measuring Outsourcer's Performance

Once an appropriate outsourcer is found and outsourcing has been implemented, the next concern is the performance monitoring. Because a large amount of responsibility is transferred to the contractors, the owner's main assignment is monitoring the contractors' performance. How should one monitor the outcomes of outsourcers? A performance-based contract is better than a method-based one in terms of simplicity and usefulness. In strategic outsourcing, outsourcers are not merely providing specific services written in a contract, but they have a wider range of rights about their work. In other

words, they have rights to choose the way of performance by making their own decisions.

In order to measure the outsourcer's performance, it is quite important to set effective packages of metrics that measure the performance.

The relationship between the individual performance and the metrics is described by Hauser and Katz (1998).

*“The link is simple. If a firm measures a, b, and c, but not x, y, and z, then managers begins to pay more attention to a, b, and c. Soon those managers who do well on a, b, and c are promoted or are given more responsibilities. Increased pay and bonuses follow. Recognizing these rewards, managers start asking their employees to make decisions and take actions that improve the metrics. Soon the entire organization is focused on ways to improve the metrics. The firm gains core strengths in producing a, b, and c. The firm becomes what it measures...”*¹³

This description is quite insightful by warning those firms trying to introduce performance metrics to evaluate outsourcer's performance. If the settings of performance metrics are not appropriate, outsourcers will be misled by them and result in unexpected performance that will be different from what owner expected at the beginning of contract. In particular, simple metrics are preferred in terms of implementation; however, a single performance metric is usually not enough to manage outsourcers, because the scope of outsourced work is not so simple that it can be measured by using a single scale. Multiple measurement scales are preferred in most cases.

Therefore, generally speaking, special attention is required to effectively choose combined performance metrics, which cover whole activities that outsourcers are required to do.

Performance Measurement in Maintenance Contractors

We will focus on, for instance, the performance measurements of maintenance sectors or contractors. Maintenance sectors should be well managed to perform maintenance activities in a cost effective manner, because the budget for maintenance is usually limited in a transportation organization.

Economic sense is indispensable not only for internal constraints, but also value for customers. As is often the case with service provisions, customers expect high quality of service with lower costs. Private sectors should be very sensitive about this matter, since they are usually exposed to rigorous competition among other competitors. A firm that cannot give their customers good service with low prices will lose customers and will eventually be obliged to leave the market.

¹³ Hauser, John R., and Gerry Katz (1998), “You are What You Measure!”, European Management Journal, Vol 16 No.5, pp 516-528

In order to analyze the performance accompanied with cost effectiveness, we need to clarify these attributes about maintenance activities: inputs, outputs, outcomes, and value for customers.

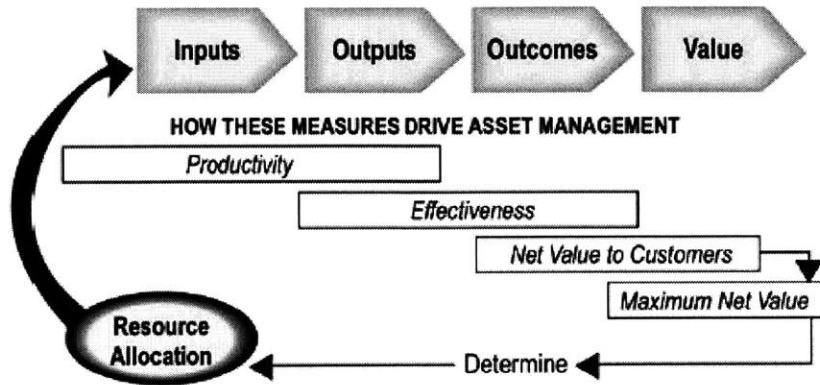


Figure 5 Product and Service Delivery Process¹⁴

a. Inputs

Inputs are the resources used to deliver a product or service, perform an activity, or undertake a business process. In highway and railway maintenance, the inputs consist of labor, equipment, and materials. The funds needed to pay for these resources may also be considered as an input. Under certain circumstances, other productive resources—such as land, water, or air—can be treated as an input.

b. Outputs

Outputs are a measure of production or accomplishment. It is usually counted by numbers, regardless of its contribution to serving customers' desire. In highway maintenance, examples of output measures are lane miles of roadway surfaced, the number of bags of litter picked up, and the number of acres mowed.

As illustrated in Figure 5, maintenance agencies focused on measures of productivity use these measures by looking at the ratio of output to various types of inputs. One could measure output per labor hour, per equipment dollar, per quantity of material used, or per dollar of expenditure. One might also examine unit costs expressed as the cost per unit of output.

The trouble with input and output measures is that they are internally focused on the work

¹⁴ William (2004)

maintenance personnel do. They are not externally focused on customers.

More recently, in highway maintenance, especially since the enactment of the Government Performance and Results Act of 1993, the focus has been increasingly on outcomes.

c. Outcomes

Outcomes are the results, effects, or changes that occur due to delivering a product or service, conducting an activity, or carrying out a business process. For example, an outcome of pavement resurfacing might be smoother pavement. An outcome of litter pickup might be cleaner roadsides, and the outcome of mowing might be increased sight distance at intersections and around curves and, consequently, a reduction of accidents.

Outcomes are more likely to be externally focused and frequently relate to customer preferences, expectations, and satisfaction. By looking at the ratio of outcomes relative to inputs, one can address the effectiveness of a program by addressing customer oriented results. Typical measures might be an outcome per labor hour, per equipment hour, or per dollar of expenditure.

One might also examine cost effectiveness, which is the cost per unit of outcome achieved. Figure 5 illustrates that as one transitions from using output measures to outcome measures, the emphasis shifts from productivity to effectiveness.

d. Hardship

Objectivity is quite important in performance measurement. Biased measurement does not make sense when it is used to compare the chronological data or regional data. In order to evaluate outsourcers' performance without any bias, hardship that obstructs the maintenance contactors' mission should be clarified and quantified. The definition of hardship is "factors outside the control of the maintenance organization such as weather and terrain that influence the outcomes and level of resources used".

Traffic load, for instance, is one of the typical hardships for maintenance contractors. Heavier traffic means more requirements for maintenance. The amount of accumulated snow on the right of way is also a hardship. Extraordinarily deteriorated infrastructure and inclement weather condition can be, too.

e. Value Added

Value-added measures are customer-oriented outcome measures expressed in terms of the value received by the customer. Measures of value added include an increase in customer satisfaction or an

increase in economic value from, for example, travel time saved or life-cycle costs avoided.

3-1-7 Alternatives of Outsourcing

In case that, after careful discussion, the organization makes the decision not to employ outsourcing, what kinds of alternatives do they have? Possible solutions are;

- Selling the unit
- Setting up a joint venture
- Spinning off the unit to its employees

These alternatives should be discussed in the organization if outsourcing is determined to be avoided.

3-2 Types of Contracts and its Characteristics

Needless to say, contract is also popular for us and easy to understand what it is. However, before discussing practical issues about contracting, we need to confirm the various kinds of it and its characteristics respectively. In this section, we will briefly confirm the principles associated with contracting and the current trends associated with it, too.

3-2-1 Contract

According to a dictionary, the word 'contract' is, 'a legal document that states and explains a formal agreement between two different people or groups, or the agreement itself.' Each prospective party, who is going to make a contract, has an expectation toward another party, and negotiates with each other on monetary and environmental conditions, and finally, if it is acceptable, reaches a formal agreement. A contract is a product of these rigorous processes.

Firms need to rely, by and large, on the others' resources and skills to achieve their business goals; thus contracting is a necessary skill in order to survive. Transportation agencies, of course, are not exceptional and actually, as noted in the previous chapters, they heavily rely on contractors that have special skills in each specific area. One thing we should mention is that there are various kinds of contracts to be chosen in terms of relationship types, pricing methods, and ordering methods (Fig 6). Relationship types range from traditional to alliance, pricing methods vary from fixed-price to cost-plus, and ordering methods consist of method-based and performance-based. Each method has strengths and weaknesses respectively.

Therefore, choosing the appropriate kind of contract that is tailored to the situation is a key maximizing the benefit from a contract. In this chapter, we will confirm the fundamental issue about contracting, characteristics of various types of contracts, and discuss appropriate combinations to enhance the benefit of contracting. We will basically have a discussion based on public procurement contracts in this chapter, unless otherwise noted.

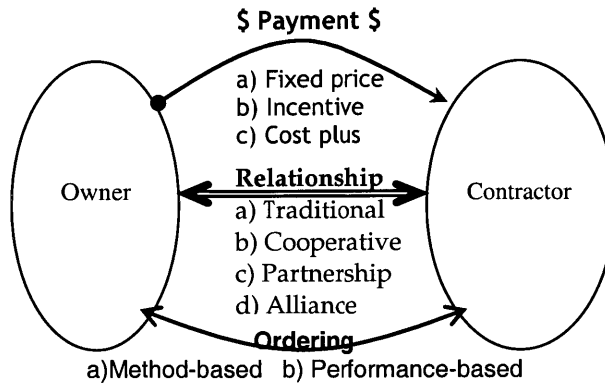


Figure 6 Categories and types of contracts

3-2-2 General Topics about Contract Management

Multiple Phases in Contract Lifecycle

In considering a lifecycle of contracting, we could divide it into three phases, which are transition, ongoing, and succession phases, chronologically (See Table 10).

The first phase is the transition phase when the details of the contract are finalized, and a strategy for smooth transition from the previous arrangements to the new arrangements should be developed. Through the selection process, recommended tender is announced, and the contractual relationships are established. Special care should be paid not to interrupt service delivery and impact on clients and stakeholders should be avoided.

Table 10 Lifecycle activities of contracting

| Phase | Step | Lifecycle Activities |
|------------|--------|---|
| Transition | Step 1 | Specifying the activity |
| | Step 2 | Selecting the acquisition strategy |
| | Step 3 | Developing and releasing the tender documentation |
| | Step 4 | Evaluating the tender bids |
| | Step 5 | Decision and implementation |
| Ongoing | Step 6 | Ongoing management |
| Succession | Step 7 | Evaluation and succession planning |

Common Risks associated with Contracting

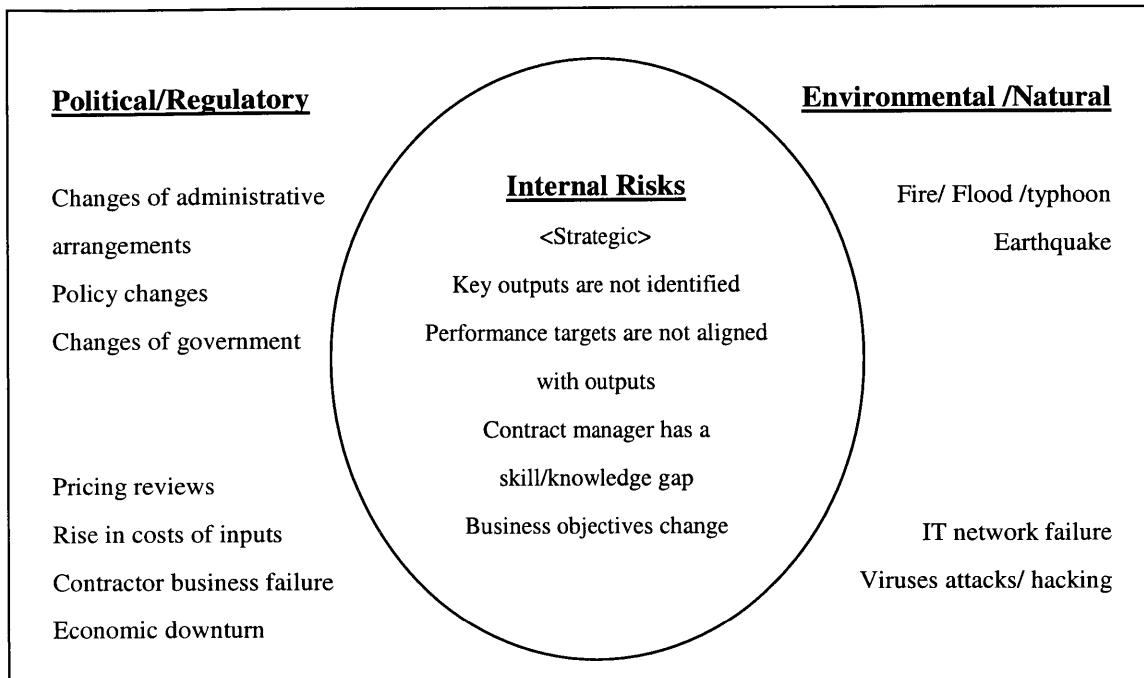
Well-managed contracts can bring significant benefits to an organization. The distinction between a beneficial a contract and an unsuccessful one falls in the way that the risks associated with the delivery of those services are managed. Risk management is among the important issues in contract management.

The first step in risk management associated with contract management is ensuring that the contract is completely understood by all parties. The three key issues are; the output that the contracted service supports; the critical success factors to the delivery of the outputs; and the internal input necessary for the delivery of the outputs.

Risk assessment is the second step. There are two kinds of risks that should be clarified, contract risk and contract management risk. Contract risk is the risk associated with the delivery of the service, in other words, the probability that the service will not be delivered in accordance with the requirements of the contract in terms of time, cost, quality and quantity. Most of these risks arise externally, which may be considered 'uncontrollable'. On the other hand, contract management risk arises from within the organization. In general, this type of risk is less likely to occur; however, it may lead to the erosion of the contractual relationship and ultimately adversely affect service delivery.

After the identification of risks, the third step is risk analysis. The magnitude of the impact given by each unfavorable event should be figured out in order to understand the vulnerability of the system in terms of service provision. Some alternatives can be suggested to reduce the impact and enhance stability of service by accurate risk analysis.

The final step is risk treatment. The owner may accept, control, reduce, or transfer these risks identified and analyzed. The common risks which have been related to contracting are shown in Figure 7.



Resource: ANAO, 2001

Figure 7 Examples of Common External and Internal Risks to be Considered

3-2-3 Types of Pricing Method

A wide selection of contract types is available to the owners and contractors in order to provide needed flexibility in acquiring the large variety and volume of supplies and services required by owners. Contract types vary according to

1. The degree and timing of the responsibility assumed by the contractor for the costs of performance; and
2. The amount and nature of the profit incentive offered to the contractor for achieving or exceeding specified standards or goals.

The specific contract types range from **firm-fixed-price**, in which the contractor has full responsibility for the performance costs and resulting profit (or loss), to **cost-plus-fixed-fee**, in which the contractor has minimal responsibility for the performance costs and the negotiated fee is fixed. In between are the various **incentive contracts**, in which the contractor's responsibility for the performance costs and the profit or fee incentives offered are tailored to the uncertainties involved in contract performance.

Fixed-Price Contracts

Fixed-price contracts are generally appropriate for services that can be defined objectively and for which the risk of performance is manageable. Simple service provisions, such as office cleaning, are suitable for fixed-price contracts¹⁵.

Firm-fixed-price contracts are fixed price contract without any adjustment during the term of the contract. Careful estimation in advance should be required to figure out the accurate total cost to deliver service; however, it is so difficult that overpayments are usually problems related to this payment method. Therefore, employing this method for a complex service that involves several high risks is not suitable.

Fixed-price contracts with economic price adjustment are sometimes applied when the duration of the contract is longer than one year. Adjustments are usually based on established prices, actual costs of labor or material, or cost indexes of labor or material.

Cost-Reimbursement Contracts

A cost reimbursement (cost-plus) contract enables contractors to be reimbursed for all the cost that is incurred during the contract period. A cost-plus contract is suitable for contracts that involve high risks for contractors, such as research and development (R&D) for totally new technology, or a material supply contract under highly fluctuating raw prices. When uncertainty is too high, contractors cannot expect enough profit under a fixed-price contract, and then contractors will not even try to join the bidding. Cost-reimbursement contracts are preferred in such situations.

Incentive Contracts

Federal Acquisition Regulation denotes, 'Incentive contracts are appropriate when a firm-fixed-price contract is not appropriate and the required supplies are services that can be acquired at lower costs and, in certain instances, with improved delivery or technical performance, by relating the amount of profit or fee payable under the contract to the contractors' performance.' This means that the final payment is not exactly fixed in advance, but will be determined in accordance with the quality of performance that the contractor has implemented during the contract period. If the quality of performance was inferior to expectations, some degree of penalty should be imposed, so that moderate tension can be maintained between contractors and owner. Negative incentives are also required to motivate the contractors.

¹⁵ In addition, Fixed-price contracts with prospective price re-determination, Fixed-ceiling-price contracts with retroactive price re-determination, Firm-fixed price level-of-effort term contracts, are listed in FAR.

There are two major tools to activate the incentive scheme, cost incentives and performance incentives. First, if the actual cost for the contractor is below the estimated cost, the saved cost can be shared with the owner and the contractor based on an adjustment formula. A contractor, thus, will be encouraged to perform in a cost effective manner. Most incentive contracts include only cost incentives. Second, performance incentives, even though they are not utilized often, may be considered in connection with specific elements of the contractor's performance. Positive and negative performance incentives shall be considered in connection with service contracts for performance of objectively measurable tasks, when quality of performance is critical and incentives are likely to motivate the contractors. In addition, when the owner's significant concern is the time of delivery, delivery incentives can be considered.

When the owner tries to structure a multiple-incentive arrangement, it should motivate the contractor to strive for outstanding results in all incentive areas. However, incentives can conflict with each other. For example, when very attractive performance incentives that overwhelm cost incentives are provided, the contractor can focus on performance improvement neglecting some cost overruns. If the owner's primary objective was low cost, the result would not be in accordance with the owner's expectation. Therefore, arranging multiple-incentive to balance each component is essential to the success of contracting.

Historical Transitions of Pricing Types and its Characteristics

Traditionally, government contracts under sole-conditions have been awarded either as fixed-price or cost-plus contracts. The use of fixed-price contracts has been confined to projects with relatively few technological and economic uncertainties. Governments are usually reluctant to sign fixed-price contracts when there are these uncertainties or major information asymmetries. Moreover, governments tend to pay too much due to the difficulty in evaluating appropriate costs in advance. Therefore, the usage of fix-price contracts is limited. On the other hand, cost-plus contracts avoid the problem of overpayment by governments, but the government subjects itself to the problem of 'cost padding', because the contractors' efforts for cost reduction tend to be limited in this scheme.

To control the negative incentives of cost-plus contracts, it has become common practice in the US to replace standard cost-plus contracts with 'cost-plus-fixed-fee contracts', so that the firm's profit allowance is fixed rather than being proportional to actual project costs. 'Cost-plus-incentive-fee contracts' are also used nowadays, in which the contractor's profit increases proportionally with cost

under-runs relative to the cost target.¹⁶ An incentive contract lies between the fix-price and cost-plus contracts, and it is quite an ideal scheme that could bring benefits for both owner and contractors.

As a summary, the relationship between these pricing methods and risk allocation is shown in Figure 8. Such projects like totally new research and development might involve a certain amount of risk and uncertainty due to the lack of experience; thus they are likely to be priced under cost-plus contract. On the other hand, relatively simple tactical contracts, such as cleaning classrooms at a university, might not have a risk to be taken care; thus the (firm) fixed-price contract is suitable. The problem is how both parties reach agreement in terms of the understanding of involved risk. If it is agreed and settled in an inappropriate form of pricing method, both parties will never feel comfortable during the contract term.

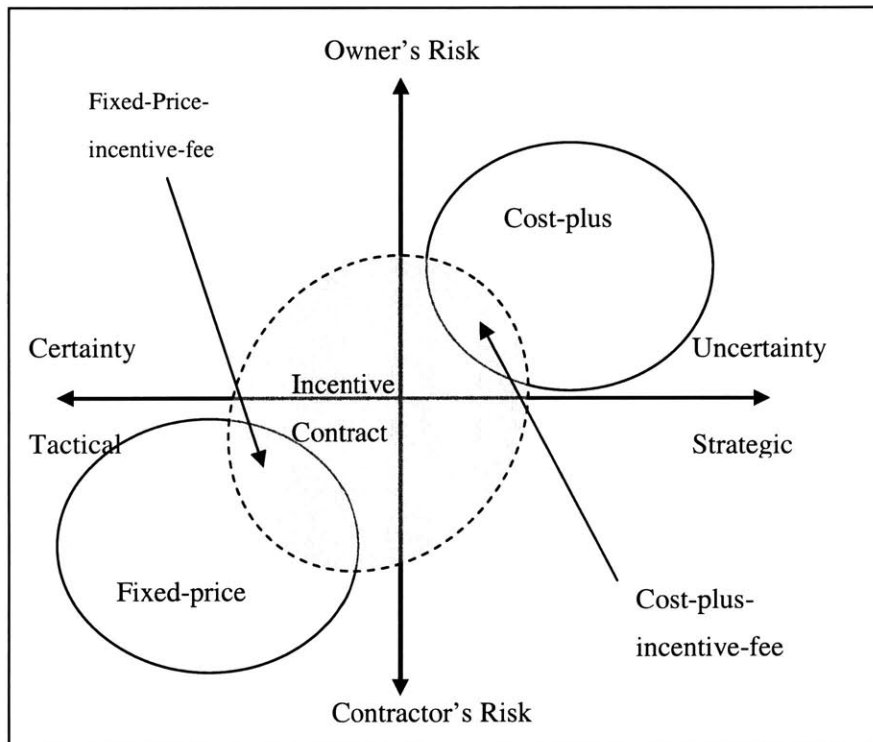


Figure 8 Relationship between Three Major Pricing Methods and Risks

¹⁶ Stefan Reichelstein, Constructing incentive schemes for government contracts: an application of agency theory, THE ACCOUNTING REVIEW, 1992 October

3-2-4 Order Styles; Method-based and Performance-based Contracting

Conventionally, specification based contracts; by which owners order methods and outputs precisely, whereas contractors implement just as they are ordered to do; have been common in the service procurement contracts. However, in some areas nowadays, the performance-based contract (PBC) is becoming common.

Brief History of PBC in the US

It is said that the US federal government annually spends about \$100 billion for contract services. However, it turned out that these contracts are plagued by significant cost overruns, performance problems, and waste. As a result, the Office of Federal Procurement Policy (OFPP) issued Policy Letter 91-2, "Service Contracting," in the beginning of the 1990's, and PBC was introduced aiming to correct these problems associated with the conventional contracting methods.

Early results from the pilot project have been positive. For example, aircraft maintenance contracts by the Department of the Navy and vehicle maintenance contracts by General Services Administration were converted to PBC. As a result, eight agencies reported that the 12 contracts converted achieved an average price reduction of 15 percent.

In the transportation area, the Department of Transportation just began applying PBC methods¹⁷ recently in the area of highway maintenance contracts, which resulted in a great success both from cost control and pavement performance perspectives. Because of the PBC method, the International Rough Index (IRI) of the state highway had been kept around 0.80 for three years, while those of other highways, which are covered by conventional contracts, got worse from 1.00 to 1.36 during the same periods¹⁸.

Definition of PBC

The definition of a performance-based contract is, 'essentially structuring all aspects of an acquisition around the purpose of the work desired as opposed to either the manner by which the work is to be

¹⁷ Strictly speaking, it is a warranty contract by which contractors should maintain the highway with outcome base. This types of contracts can be found in Ohio, Michigan, Washington, Arizona, and Florida states.

¹⁸ Williams (2004)

performed or broad and imprecise statements of work¹⁹.’ Critical elements of effective PBC have attributes such as;

- Well-defined and clearly written statements of work with achievable performance standard,
- A performance requirement summary which sets the performance standard for each measurable service for the contract, defines acceptable quality levels,
- Methods of surveillance and percentage of the contract price each service represents to establish the basis of payment for acceptable and non-acceptable performance, and
- A quality assurance surveillance plan.

In short, PBC is a contract that defines performance expectations in terms of outcomes or results. In contrast, the traditional method-based contract defines methods and processes to produce the outcomes. The focal point shifts from output to outcome, as shown in Figure 9.

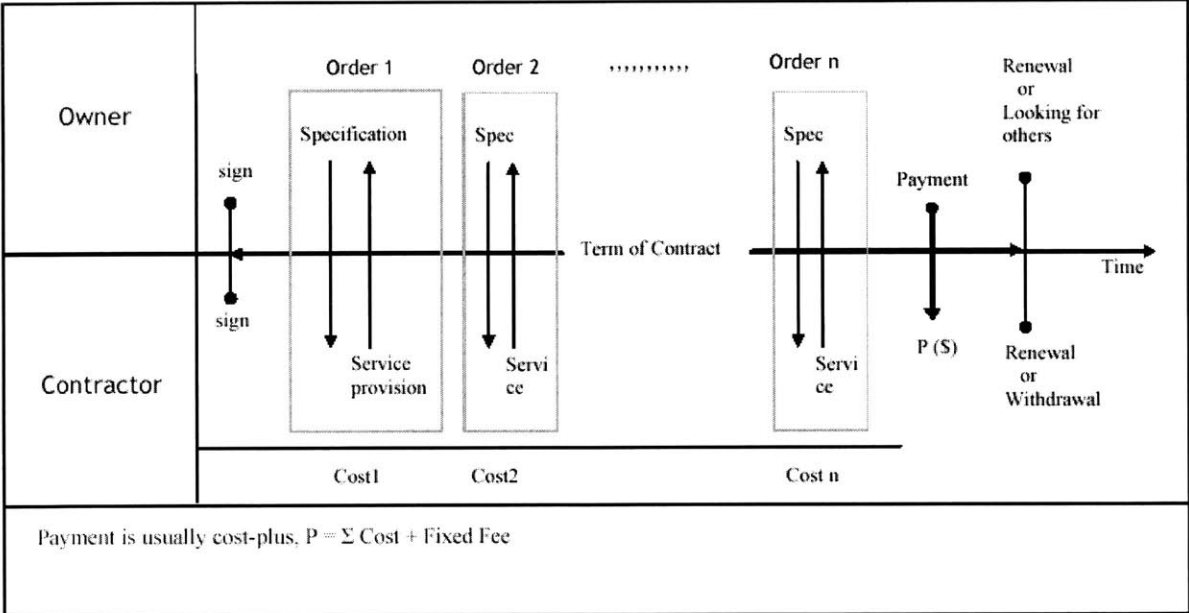
| | Input | Output | Outcome | Value added |
|-------------|-------------------|--------|---------|-------------|
| Traditional | [Blurred content] | | | |
| PBC | [Blurred content] | | | |

Figure 9 Different Focus Points between Traditional Contract and PBC

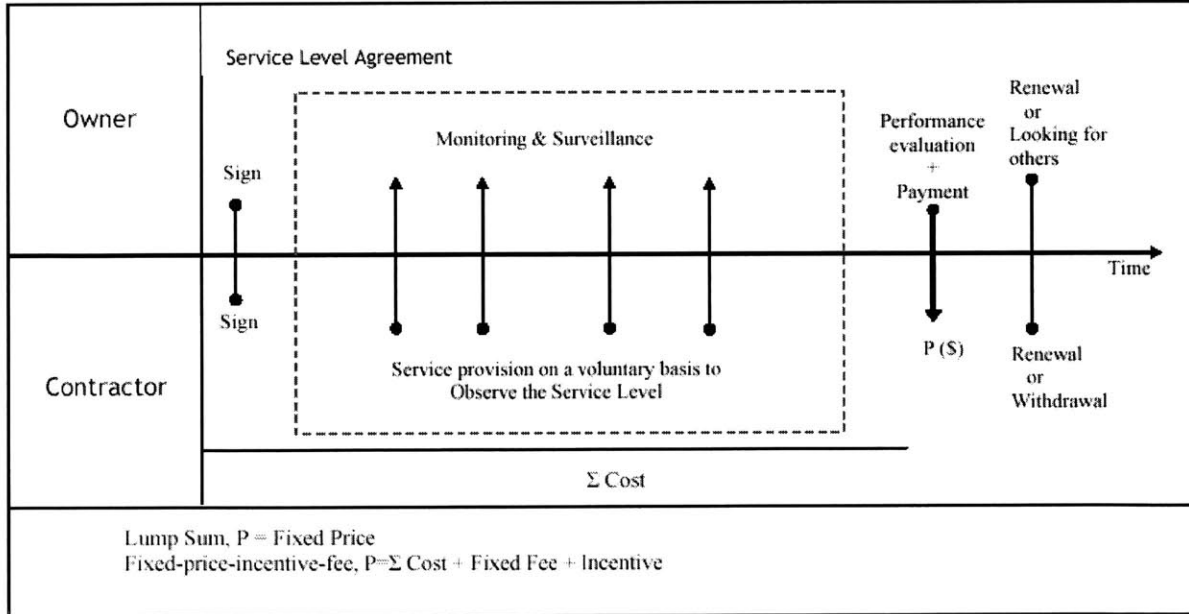
Figure 10 illustrates the comparison between both types of contracting. Traditional method-based contracting requires owner’s involvements in every single opportunity when contractor’s service provision takes place, because owner needs to diagnose the ‘method’ of the service. Usually, quality assurance follows every time, too; thus owner is involved frequently and contractor’s freedom is limited in terms of choice of method.

On the other hand, PBC releases owner from these administrative work, focusing mainly on the outcomes of service. Prerequisites are that both parties agreed the level of service in advance and only qualified contractors should be chosen. Contractors are free from method constrain; thus their productive ideas can be utilized effectively.

¹⁹ Department of Energy, Performance Based Contracting Guide, June 1998



Traditional Method-based contracting



Performance-based contracting

Figure 10 Illustration of Traditional contract and PBC

Performance Measurements

Under Performance-based Contracting, the key issue is how an objective measurement scale can be set and agreed upon by both the owner and contractors in advance. Without appropriate scales, both parties would be confused when evaluating the contractor's performance and finalizing total payment at the end of the contract period.

Outputs and outcomes should be distinguished by using a measuring performance. Outcomes are results, effects, or changes that occur due to delivering a product or service, conducting an activity, or carrying out a business process, while outputs are a measure of production or accomplishment regardless of its quality. In terms of performance measurement, outcomes are more important than outputs only.

Costs and Benefits of PBC

PBC methods are intended to ensure that the required performance quality levels are achieved and that total payment is related to the degree that services performed meet contract standards.

Nowadays, among the public sectors which are trying to reduce their operating costs, PBC is gradually applied to their procurement contract. From the owner's point of view, the merits of employing PBC instead of a conventional contract are;

- 1 Reducing a level of commitment in contracting administration work,
- 2 Responsibility for assuring quality performance is also transferred to contractors,
- 3 Cost reduction and performance improvement can be expected, and, as a result,
- 4 Dynamic reallocation of their resources and organizational restructuring are possible.

On the other hand, contractors also enjoy several merits associated with PBC. Compared to the conventional specification based contract, there is much more room for contractors to activate their own resources and improve the way of service delivery. Without any constraints on delivery methods, contractors are allowed to make the best use of their accumulated skills, techniques, and newly developed technology and materials. If they have had a lot of experience in the service provision and accumulated a certain level of know-how, it would be much more possible for them to manage and improve their service delivery methods, and at the same time, reduce their operating cost, which may result in gaining more profit.

As noted above, performance-based contract has a high potential to reduce waste as a total system by

utilizing the efficiency that contractors inherently possess.

However, we should not ignore the downsides of this contract. There are three major disadvantages in PBC from the owners' perspective. First, the difficulty in choosing an appropriate contractor should be mentioned. An owner should look for a reliable contractor that has enough skills and resources to accomplish an expected level of service. Due to the larger freedom for a contractor's choice of methods and materials, a reliable contractor should be awarded in PBC, otherwise, the project itself can fail. In addition, contractors tend to be reluctant to join in the bidding process because of the increased liability and risk in PBC. It makes it more difficult for the owner to find an appropriate contractor. Second, clear statements of work (SOW) should be prepared before starting the contracting phase, or bidding, to avoid any misunderstandings about the content of the project. If outcomes are too complex to be measured, bidders would be confused and could not estimate costs accurately. Third, surveillance costs can be higher than prospective cost reduction driven by PBC introduction. If quality assurance is too frequent or precise, administrative costs can be much higher than prospective cost reduction, so the disadvantages of PBC overwhelm the advantages.

3-2-5 Relationship Types between Owner and Contractors

In light of the relationship between the owner and the contractors, contracts can be categorized into four kinds, such as traditional, cooperative, partnering, and alliance contracting. In particular, the advantages of alliance contracting are focused nowadays in construction and maintenance to establish a productive relationship between the two parties.

Traditional Relationship

Historical relationships between owners and contractors have been dominated by legal and contractual obligations. The legal framework creates a strong compliance/control relationship relying on extensive checking and verifying of the contract against the service delivery and a tendency toward an 'adversarial' culture. However, this type of contract is appropriate where the scope of the service is narrow and accurately defined, in other words; the potential for variation during the contract period is low, and the risk of failure is also low. For instance, cleaning, catering, and grass cutting are appropriate in a traditional relationship. Downsides of this type are poor communication; lack of continuity between projects; time-consuming administration in processing variations, claims and negotiations; and a tendency for an adversarial relationship.

Cooperative Relationship

Cooperative relationships bring the contracting parties closer together and involve both parties in cooperative management of the contract. This approach incorporates ideals, such as developing trust, obtaining commitment and improving communication, but does not extend to some of the higher ideals such as risk sharing. This style of relationship can be used as a stepping stone to ascertain whether there is potential to develop the relationship further.

Partnering Relationship

Partnering is a formalized process underpinned by both a legal contract and moral commitment by key stakeholders and other parties to act in the best interests of each other. The basis of partnering is: together we can solve problems and maximize opportunities. This relationship has existed in the construction industry in Australia for over 10 years.

Principles of partnering can be applied at an operational level with contracts that deliver support services to core businesses, in order to promote contract effectiveness and efficiencies through: commitment by both parties based on common objectives; equity and trust; implementation of joint strategies for developing mutual goals; and continuous and joint evaluation.

Alliance Relationship

Alliance relationships describe the situation where the owner and contractors assume a degree of joint management responsibility for the delivery of the prescribed goods and services. It takes the key elements of partnering to the next level by having a risk/reward sharing philosophy as well as a transparent or open-book approach towards all financial matters, including cost and profit.

Alliance relationships are best suited for providing services that are difficult to define or are likely to change substantially over time, critical to an organization's performance or requiring innovative solutions from the contractors and creative management by the owner. Long-term, strategic contracts when each party relies on each other are suitable, too. As a tool for measuring performance, key performance indices (KPI) are usually defined beforehand according to the characteristics of service. These indices are also used as evaluation for the contractor's contribution, which will result in bonuses and penalties for contractors. Milgate (2001) denoted that alliance is employed to achieve the following three objectives;

- To provide extra leverage for the organization's core competencies in order to deliver long-term sustainable competitive advantage;
- To move the organization into long-term and developing commitment to new markets,

- territories, or technologies that were previously closed to it; and
- To provide a platform for the kinds of organizational learning that is central to its future business success, but would otherwise be unobtainable.

Figure 11 maps the appropriateness of these types of relations according to the risks and likelihood and significance of failure in the contracted service.

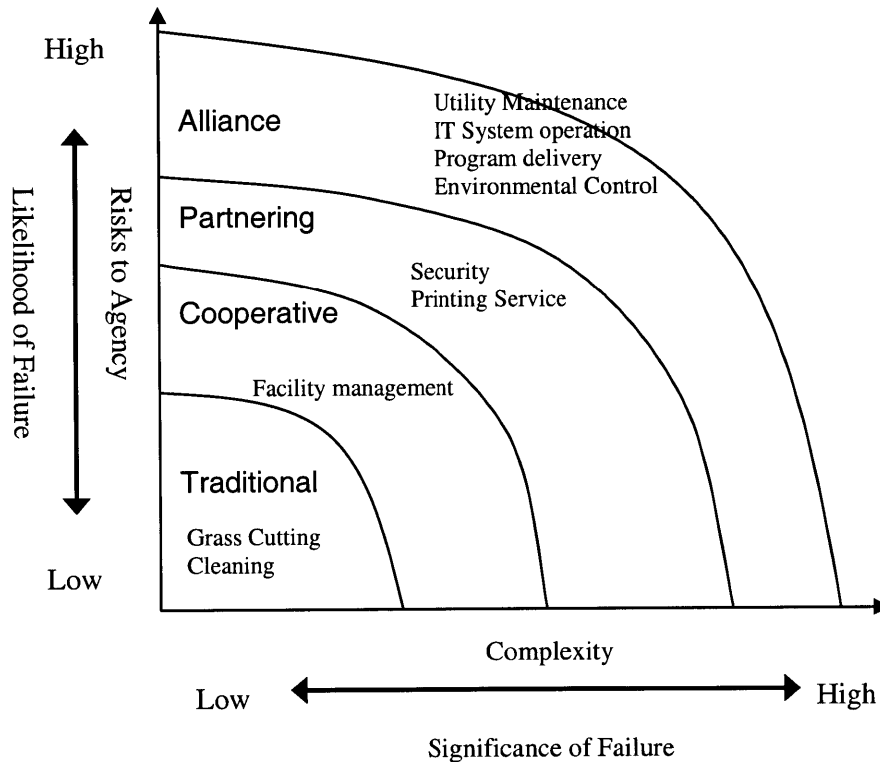


Figure 11 Relationship Styles, Magnitudes of Risks, and Complexity of Service

[resource; ANAO, 2001]

3-2-6 Combinations among these Attributes of Contracting

As we discussed above, the characteristics of various kinds of contracts are clarified. Attributes of pricing, ordering, and relationship styles are in accordance with each other, and enhance the benefit that the contract would bring. In general, the magnitude of risks that a certain contract possesses is a key in determining the fitness of each contract's attributes.

For instance, PBC is one of the innovative contracting methods that has emerged in a decade, and has

a significant possibility for improving the contractual framework. As noted before, PBC is the method to encourage the contractors' effort and to aim the benefit for both the owner and the contractor. In light of this, the pricing method should be synchronized with the characteristics that PBC possesses to enhance the incentive scheme. Therefore, an incentive contract or fixed-price contract fits PBC, but a pure cost-plus contract does not fit. (However, a cost-plus incentive-fee contract would fit).

As a summary of this section, Table 11 is shown below to illustrate the appropriate relations among those attributes discussed so far. In conclusion, risks and complexity associated with the contracted work are the key variables to determine the appropriate contract structure.

Table 11 Matrix of Relationship between Pricing and Ordering Methods

| | |
|--------------|---|
| Complexity | Low ←-----→ High |
| Project Risk | Low risk ←-----→ High risk |
| Pricing | Fixed Cost Incentive Cost plus |
| Ordering | Performance-based* |
| | Method-based |
| Relationship | Traditional/Cooperative Partnering Alliance |

* PBC should be applied only when service provider possesses enough competitiveness.

Chapter 4 Railway Track Maintenance and its Contract Structure

In this chapter, we study the situation in which the railway organization tries to outsource maintenance activity to contractors. According to the discussion so far, we understood that the appropriateness of employing outsourcing depends on the organization's core competency, and contract structure depends on the risks and complexity of work that is going to be outsourced.

In the first part of this chapter, the attributes of track maintenance will be discussed. In addition, we will discuss the complexity of track maintenance and draw conclusions about the ideal contract structure.

4-1 Railway Track Maintenance

4-1-1 Typical attributes of Track Maintenance

Long History and Experience

The railway itself has had a long history since it was invented, as do maintenance. It means that the methodology of track maintenance has already been established, and the cost structure has also been learned by experience. In this point, track maintenance is totally different from highly uncertain projects such as constructing a new jet plane by incorporating brand new technology.

Slow Technological Development and High Maturity of Service

In contrast with product development in the manufacturing industry, whose technological clock speed is usually too fast to follow, technological development in track maintenance is relatively slow nowadays. However, in some areas, such as inspection and database, technology developed in other industries has been adopted to enhance the efficiency of inspection.

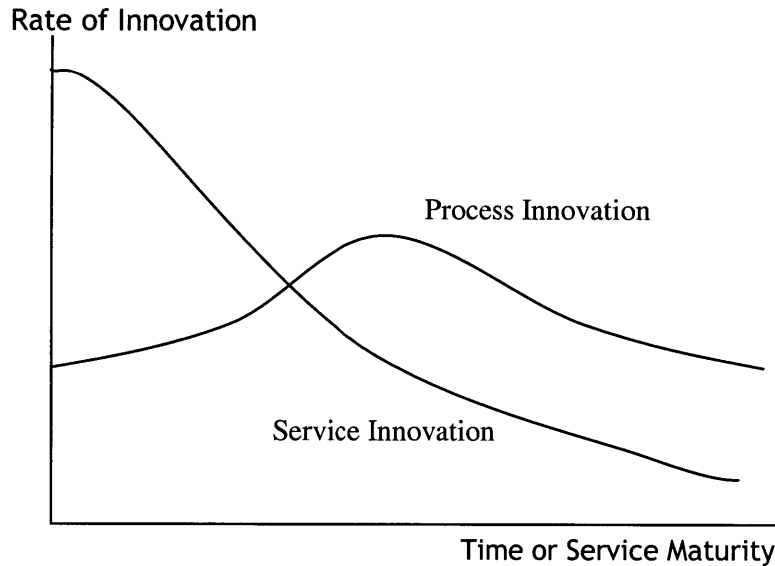


Figure 12 Level and Type of Innovation [reproduced: Abernathy 1975]

Track maintenance can be regarded as a highly matured service; thus, the rate of process innovation is supposed to be much higher than service innovation itself. Figure 12 shows the chronological change in the level and type of innovation. This graph indicates that the methodology of track maintenance has already been innovated, while the process of it still has much room for innovation.

In terms of track maintenance, the 'process' means total procedure to maintain track assets, which includes the organizational structure and maintenance procedure ranging from inspection to decision making about upgrading and replacement. This process management should be focused, rather than maintenance methodology itself.

Cyclic and Continuous work

Maintenance is continuous throughout 24 hours a day, 365 days a year. As long as the railway operation is going, maintenance is a needed service. Moreover, current maintenance policy can be influential for future conditions, too. In this sense, continuous effort is very important in track maintenance. Once maintenance is neglected, the deterioration accelerates, which results in more maintenance. Technical standard is usually regulated by the government. Maintenance sectors are required to meet this standard by inspecting and repairing infrastructure.

Less Competition amongst Local Service Providers

In general, as noted before, track maintenance is commonly performed by in-house railway engineers. Moreover, even if track maintenance is outsourced, contractors are not exposed to rigorous competition because the assets to be maintained are geographically fixed and widely spread. This requires more geographical knowledge and culture about a particular region, which usually prevents other contractors from penetrating the operating area at hand. Under this inherently protected environment, maintenance contractors can earn moderate profits for a long time.

High Labor Costs in Railway Track Maintenance

In general, railway track maintenance is highly labor-oriented and complex job which is comprised of multiple kinds of tasks. The American Public Transportation Association (APTA) has identified that about 10% of operation cost is for track maintenance, and 78% of it is just labor cost²⁰. This fact indicates that, in general, the ratio of labor cost is very high in railway track maintenance.

Wide Scope of Work

Generally, the scope of practical maintenance work can be divided into two parts; planned routine maintenance and emergent scrambles. Routine maintenance, in this context, ranges from inspection to repair work, and it sometimes includes decision making on replacement. This area is more in the engineering-oriented field based on the principle of proactive maintenance.

On the other hand, emergent scrambles mean unplanned treatment for some accidents associated with infrastructure or inclement weather, such as heavy snow or storms. These are totally unpredictable, however, if the treatment is delayed, train operations would be greatly jeopardized, which results in the amplification of the customers' complaints. Quick responses to these kinds of accidents are also an important role for maintenance sectors in order to prevent the deterioration of customer satisfaction. All in all, the scope of maintenance is wide, from the engineering aspect to security against natural disasters. Putting all the scope of maintenance work in the statutory form is difficult in railway infrastructure maintenance.

²⁰ Wribhu Tyagi, 2002

Tight Relationships between Operation and Maintenance in Railways²¹

Relations between operation and maintenance should be much tighter in the railway than that of the highway and other infrastructures. The major reasons for this required tight relationship are;

- Vulnerable service -- Service operation can be interrupted easily and widely by any single deficit in the infrastructure
- Limited availability of service -- Customers cannot enjoy their service at all while operation is interrupted
- Customers' perception -- Their direct perceptions are usually reflecting operations, but often these are related to maintenance issues.

From the operator's point of view, operation and maintenance should communicate with each other to provide higher quality of transportation service and to maximize the customer's satisfaction. In the case of US freight rails, maintenance work is basically planned during the daytime which ends up interrupting a part of the scheduled operation; thus more frequent communication is required between maintenance and operation to minimize the loss of money. In addition, in the case of an emergency, this harmony among different sections is required in order for operation to resume to normal.

4-1-2 Basic Structure and Function in each Component of the Railway Track

Even though several innovations have taken place, the overall shape of the railway track has not changed since it was invented in the United Kingdom. As shown in Figure 14, a pair of rails is fixed on the sleepers which are connected by fastenings, and sleepers are supported by plenty of ballasts that are stacked on the ground. Each component has its own function to perform so as to create harmony among them.

The function that the rail should perform is to support and guide the movements of rolling stocks by the appropriate vertical and horizontal alignments and firm material. A steering wheel is not equipped in a rolling stock; thus the rail should guide the train's movement correctly. When the alignments of dual rails are wrong, the train will shake uncomfortably or, if the degree is



Figure 13 Basic Structure of Railway Track

²¹ Refer to Appendix B for more detailed description about interaction relationship in railway organization.

extreme, it can derail on the site, which will bring significant damage to punctual operation and will also jeopardize the passengers' safety. In addition, material soundness is also important for the rail to accomplish its function. Overlooked rail fatigues can be a broken rail, which can cause a delay of train operation or an accident. In general, the progress of rail fatigue is difficult to be detected by sight inspection; thus inspection by ultrasonic sound by which even small cracks inside rails can be detected is useful.

The function of sleepers is fixing the gauge and holds the rails so as not to move in the longitudinal and vertical directions. Sleepers in the wrong condition cannot hold fastenings and cause the rails to move. This can cause a rail irregularity.

The function of ballasts is holding the sleepers to prevent them from moving. The ballasts should be angulated in order to keep their resistance to hold the sleepers firmly in place. The role of the ballasts is to hold the sleepers by interlocking them to each other. If this resistance is not enough, the sleeper can move easily and, as a result, rail irregularity or rail buckling tends to take place. When the ballasts become old, they should be replaced by using an under-cutting machine.

4-2 Frameworks applied to Railway Track Maintenance Outsourcing

We have already discussed the characteristics of track maintenance. We will discuss the availability of maintenance outsourcing in the railway, incorporating the frameworks given in the previous chapter.

4-2-1 Make or Buy? Decision Making about Outsourcing Track Maintenance

In chapter 3-1, the screening process of make-buy decision making is discussed. In response to the process, we will discuss the track maintenance outsourcing procedure.

Strategic Factors

Core Competency in railway business should be identified before deciding on an outsourcing strategy in each railway organization, as noted in Chapter 3-1. Of course, this identification depends on each railway's CEO's philosophy; thus there are no universal answers for this question. However, within the bounds of common sense, we can share a common view about the core competencies that the railway service possesses against other modes of transportation.

Core competencies that the railway possesses, in general, are punctuality, affordability, and service

stability. Maintenance supports these competencies by keeping the infrastructure's soundness, but maintenance itself is not one of the railway's core competencies.

Market Factors

The quality of maintenance contractors is an important matter to be mentioned. If it is extremely inferior, railway should maintain internally; otherwise, outsourcing can be chosen. In general, railway maintenance contractors are not exposed to rigorous competition, because the number of contractors is limited in each community. Finding well-qualified maintenance contractor actually might not be easy for the railway due to these reasons.

Service and Technology Factors

The scope of track maintenance is wide, which enables partial outsourcing for the railway. Partial outsourcing is much easier for the railway to employ, especially for the first step of launching an outsourcing strategy, because contracting structure can be limited in terms of the range of work to be done. For instance, solely geometry car inspection, which measures rail alignment, is likely to be outsourced to enhance the efficiency of inspecting large assets which spread widely in the operating area. Moreover, it is possible for the railway to only outsource repair work. Another way of disintegration is possible, such as inspection and repair for bridges only. In this sense, track maintenance can be broke down into pieces, enabling partial outsourcing, which might be easy for the railway to employ.

Economic Factors

Cost estimation is also important, because cost reduction is the most hard-pressed problem in railway maintenance. As noted in Table 6, the cost of service delivery, investments, transactions, and surveillance should be examined in advance to ensure there is a cost advantage to the outsourcing strategy that may potentially be implemented.

Labor costs can be expected to be reduced dramatically by introducing outsourcing, because, in general, railway employees are protected by the labor union, which disables flexible management in terms of labor. Once a job is outsourced, the contractor should be able to manage the employees more cost effectively than those in the railway.

Even if direct labor costs were reduced by utilizing the contractors' cheap work force and effective

management, the railway should not neglect the other costs incurred by monitoring the contractors' performance and by switching from in-house to outsourcing. In particular, track maintenance requires a lot of specialized machinery and equipment. At the time of takeover, administrative work on transferring huge amounts of assets peaks, this is so time consuming that the routine maintenance work may be interrupted. The railway should be careful in terms of cost estimation. In addition, railway should make decisions only when total cost could be reduced.

If these factors are all taken into consideration, maintenance can be outsourced to the appropriate maintenance contractors.

4-2-2 What kind of Contracting is Suitable for Track Maintenance?

Let us assume that, after the screening process, the railway decides to outsource their track maintenance to an external contractor. Then, the next concern is what kind of contracting they should choose to ensure that the outsourcing is successful.

Performance-based Contracting

Rail track maintenance possesses a certain number of possibilities in applying performance-based contracting. The reasons are;

- Outcomes of track maintenance are more important than methods, and
- There are several measurable indices for outcomes of track maintenance.

First, the most important objective of track maintenance is keeping up the function of track in a cost effective manner, as noted before. Therefore, results do matter, while methods do not, as long as it is implemented effectively.

Second, the track is a tangible asset; thus we can measure the quality of the track in several ways. A more detailed description will be given in the next section. In contrast, evaluating the outcomes of school teachers in elementary school, for instance, is much more difficult in a subjective manner, since intangible contributions from teachers are generally much larger than tangible ones, such as an average score on an examination, in a stage of mandatory education.

A traditional method-based contract is the most reliable and steady way for transportation infrastructure maintenance, because each action, such as inspection and repair, is double-checked by the railway and by contractors. However, it requires a lot of contribution for owners in contract execution, as illustrated in Figure 12. In general, track maintenance is nothing new, have been in play since the origin of the railway; thus the methodology has already been established. Both parties

generally know how to do repair and what should be done. Therefore, the railway's contribution can be regarded as a waste that can be trimmed.

Combination of Fixed-cost-incentive-fee & Cost-plus

If the railway is going to outsource most of all maintenance, the combination of fixed-cost-incentive-fee and cost-plus would be suitable in terms of pricing. The reason is the wide variety of track maintenance, ranging from planned inspections and repair to unpredictable scrambles. In general, the former can be priced under fixed-cost basis, because its uncertainty is lower than the latter, which should be priced cost-plus basis due to its high uncertainty. Moreover, there are several measurable indices in evaluating outcomes of track maintenance, which will be mentioned later.

Alliance Relation

In terms of relationship, an alliance relation is better, because;

- Long-term perspective is essential in track maintenance, and
- Both parties need information accumulated individually by each party.

First, track maintenance requires a long-term perspective, thus a single year contract is not suitable. 5-year or 10-year contract are appropriate, if a reliable contractor is found. Long-term contracts would encourage contractors to invest in high-quality machinery and equipment which may be amortized in a contract period. Second, the maintenance contractor's information about the current condition of infrastructure is indispensable for the railway to make decisions about capital investment for upgrading infrastructure, while capital investment planning (CPI) would also affect maintenance planning for contractors. Adversarial relations would result in a zero-sum game, which would be the least ideal relationship in track maintenance.

In conclusion, theoretically and generally, performance-based contracting with contractors whose relation is 'alliance contract' under the combination of fixed-price and cost-plus basis fits the railway track maintenance outsourcing.

4-3 Performance Measurement in Track Maintenance

Needless to say, the maintenance contractors' minimum responsibility is observing the industrial standards that are regulated by the government or by railway organizations. However, in terms of performance measurement, outcomes should be taken into account, rather than outputs.

As mentioned in Chapter three, these four parameters are beneficial in evaluating the performance of maintenance contractors. We will discuss performance measurements based on these parameters in

railway track maintenance.

Inputs of Track Maintenance

Labor, equipment, material, and financial cost are major resources in terms of track maintenance. As noted before, the labor costs are relatively high compared to those of the other industries.

Generally speaking, transportation infrastructure maintenance is not in a technological field where cutting-edge technologies are developed intensively day by day, such as aerospace engineering or biotechnology. Conversely, it still remains to some extent a labor intensive industry. Of course, as is often the case with labor intensive industries, they try to mechanize in order to enhance the accuracy of work by introducing computer technology that has recently been developed. As a result, especially in the area of inspection, high technologies are gradually adopted; therefore the efficiency and accuracy have been improved dramatically. However, in terms of field work, such as spot repairing on switches or signals, manual works still play major roles and direct labor is still necessary.

Resources for track maintenance, in other words, inputs of maintenance vary. Maintenance sectors should hold a wide range of resources that span all the way from large machinery to tiny tool boxes.

Outputs of Track Maintenance

The structure of the railway track is relatively simple as shown above, but the maintenance engineers should pay attention all the way from alignment to material soundness in each component. The government or railway association in each country usually set the standards; thus maintenance sectors, at least, need to meet particular specifications. As outputs of track maintenance, these factors can be listed;

a. Repair for Rail Alignment

The primary function of rail is making fleets run smoothly on it. Thus, the alignment of rails is very important to satisfy this function. Alignments of rail can be broke down into several attributes, whose errors should be kept within the regulated ranges. Multiple Tie Tamper (MTT) is a powerful machine that fixes the alignment of rail for a long distance at once. The line miles of alignment repair is one of the outputs of the maintenance sectors' performance.

b. Replacement of Used Components

Each component should be kept intact; thus maintenance sectors need to inspect and detect any insights which indicate upcoming breakdown in a component. In this sense, the amount of replaced components, such as length of old rail replaced or the number of old sleepers replaced, can be regarded as outputs of maintenance work.

Traditionally, these two types of measures: inputs and outputs are emphasized in evaluating maintenance sectors' performance. For instance, average output per labor hour is a common variable to compare the efficiency of performance. However, the stress has recently shifted from outputs to outcomes.

Outcomes of Track Maintenance

Outcomes are more customer-oriented indices than outputs, as noted before. Outcomes that maintenance sectors can contribute to are;

- Contribution to the quality of infrastructure,
- Contribution to the operation punctuality, and
- Cost-effectiveness.

a. Quality of Rail Infrastructure

As noted before, measurement for the quality of rail track infrastructure is comprised of two major elements; alignment and material soundness. In evaluating the quality of rail infrastructure, these two elements are mutually interacting as if they are two sides of the same coin. Both elements should be in perfect condition when the quality of rail track is considered to be excellent. For instance, perfect alignment is not necessarily equal to the high quality of rail tracks, because the information about material quality is lacking.

The P-index that is figured out from detailed data collected by a geometry inspection car is commonly utilized in Japan to evaluate the degree of rail irregularity. Q and K indices²², used in European railway, are another kind of indices to measure rail track condition. All indices reflect the properness of rail alignment, which might be beneficial for the formulation of analytical track maintenance planning. In addition, these indices are a continuous measure, which is favorable for condition assessment as noted in chapter two.

On the other hand, generally speaking, material quality is hard to be measured by a continuous scale, because of its complexity; thus, discrete scales are suitable for describing these conditions. Rail

²² $Q = 150 - 100 [\sigma_H / \sigma_{H \text{ lim}} + 2 * \sigma_S / \sigma_{S \text{ lim}}] / 3$, $K = \Sigma l / L$

where σ_H and σ_S are the average standard deviation of height and interaction on the section measured.

$\sigma_{H \text{ lim}}$ and $\sigma_{S \text{ lim}}$ are comfort limits for a given track class. Σl is the sum of track length where all values are better

fatigue, condition of sleepers, condition of ballast is appropriate to be described in discrete scales, but there is no literature that analyzes the deterioration process in these elements.

All in all, we need to use track geometry index to represent the total quality of track infrastructure so far.

b. Operation Continuity—How the maintenance sector supports punctual operation

Customer-oriented managers will never miss the chance to evaluate the maintenance sectors' contribution to the operation punctuality. From the customers' point of view, it does not matter how good the materials used in rail infrastructure are. Their short-term interest is how punctual and comfortable railway service is.

If there are no service delays stemmed from the infrastructure's deficits, maintenance contractors should be applauded in some manners. The high quality of infrastructure might be the main reason for trouble-free service, but this scale is more easily understood by customers as an evaluation of the contractors' performance.

c. Cost effectiveness

Even though cost effectiveness will not directly give any benefits to customers, it might be in the long run, because cost saving can be transferred to other parts of improvement for the railway service, such as upgrading fleet interiors or station equipment. These indirect effects will matter in the long run.

Hardships Factors

The total amount of external obstacles should be considered when measuring the performance of the maintenance contractors.

A heavy traffic load is the most noticeable hardship for maintenance sectors, because it is the primary reason why the track deteriorates. In general, the tonnage on a freight line is higher than that of a passenger train, because the passenger fleet is developed to be lighter and lighter these days. The required amount of maintenance is usually figured out based on total tonnage on the line.

Moreover, due to the geographically wide spread assets, hardship for maintenance is relatively high compared to the other kinds of maintenance. Snow removal in severely cold areas is the main task during winter time. Heavy rain and storms should be taken into consideration, because this terrible weathers can interrupt operations. During these inclement weather conditions, routine maintenance plans would be jeopardized, which is an indirect disadvantage for maintenance contractors in these

than the comfort limits of a given track class, in the inspection of length L.

area. It may be difficult to quantify these hardship factors objectively, however, we should not neglect this point in performance measurements.

4-4 Incentive Scheme in PBC

As noted before, a planned and controllable part of maintenance should be priced under fixed-price-incentive-fee contract whose formula can be suggested as follows;

$$\begin{aligned} \text{Payment} &= \text{Fixed price} + \text{Base Profit} + \text{Incentive Profit} \\ \text{Incentive Profits} &= a * f_1(\text{Infrastructure quality}) \\ &\quad + b * f_2(\text{Operation delay caused by infrastructure}) \\ &\quad + c * f_3(\text{Cost incentive}) \end{aligned}$$

Where, a, b, c are variables to weigh these factors.

As an incentive part, not only cost incentive, but quality of infrastructure and contribution to service stability should be considered. The incentive formula can be customized based on each railway's philosophy; however, incentive should be directly connected with the desired outcomes that the railway expects, rather than outputs or other indirect factors.

Figure 14 shows the examples of the formula to figure out the incentive fees, rewards and penalties, in each component. In setting each formula, it is important to pay attention that negative incentives should not be so large that contractor can lose money. The primary aim of an incentive scheme is to increase the contractor's performance, rather than punishing contractors' inferior performance.

Of course, there could be another set of incentive schemes. However, the railway should be careful in choosing the combination of components linked with incentives, in order to build comprehensive and moderate incentives which are also accepted and agreed upon by the contractors.

In addition, hardship factors should be taken into account for incentives, especially when multiple contractors are involved.

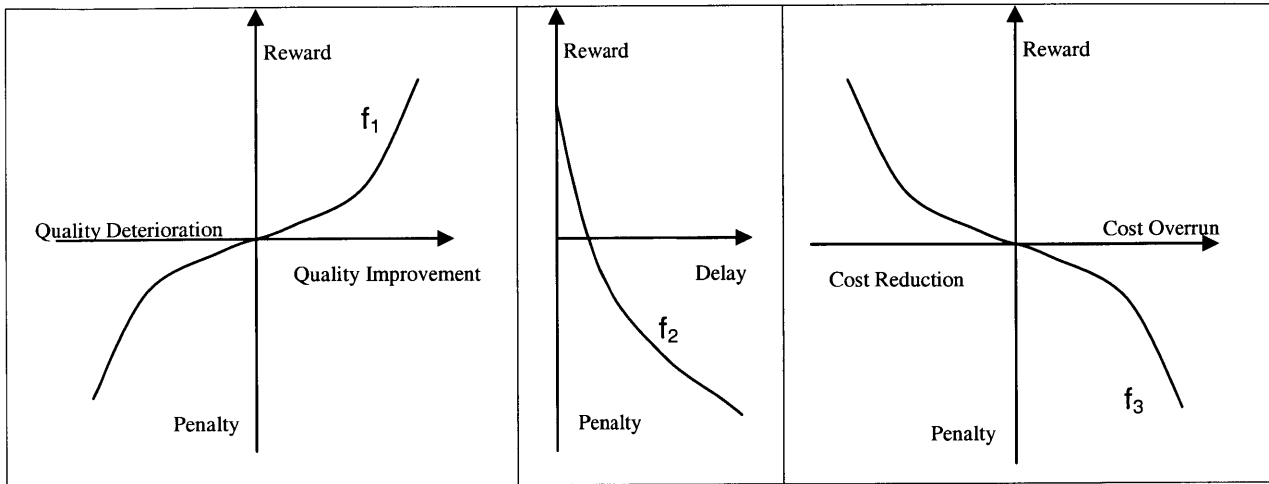


Figure 14 Example of incentive formulas (conceptual)

Chapter 5 Case Studies on Maintenance Outsourcings in Transportation Infrastructure

We have explored theoretical attributes of outsourcing strategies in the previous chapter. In this chapter, several examples in which characteristic contracting methods are employed will be introduced. Queensland Rail, an Australian railway mainly serving freight service, and Massachusetts Bay Commuter Rail, a commuter rail service in Boston, will be discussed as examples of railway maintenance outsourcing. Several successful examples of highway maintenance outsourcing will follow.

5-1 Queensland Rail (QR)

5-1-1 Background Information

Queensland Rail (QR) is one of the Queensland Government Owned Corporations (GOC), whose Headquarters office is located in Brisbane, Australia. QR's infrastructure is owned by the government; thus operation and infrastructure ownership are vertically integrated.

In 1995, Australia's National Competition Policy was introduced, which altered both the nature and future direction of Australia's rail transport industry. Owing to this policy, Australian State borders are irrelevant and QR's network is open to competition from interstate, national, and international rail operators. This enhanced competition has driven QR toward more well organized corporate management by reducing the waste and maximizing its profits.

The main service that QR provides is freight rail that transports coal produced in Australia. Other general freight service and passenger rail in metropolitan area are also provided, but the sales ratio of passenger rail is relatively small. Their total sales are growing year by year; and State Government shareholders were paid 170 million Australian dollars dividend in 2002. Due to this high performance, QR is ranked as one of the top ten businesses in the country.

QR is comprised of five main segments in terms of operation and maintenance; Passenger Services group, Coal & Freight Services, Network Access, Workshops group, and Infrastructure Services group. Network Access Group (NAG) and Infrastructure Service Group (ISG) are involved in infrastructure maintenance.

NAG's main roles are; managing railway access, infrastructure asset management, and network capacity and traffic management. They are negotiating with other rail operators seeking access to the QR network, at the same time, retaining ownership of rail infrastructure. Since the formation of the

expanded NAG in 1998, they have been in charge of managing whole rail track infrastructure, which should improve the efficiency of infrastructure management.

Infrastructure Service Group (ISG), which is composed of four regional teams, provides services and resources for maintenance, construction and management of the Corporation's rail infrastructure, with approximately 3800 employees. ISG annually carries out around \$452 million in works including QR and external clients interstate and overseas. ISGs are internal service providers that were set up as profit centers, which is a business unit that is treated as a distinct entity, enabling revenues and expenses to be determined so that profitability can be measured. Their continued employment is assured as long as the CEO thinks costs are under control. This separation of their internal maintenance unit is the first step in the process of outsourcing maintenance²³.

5-1-2 Maintenance Contract and its Incentive Scheme in Queensland Rail

In terms of maintenance planning and implementation, the alliance approach is employed between NAG and ISG. Five and ten year plans are drawn up by consultation at a regional and district level between field staff. The strongest point in infrastructure maintenance at Queensland Rail is that NAG is effectively encouraging their maintenance groups under a well-organized incentive scheme. NAG has set appropriate performance indices in evaluating maintenance groups' performance, which are associated with incentive packages. This scheme is unique and should be effective for encouraging maintenance groups to perform better. Even though the results has not been announced yet, their potential contract structure is worth scrutinizing.

Because ISG is an internal group, it does not fit the literal term of outsourcing. However, we hypothetically regard it as an outsourcing in this thesis. The scope of contracting is mainly on repair, rehabilitation work, and inspections by a geometry car.

The first step was setting measurements of ISG's outcomes. Five major Key Result Areas; safety, asset reliability, asset condition, maintenance performance, and cost control, are chosen. Each area is composed of several Key Performance Indices (KPIs).²⁴ These KPIs are utilized to;

- Set new performance targets,
- Check the performance of individual managers in ISG,
- Assess delays caused to particular trains, and

²³ Email communication with a manager of Network Access group in Queensland Rail.

²⁴ Refer to Appendix C for detailed information.

- Assess bonus or penalty payment for ISG.

KPIs are used as a communication tool between NAG and ISG managers.

As for payment, cost-plus-incentive-fee is employed as a payment method in QR. Incentives are determined based on six KPIs chosen for assessment of bonus or penalty. There are two important issues in regards to the building incentive scheme; those are the choice of incentive attachments and the size of incentives. First, bonuses and penalties are directly attached to desired outcomes, rather than intermediate processes that in themselves may not deliver the desired outcomes. Second, the penalty is generally set so that ISG never actually loses money. They would make no profit only when at worst. This is to ensure the stability of the maintenance group for a predetermined minimum period.

Even though QR is a publicly owned corporation, they work hard to improve customer satisfaction; the infrastructure maintenance sector is also employing innovative approaches to maximize their effectiveness and to support QR's financial stability. This corporate wide activity should be a good example for transportation infrastructure owners in the world.

5-2 Massachusetts Bay Commuter Rail (MBCR)

5-2-1 Background Information

The commuter rail service in Boston is operated by the Massachusetts Bay Transportation Authority (MBTA). The nation's oldest subway service has been owned and operated directly by the MBTA, while commuter rail service's operation and maintenance are totally provided by an external contractor that is chosen by competitive bidding.

In July 2003, Massachusetts Bay Commuter Railroad Company (MBCRC)²⁵, which is in a partnership with three leading transportation companies: Connex North America, Bombardier, and Alternate Concepts, Inc., took over the operation and maintenance of the commuter rail. MBCRC was qualified by the MBTA and won the competitive bidding process after having competed with several competitors.

5-2-2 Characteristics of Maintenance Contract in MBCR

As noted above, both operation and maintenance are outsourced in MBCR. The maintenance contract has three major characteristics. Those are wide range of responsibility in maintenance contractor,

fixed-price-incentive-fee contract, and performance-based contract.

First, the contractor’s responsibility widely ranges from inspection to repair. Moreover, the contractor is obliged to propose an annual capital investment program to the MBTA, such as a replacement plan for the rail, sleepers, and ballasts, by examining the current condition of the track infrastructure. Relatively wide responsibility about maintenance implementation and planning is given to the contractor, while the MBTA is only responsible for surveillance. In practice, most of all maintenance work is implemented by the contractor. The citation below is extracted from their service agreement;

“Contractor shall inspect, serve, repair and maintain the Service Property and Support Property owned and controlled by the MBTA and included in this Agreement in accordance with the procedures and standards set forth in this Agreement.”

The second characteristic is that this contract is Fixed-Price with some incentive fees. The average amount of fixed payments is about 210 million US dollars, as shown in Table 12, including an allowance for snow removal and special maintenance for unused rail. The contractor should manage to perform train operation and maintenance under this budget; otherwise, they will lose money²⁶. The primary reason why this fixed price contract with such a large amount of payment was agreed to is that the cost can be predicted, since both parties have an enough experience in this business. The MBTA had a long experience as the MBCR owner, while the MBCRC consists of several companies which have expertise and know-how in this business; thus accurate cost estimation for over five years might be viable for them.

Table 12 Fixed Price Contract in MBCR²⁷

| | Average price (year 1 to 5) [thousand US\$] |
|---|--|
| Annual Fixed Price | 209,060 |
| Price for Special trains | 106 |
| Allowance for snow removal | 750 |
| Allowance for Special Maintenance | 100 |
| Total Annual Fixed Price (average) | 210,016 |

In terms of incentive, the MBTA does not offer any reward programs, but only penalties are predetermined to encourage the contractor to operate the train as scheduled. In addition, there is no

²⁵ <http://www.mbcrc.net/>

²⁶ MBTA can order emergency work to MBCRC, which is called Force Account Work, and it is cost-reimbursable base.

²⁷ resource; MBCR Service Agreement

penalty clause about the quality of deteriorated infrastructure. The contractor is punished only when train is delayed due to the malfunction of infrastructure as shown in Table 13 and 14. This is a quite unbalanced incentive scheme, which might not give a positive incentive for maintenance sectors to improve the total quality of infrastructure. Instead, it may cause a negative atmosphere in maintenance sectors if they feel as if they accomplish their assignment perfectly as long as no accidents or delays occur due to their negligence in infrastructure maintenance. At the time of the expiration of the contract, MBTA has a decision right to extend the contract. This is also one of the incentives for the contractor, though it is a typical incentive for a service provider.

This contract involves an attribute of Performance-based contract (PBC), which is the third characteristic to be mentioned. This is because the MBTA predetermines the expected outcomes of the contractor's contribution, but never determines and designates the methods of repair in the agreement. Even though the levels of outcomes are not fixed in advance, a certain amount of freedom is given to the contractor to choose the repair method, which is similar to the philosophy of PBC. Again, citation from the service agreement is listed below;

Contractor shall maintain the condition and availability of the Service Property and Support Property for the operation of the MBTA's commuter rail service. This effort will require that Contractor cooperate with Other Contractors; cooperate with the MBTA's efforts to procure, renew, and dispose of Service Property and Support Property; and cooperate with various public agencies and communities.

If there are itemized targeted performance indices in the clause, it would be exactly PBC.

Table 13 Examples for Delay Descriptions and its Approved Executions

| DELAY DESCRIPTION | EXCUSED IF CAUSED BY |
|--|---|
| | (blanks indicate no delay of that description is excused) |
| General Delays | |
| Mechanical (incl. Frozen doors & traps) | |
| Derailment | Caused by 3 rd party |
| Grade Crossing Accident | Accident |
| Amtrak Intercity Conflict | Third-Party |
| Delays Resulting from Engineering Performance | |
| Damaged Rail | Caused by 3 rd party |
| Communication System Failure | |
| Detector Devices | Malfunctioning detector maintained by a 3 rd party |
| Drawbridge Failure | |
| Frozen Switches | |
| Late Clearing Up | |
| Signal Code Line Failure | |
| Signal Failure | |
| Speed Restriction | When delay is within MBTA authorized delay window |
| Switch Failure | |
| Track Equipment | |
| Track Failure | |
| Late Train | If roost cause was assisting disabled train |

Table 14 On-time Performance Penalty

| Type of Train | Category of Non Performance | Penalty Per Train |
|---------------|-----------------------------|-------------------|
| Peak | Late Train | \$500 |
| Peak | Cancelled Train | \$2,000 |
| Off-Peak | Late Train | \$250 |
| Off-Peak | Cancelled Train | \$1,000 |

Due to lack of information about the quality of infrastructure, we could not analyze the effectiveness of this contract in MBCR. However, we need to keep paying attention to the future of infrastructure maintenance in MBCR.

5-3 Highway Maintenance Outsourcings in the US and Latin America

In highway maintenance in the US, an aggressive trial to utilize outsourcing has been tried from late 1970's as shown in Table15. The bottom line is that the infrastructure condition has been

deteriorating rapidly due to significant increasing in usage, aging infrastructure, and a smaller budget for maintenance. As a result, the overall grade of the highways in the US is below D⁺, according to the report published by the American Society of Civil Engineers (ASCE), which means that more than half of America’s highways and urban roads are in poor, mediocre, or fair condition.

Table 15 Brief History of Privatized Highway Maintenance (1977 to present)²⁸

| Projects [examples] | Year | Long term Impact |
|---|--------------|--|
| Initial Contract Maintenance Project (Public Sector) [Pennsylvania DOT, Brazil, Yugoslavia] | 1977-1985 | Pioneering projects in outsourcing that established contract approach, documents and procedures. |
| Innovative Maintenance Contracting Methods [CREMA, Warranty contracts] | 1986-1994 | Agencies looking at other ways than traditional contract methods |
| Highway Maintenance Contracting [Virginia, Florida I-95, Massachusetts, British Columbia, Australia, NZ,] | 1993-present | Establishing procedures for privatizing maintenance in use today |
| Design, Build, and Maintain Project [Utah I-15, Massachusetts Rt-3] | 1997-present | Established concepts for long term maintenance as part of DBOM |

Traditional contracts for road and highway maintenance are unit- or work-order oriented. Contractors are paid for the amount of work they do, not for the quality of work. Any number of activities can be contracted for, including but not limited to maintenance, lane striping, litter removal, snow plowing, and pothole repair. Contract terms are usually limited to one year with an option to renew for another two years.

In this section, we will confirm the actual contracts in highway maintenance in the US and Latin America, which has been successful so far in terms of improvement in both service quality and cost effectiveness.

5-3-1 National Highways Maintenance in Argentina

Background Information and CREMA project

In Argentina, significant transitions in toll road maintenance took place in the late 90’s. The first

²⁸ Geoffrey F. Segal, Contracting for Road and Highway Maintenance, 2003 March, Reason How-To Guide21

transition was from in-house maintenance to contract maintenance. Among Latin American countries, Brazil and Chile also successfully followed this way of contracting out maintenance. At the same time, Argentina switched from traditional quantities and unit-price based contracts to long-term performance-based contracts, which is a widely recognized project called CREMA. This project has already been implemented and covers approximately 12,000 km of highway; it comprises about 40 % of the national paved highway network.

The traditional way of maintenance contracting in Argentina is that the single-year based, method-based contract as is often the case. However, the disadvantages of this method had been emerged because of; lack of excellent personnel in the National Road Departments, the high frequency of claims, the need to focus more on customer's satisfaction, and the need to shift greater responsibility to contractors. Therefore, the benefits of performance-based contracting are expected to overcome these downsides of traditional contracting.

The Maintenance Contract in CREMA

CREMA stands for Contrato de Recuperacion y Mantenimiento, which means combined rehabilitation and maintenance contract that requires the contractor to rehabilitate and subsequently maintain a sub-network of roads. The concept is that rehabilitation and maintenance is combined in one contract.

The scope of the contract widely ranges from rehabilitation to maintenance. CREMA is intended to be applied to a paved sub-network which needs to be rehabilitated over a part of its length and subsequently maintained over the whole of its length. Rehabilitation work is supposed to be carried out during the first year of the contract, while maintenance activities are continuously undertaken throughout the five-year contract period.

Each contractor has a responsibility in maintaining an allocated highway sub-network. The average length per contractor is 194 kilometers; 61 contracts are awarded in nationwide. The payment method is a lump sum; thus, most financial risks are transferred to the contractors. Only cost overruns due to uncontrollable natural disasters, such as earthquakes and hurricanes, are reimbursed. Instead of this negative factor, the number of bidders was at least five, which was a large enough number to activate the sense of competition among the potential contractors.

The payment schedule, shown in Table 16, employs a unique way to bring some degree of time incentives to contractors. The contractor receives a payment of about 60 percent by the end of first

year, when rehabilitation is to be finished. The rest of the payment is to be divided into each month after the second year. Performance assessment, implemented by government engineers and the contractor, is required before each payment is executed; thus the contractor is encouraged to perform so as not to miss the performance standard predetermined by government.

Table 16 Payment schedules in CREMA

Surveillance in maintenance phases is regularly scheduled to ensure compliance with specifications such as potholes, cracking, rutting on the pavement, and the condition of shoulders, culverts, and drains. The penalty schedules for non-compliance are predetermined, as shown in

| Timing | Percentage of payment |
|--|---------------------------------------|
| At the beginning | 5 -10 % |
| End of Six month | 15- 25 % |
| End of First year | 25 % |
| Second year to the end of Fifth year [every month] | 40 % will be divided and paid monthly |

Table 17, based on performance indicators in both safety features and riding quality. Each violation will result in a penalty payment in accordance with the periods while it has been left without any repairs.

Table 17 Examples of Technical Specifications in CREMA²⁹

| Service categories | | Performance Indicators |
|---------------------|-----------------------------|--|
| Rehabilitation | Riding and Strength Quality | Roughness IRI<3.3 |
| | | DNV Surface Condition Index to be>6, PSI to be>2.8 |
| | | Rut depth to be kept below 12mm |
| | | Cracking to be less than 20% after rehabilitation |
| Routine maintenance | Riding quality | No pothole more than 2 cm deep on paved roads. |
| | | All cracks to be sealed |
| | | Trafficability ensured at all times |
| | | Rut depth to be <3 cm, cracks to be <30%, and no raveling on paved shoulders |
| | Safety | No obstructions on the pavement |
| | | Drains ditches, culverts to be cleaned |
| | | No gullies or rutting more than 2 to 5 cm deep and extending over 0.5meter from pavement edge on unpaved shoulders |

The benefits brought by CREMA are already reported in the literature. Cabana (1999) points out that the two major benefits; 1) improvements in the efficiency, and 2) public accountability of road

²⁹ Guillermo Cabana, "Areawide Performance-Based Rehabilitation and Maintenance Contracts for Low-Volume Roads" Seventh International Conference on Low-Volume Roads, 1999

maintenance operation. Even though this project is still young; its benefits are much greater than expected. Moreover, downsizing of the Government establishment, such as staff, equipment, and buildings is another benefit. It should be a good effect for its government, because they now suffer from a lack of excellent staff. Of course, we should not neglect the high potential of maintenance contractors in Argentina. Even though the pricing method is fixed-price, which might be risky for them due to cost overrun, multiple contractors joined all biddings. Well-qualified contractors and moderate competition are keys to the success of performance contracts.

5-3-2 Virginia Highway Maintenance

In 1995, the Virginia legislature passed the Public and Private Transportation Act (PPTA) mandating that the state of Virginia DOT (VDOT) evaluate proposals to maintain and reconstruct roads. As a result, VDOT has outsourced their state highway maintenance and saved between 16 and 23 million US dollars, according to a survey by Virginia Tech. The most outstanding point in this case is that VDOT employed performance-based contracting in long-term maintenance contracting. This is called ‘the first project in which a private firm assumed full responsibility for comprehensive maintenance of significant portions of a state's interstate highway system.’³⁰

Table 18 General Information about Virginia State Highway Maintenance Outsourcing

| | |
|-----------------------|---|
| Contract term | 1996-2001, five and a half years |
| Length of highway | 251 miles of interstate highway |
| Awarded Contractor | VMS Inc. |
| Awarded Price | 131.6 million dollars |
| Scope | Total Asset Management |
| Estimated Cost Saving | 16 to 23 million US dollars in five years |

VMS Inc., the selected contractor, is responsible for determining the maintenance method, types of materials, techniques, and procedures it will use. The scope of the contract varied, such as maintaining all fencing and guardrails, and to mowing, snowplowing, repairing potholes and cracks, repairing and rehabilitating roadways and bridges as needed, and attending to vegetation, drainage, lighting, and striping concerns along the 251 miles of highway to standards established by the VDOT and VMS during contract negotiations. VMS subcontracted this work to other subcontractors, and managed them effectively.

³⁰ <http://www.vmsom.com/company-profile/default.asp>

This large scaled outsourcing resulted in a great success in both quality and cost control. VMS Inc. is a very new company that specializes in highway infrastructure maintenance, searching for high effectiveness in maintenance.

Moreover, as a successful result of this outsourcing, VDOT employees can pour their energy into other productive projects to enhance their service quality. This benefit is the ultimate goal of employing outsourcing; thus, this example can be regarded as an ideal of the outsourcing strategy.

5-4 Summary of this Chapter

We covered several examples of successful or innovative maintenance contracting in both railway and highway maintenance.

First, performance-based contracting (PBC) can be found in both CREMA and Virginia state highway maintenance. In the latter cases, dramatic performance improvement and cost reduction had been achieved compared to the previous contracting style. This result indicates the possibility of PBC's applicability in transportation infrastructure maintenance. Second, in terms of monitoring the maintenance contractors' performance, Queensland Rail's challenge is quite meaningful. Several performance indices are predetermined for the use of maintenance unit's performance, which is linked to an incentive payment. Introducing incentives is one of the most useful management tools to encourage contractors. Third, owner and contractor are united by long-term contracts which are about five years long. Even though these contractors are awarded through competitive biddings, long-term contracts would induce the sense of alliance between the owner and the contractor for minimizing the total maintenance costs in the long run.

Chapter 6 Case study on Track Maintenance Outsourcing in East Japan Railway

6-1 Background Information

6-1-1 Brief History of JR East

The origin of East Japan Railway (JR East) is the privatization of the Japan National Railway (JNR) which took place in 1987. JNR, established about 130 years ago, was divided into six passenger rail companies, and one nationwide freight railway. The way of JNR's privatization was that of regional division, not the vertical division such as was done in the United Kingdom.

This privatization is applauded as a successful example of privatization, because the major passenger rail companies; JR East, JR Central, and JR West, have been making profits every single year just after being privatized.

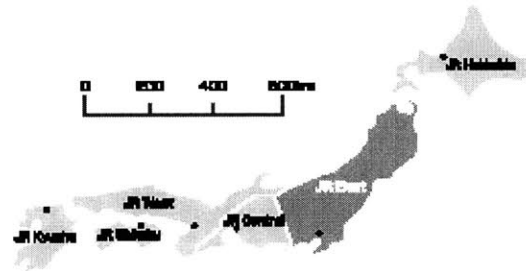


Figure 15 Operating Area of JR East

6-1-2 Business Scope and Operation area

Even though JR East has launched a lot of business related to the railway, the core business of JR East is the passenger railway, which includes five Shinkansen (bullet express) lines and regional commuter rail services in its operating area, which is shown in Figure 15. It is in the eastern part of Honshu Island, which includes large metropolitan cities, such as Tokyo, Yokohama, and Kawasaki and northern regional cities, such as Sendai, Morioka, and Akita. This geographical variety of service areas ranging from busy metropolitan cities to regional snowy towns is one of the characteristics that JR East possesses.

Development of hotels and department stores which are adjacent to railway stations is also beneficial to the railway business. Due to an aging society in Japan, the revenue from railway business will not rise in the future; thus these kinds of businesses are enhanced to support the future development of this company.

6-1-3 Size of Company

The number of employees is about 72,500 (as of 2003). The number of passengers is 16 million per day, which is the largest number among those of passenger rail service providers in the world. Due to the large scale of its service area, JR East also owns huge number of assets, such as tracks, tunnels, and bridges.

Table 19 Outline of JR East (as of 2003)

| | |
|--------------------------------|------------|
| Number of lines | 70 |
| Average number of Train km/day | 708,000 |
| Number of Passengers per day | 16 million |
| Number of stations | 1695 |
| Track length (km) | 11,602 |
| Number of Tunnels | 1,263 |
| Number of Bridges | 14,861 |

6-2 Main Customers in Passenger Rail Business in JR East

Who is the main customer for JR East? Statistics shows that the number of passengers for the Shinkansen was 92 million in 2002, while that of conventional lines was 5.8 billion.

The main customers for conventional lines are commuters and students in the greater Tokyo area. They rely on train service rather than automobiles, since traffic jams are terrible in the Tokyo metropolitan area during peak hours. Operating stable service is quite important in this area. On the other hand, in terms of revenue, Shinkansen passengers contribute as much as 27 percent of the total revenue for JR East due to the high ticket price. High speed and comfortable travel are expected from passengers, which is different from that of the commuter rail.

Paying attention to customer's needs is extremely important for JR East nowadays, because it became a completely private company by the sale of equity which was held by the Japanese Government. Enhancing the customer's value is one of the most important roles the company should play.

Although passenger railway is regarded as a natural monopoly, the gradual developments of other modes and subways in Tokyo and the eastern Japan area, substitutions for railway are increasing year by year. Tokyo is a busy city; customers are usually time sensitive. Only a single minute delay can be the cause of complaints from customers. Reliable and stable operation is key, especially in the Tokyo area. Understanding the level of customer satisfaction and efforts to meet it is indispensable for developing customer intimacy even in the passenger railway service.

6-3 Facts about Infrastructure Maintenance in JR East

6-3-1 Resource for Maintenance

Approximately 30 percent of the operating cost is consumed by the maintenance sector, which includes maintenance for rolling stock and infrastructure. (See Fig. 16)

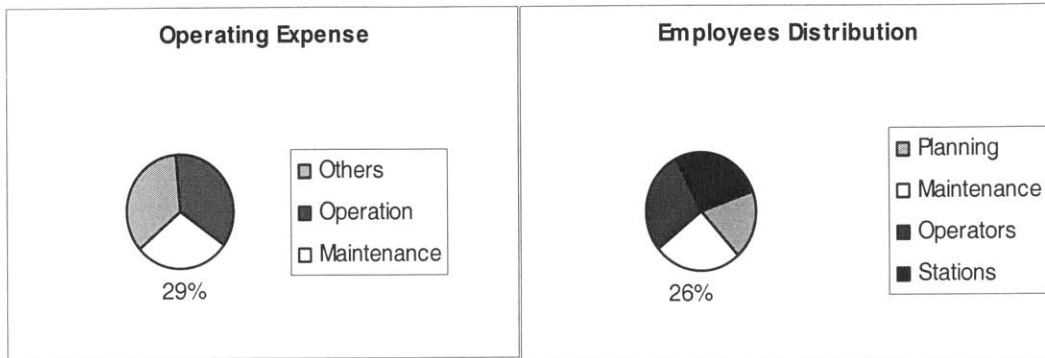


Figure 16 Maintenance Cost and Employees in JR East (as of 2002)³¹

6-3-2 Asymmetric Distribution of Employees

Because of its process of being privatized, JR East had imposed several constraints in its recruiting policy. They had refrained from recruiting new graduates from university and high school for a long time around the time of privatization; as a result, its age distribution is relatively asymmetric as shown in Figure 17. The number of employees older than 40 years old is 55 thousand, while that of below 40 years is only 16 thousand. The employees in the maintenance sector are distributed in the same way. This poor balance applies to the age distribution in the maintenance department, which has several potential problems to be solved within a decade or so. The number of employees JR East will lose in a decade by natural attrition is about 40 thousand, which accounts for 60 percent of the current staff.

³¹ East Japan Railway annual report.

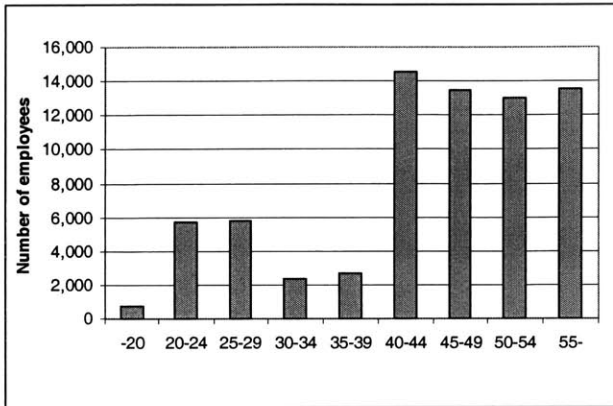


Figure 17 Asymmetric Age Distribution of Employees in JR East (as of 2002)³²

6-3-3 Re-structuring Maintenance for 21st Century

One of these problems is the lack of labor in railway operation and maintenance, which might directly influence JR East's railway service provision. As mentioned before, railway business is traditionally labor intensive, which implies that skills and techniques tend to accumulate not within the organizations, but in individual employees. Due to the asymmetric age distribution, JR East will suffer from not merely the lack of labor, but also the hollowing of techniques succession. Those techniques that have not been mechanized, such as welding rails, will be jeopardized if this lack of a younger generation in the workforce continues. These are common problems in the primary industries in industrialized countries, such as Australia and Europe.

In 2001, JR East launched a new program, which was named 'Maintenance structure restructuring for the 21st century', aiming to prepare for the upcoming environmental volatility. Through this program, a large number of employees and large machines possessed in track maintenance centers are transferred to maintenance contractors and, accordingly, most of the inspection and maintenance work is transferred to contractors at the same time. This restructuring can be regarded as the first step toward building a more ideal contracting structure to implement maintenance in an effective manner. One thing we should not neglect in this program is the introduction of a database network, which is called TRAMS. This large scale computer network is shared with JR East and every contractor; thus the information about the conditions of infrastructure and the history of inspection data are stored in its central server, allowing access from both parties in a timely manner.

6-4 Current Maintenance Contract Structure

We will briefly describe the characteristics of track maintenance contractors and the current maintenance contracting structure in JR East.

6-4-1 Facts about Track Maintenance Contractors serving JR East

JR East currently contracts five major track maintenance contractors. Those territories are allocated according to historical relationships and geographical conditions. Each contractor is responsible for its own territory, performing track maintenance service for JR East. Even though one of the contractors is a subsidiary of JR East, each contractor has a similar characteristic in terms of its history, business category, and size. These contractors had been established in the 1930's to serve a track maintenance service for JNR, followed by launching new areas of business such as road pavement, bridge construction, and general civil engineering work. At the present time, they are not only serving JR East, but also other railway organizations and public sectors. As shown in Table 20, the size of each contractor is similar.

Table 20 Size of Track Maintenance Contractors (\$ = 110 yen)

| Contractors | A | B | C | D | E |
|---------------------------|-------|-------|-------|-------|-------|
| Established | 1937 | 1938 | 1940 | 1938 | 1933 |
| Capital (US\$ mil) | 2.3 | 1.1 | 25.5 | 1.0 | 27.7 |
| Sales (US\$ mil, in 2002) | 271.8 | 253.6 | 847.3 | 136.4 | 410.0 |
| Number of Employee | 855 | 850 | 987 | 590 | 1056 |

Track maintenance is not competitive segment in Japanese market nowadays. The major reason is the high barrier to entry, which has kept new contractors away from entering this segment. Barrier to entry for prospective contractors is high because of the huge amount of investment that is required to purchase maintenance machinery and pay for labor. These kinds of machine used for maintenance are produced for specific purposes; thus these prices are relatively high compared to general ones. Skills and techniques can also become barriers, because they can be learned only through experience, which means that it is hard for new contractors without experience to perform at the required level for adequate maintenance service. In addition, expected profitability in railway maintenance is not high enough to attract prospective contractors. Needless to say, the railway business in Japan has already reached its maturity, which indicates that there is less opportunity for maintenance contractors to expand their revenue base. In general, this business is not attractive for new entrants for these reasons.

³² Ibid.

On the other hand, the profitability of track maintenance for existing contractors is reasonable. This phenomenon can be explained by five forces, which was propounded by Michel Porter³³. The profitability of business segment is determined by the combination of five forces; entering barrier, threat of substitution, buyer negotiation power, supplier negotiation power, and competition with rivalries. From the current maintenance contractors' point of view, as shown in Figure 18, a high entrance barrier, low rivalry, and the low threat of substitutions are desirable conditions to keep its profitability.

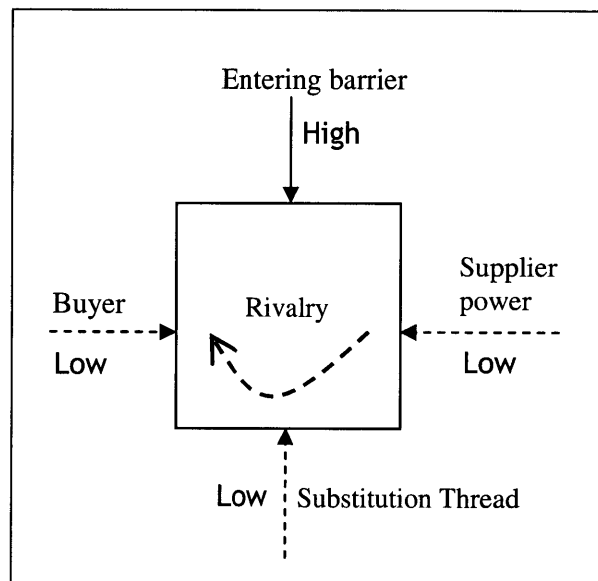


Figure 18 Five Forces in Track Maintenance Segment in Japan

For these reasons, railway maintenance has been a relatively settled market; thus major contractors have been awarded long contract period which has enabled them to attain a reasonable level of profits without rigorous competition.

6-4-2 Type and Scopes of Contracting

Most of the inspection and repairs are now the responsibility of maintenance contractors. Inspection for rail track alignment, switches, sleepers, and rail fatigues are the contractors responsibility. The major roles of JR East are; monitoring the results of inspections performed by contractors, assessing the current condition of infrastructure, ordering maintenance work if needed, and supervising maintenance work at sites.

³³ Porter, E. Michael, 1985, "Competitive Advantage"

Maintenance contracts are renewed yearly, not by competitive bidding but by negotiation. Unit cost is determined through negotiations and JR East will pay according to the amount of work that contractors perform during the specific year, until it reaches the maximum ceiling, which is budgeted in advance. Basically, unit price is determined by taking into consideration of contractor's actual cost and base profit; therefore, they will never lose money if they perform all given tasks as specified.

Research and Development (R&D) about track maintenance is still performed by JR East. JR East launched a new research center in which research for new materials and structures are now in progress. Improving maintenance efficiency is one of the most important topics at this R&D center, and several studies have already been carried out. Contractors are not closely involved in this kind of research so far.

6-4-3 Advantages of Current Contracting method and its Potential Disadvantages

The current contractual structure between JR East and maintenance contractors is not that different from the traditional one. Their relations are nearly equal to that of partnership because of frequent personnel exchanges, but the level of alliance has not been reached yet. In terms of decision making about maintenance, its relation is equivalent to a literal 'master-servant relation', because contractors are expected to perform tasks that JR East orders. Casting new constructive ideas and productive efforts are not encouraged in this current contract. There are two major advantages in this style; constant quality assurance and controllability. First, under this contract scheme, JR East has to approve all of the inspection data sent by contractors. This step is meaningful, since JR East can ensure the contractor's compliance about the frequency of predetermined inspections. This plays a role of continuous surveillance for the quality of the contractor's performance. The skills of in-house engineers will be enhanced by this involvement, too. Second, decision making is also JR East's responsibility, which enables JR East and contractors to clarify and simplify the chain of command. In particular, in the case of emergencies and accidents, this point is important so as to avoid confusion. Table 21 shows the flows of these processes and how it is distributed evenly between JR East and contractors under current contract.

Table 21 Flow from inspection to repair under Traditional contract and PBC

| Traditional | Step1 | Step2 | Step3 | Step4 | Step5 | Step6 | Step7 |
|-------------|------------|------------|---------------|-----------------|-------|--------------------|----------------|
| JR East | | | Data analysis | Decision Making | Order | | Authorizati on |
| Contractors | Inspection | Data Input | | | | Repair (if needed) | |

| PBC | Step1 | Step2 | Step3 | Step4 | Step5 | Step6 | Step7 |
|-------------|--|------------|---------------|-----------------|---------------|--------------------|------------|
| JR East | Overall Surveillance & Quality Assurance | | | | | | |
| Contractors | Inspection | Data Input | Data analysis | Decision Making | Organize Crew | Repair (if needed) | Self check |

On the other hand, there are several disadvantages in this contract, such as; time consumption, risks in JR East, and contractors' dependence on JR East. First, due to the large number of required inspections, JR East is likely to be obliged to follow a tight schedule. Huge time consuming tasks will occupy them, and in turn, they will miss the time to share other creative work. In addition, the number of employees will continue decreasing; thus the magnitude of this problem will increase as time goes by. Second, risks involved in inspection and maintenance, which means the responsibility for accidents stemming from inspection and maintenance mistakes, still remain in JR East side due to the final step that requires JR East's approval of inspection data and the results of repair work. Third, contractors tend to depend on JR East for decision making and analysis based on the inspection data. This implies that it is hard for contractors to develop independence to make decision about maintenance work under this contract scheme, because they do not need to scrutinize the results of inspection and think about the most effective way of maintenance as long as this contract is observed in a literal way.

6-5 Suggestions for Advanced Contract Structure in Track Maintenance; the possibility of Long-term, Performance-based Contracting in JR East

As we confirmed in Chapter five, the major trend in highway maintenance is to focusing on the customer's satisfaction and the contractor's higher performance. Performance-based contracting (PBC) in highway maintenance is still at a pilot program stage; however, its philosophy is quite meaningful, which involves a large potential to improve the efficiency of railway maintenance.

Railway track maintenance has a similar characteristic to that of the highway; thus it must be worthwhile to consider the introduction of this method in JR East. In addition, the upcoming shortage of in-house engineers will instigate the introduction of PBC. As suggestions for a future maintenance contracting structure, we will explore the possibility of introducing long-term, performance based contracting to JR East.

Phase 1. Transforming from Traditional Contracting to Strategic Outsourcing

Even though JR East's involvement in direct maintenance work is reduced because of the program implemented in 2002, the current contract structure still falls under the category of traditional style. Year base, method base, and unit price base are typical attributes of the traditional contract as noted before.

In general, transformation requires a larger amount of energy in proportion to the chronological length that was pursued in the previous style. In the case of a maintenance contract in JR East, it will not be the exception. Sudden drastic changes will be hard to implement.

In order to smooth this transformation, launching a pilot program is recommended. JR East and each contractor should choose the appropriate line to introduce PBC on a trial basis, and implement it for a year or so. After scrutinizing the results of this pilot program, they will be able to decide whether PBC is appropriate and cost effective or not. During this process, each contractor's technical developments can be expected due to their accelerated desires to improve the efficiency of the maintenance work. Temporary financial supports would be a good method to motivate these contractors.

In addition, as for the timing to launch PBC, it would be better to start it after a major rehabilitation project has been completed in the line. As mentioned in the case of CREMA, infrastructure in an extremely deteriorated condition requires huge amount of maintenance, which may not suitable for PBC and will not acceptable for contractors.

Phase 2. Setting Appropriate Performance Metrics

First of all, before launching the pilot program, we need to clarify the performance metrics in track maintenance. This kind of an evaluation process has not been focused on so far at JR East, because it is not necessary to acknowledge under the traditional contracting.

As Queensland Rail set several performance indices, multiple indices that can capture the overall outcomes for the contractor, who has been brought in, should be chosen. Table 22 is a set of proposed

performance indices that can be applied at JR East. Too complex indices can cause confusion, and on the other hand, indices that are too simple are not appropriate. A moderate combination of indices should be chosen, because those metrics will have more influence on the contractor's behavior.

Table 22 Performance Indices in Track Maintenance

| Proposed Indices | How to count | Description |
|---------------------------|---|---|
| Derailment | The number of derailment. [0, 1, 2,,] | Derailment is a critical event for railway company. Due to the significant negative impact on Customer Satisfaction, this index should be prioritized. |
| Service Delay | Accumulative number of minutes service interrupted. | Train delays stem from infrastructure malfunction. This is also an important factor to influence Customer Satisfaction. Based on the regional characteristics, this index should be weighted. Delays in peak hours can be weighed according to its significance. |
| Cost Control | The gap between target cost and actual cost | Target cost, based on the historical data, is to be predetermined. At the end of contract period, or annual base, if actual cost is under budget, saved cost will be partially refunded to a contractor. In case of over budget, contractor will receive no refund. This should be adjusted when hardship is much higher than usual. (such as heavy snow, higher traffic, and so forth) |
| Quality of Infrastructure | Complex index | Quality of rail infrastructure is hard to express in a single index. Rail alignment, degree of rail fatigue, and the conditions of other components should be aggregated. |
| Ride comfort | Acceleration | Vertical and horizontal acceleration of rolling stock can make passenger uncomfortable, especially on a high speed train. |

Phase 3. Full-scale Introduction of Performance-based Contracting

After scrutinizing the results of the pilot program, we can move to the step to full-scale implementation. We need to confirm performance improvement and cost effectiveness in the pilot programs. In particular, JR East's surveillance cost should be clarified before the full-scale implementation, since this cost can be much greater than the estimation according to the past examples. Cost reduction is one of the biggest aims of introducing PBC; thus this point should be clarified thoroughly.

As for payment method, it should be determined on the basis of uncertainty and complexity associated with track maintenance work in the operating area of each contractor. As noted before, the operating area of JR East ranges widely from the Tokyo metropolitan area to snowy regional towns. In each

area, hardship for maintenance contractors varies, due to the wide variety of capital investments for infrastructure, service frequency, weather conditions, and customers' sensitivity to service delay. These factors should be considered comprehensively in order to make decisions on the choice of a payment method. Basically, fixed cost can be chosen for the routine part of maintenance, while cost-plus should be chosen for unplanned and uncontrollable part of maintenance.

Phase 4. Introducing a sense of competition and incentive using Performance Indices

One of the advantages that JR East contracts with five contractors is that competition can be put to work among these contractors. In any kinds of public and private service, competition is important. How to introduce the sense of competition among the maintenance contractors is the key issue which holds the future success of PBC.

In this stage, performance indices that are set in phase 2 can be utilized again.

After the sense of competition is introduced successfully, effective incentive schemes should be added to achieve the perfect contractual relations by which contractors are encouraged to improve both their performance and cost effectiveness. However, too strict penalty is not appropriate in the maintenance contract, because critical financial damage could make the contractor go bankrupt, which might jeopardize for stable train operations of JR East.

Phase 5. Building Alliance in a Long-term Perspective

The alliance is a key concept, since having a long-term perspective is essential in infrastructure maintenance. A traditional one-year-base contract is not appropriate for a normal maintenance contract; instead, a long-term contract, such as five or ten years long should be appropriate for JR East, too. In building an alliance contract, there are three important issues to be mentioned; financial stability of contractors, frequent communication, and skill development in contractors.

First, a financial crisis in a contractor is also harmful for JR East, because there are not enough JR East engineers to perform the necessary maintenance work. JR East should pay attention to the financial health of each contractor during the contract periods. Second, communication is also indispensable in order to activate the contract relations. Periodic meetings are recommended in order to understand the current conditions of each party to ensure the same objectives are shared throughout the contract terms. Third, skills and technical development in contractors are also essential. Without these, the largest advantage of PBC will not be utilized. In particular, research and development can be studied by both parties. Tactical and practical studies will be mainly done by contractors, while large-scale systematic research by JR East.

Table 23 Chronological comparisons of the outsourcing style in JR East

| | Past | | Current | | Suggested | |
|--|-----------------|-------|---------|-------|-----------|-----------|
| | JR East | Cont. | JR East | Cont. | JR East | Cont. |
| Inspection Planning | * | | * | | | * |
| Inspection | * | | | * | | * |
| Data acquisition/ Input database | * | | | * | | * |
| Decision making about repair | * | | * | | | * |
| Decision making about upgrading/rehabilitation | * | | * | | | * |
| Repair work | | * | | * | | * |
| Rehabilitation work | * | | | * | | |
| Quality assurance for repair work | * | | * | | * | |
| <i>Outsourcing style</i> | Tactical -----> | | | | | Strategic |

If this project gets started successfully, infrastructure improvement and cost reduction can be achieved simultaneously; as a result, JR East will be able to pour their energy into other areas of their business, such as developing new business segments, or research and so on. As a summary of outsourcing strategy, Table 23 shows the chronological transformation in the past and future suggestion.

6-6 Conclusions

As is often the case with discussions about organizational management, both people and process are very important factors for a firm to provide excellent service or product. This indicates that excellent quality of employees does not necessarily guarantee the high quality of service. The quality of process management also matters.

Now is the time for infrastructure maintenance at JR East to improve the process. Maintenance outsourcing has been limited to tactical one. JR East keeps progressing by searching for the ideal and effective contractual structure, and is now in the midst of this process. In the future, strategic outsourcing can be employed, which will enhance the performance and cost effectiveness of track maintenance sections, and will lead JR East to more success in the transportation industry.

JNR’s privatization has been applauded as a successful large scale privatization. Now is the time to try a new scheme in maintenance outsourcing to achieve a more productive and reliable railway network, which might draw the attention from other railway companies.

Chapter 7 Summary of Work and Future Research

7-1 Findings and Conclusions

As is often the case with public sectors, railway organization tends to be vulnerable to political powers and regional characteristics. Therefore, short-cut comparisons between the cases in several countries and communities sometimes do not make sense at all. However, when focusing on the infrastructure maintenance, there should be a lot of similarities among them; thus it would be worth discussing the elimination of the regional characteristics. As findings and conclusions of this thesis, following five points follow;

Maintenance Outsourcing in Railway Infrastructure

It is true that track maintenance is a very important area in railway operation, because it supports punctual and safe operation which is one of the core competences in railway service. However, from the customers' point of view, track maintenance is neither what they primarily pay for nor it is the railway operators' core business. The relationship between customers and the railway maintenance sectors is quite indirect. These facts imply that maintenance outsourcing is worth considering in the light of outsourcing theory. Careful investigation is required, of course, but maintenance outsourcing has a possibility to improve the railway organization's financial condition and service quality.

Advanced Maintenance Outsourcings in Highway Maintenance in North and South America

Comparative studies in highway and railway maintenance has made it clear that highway maintenance is employing outsourcing more intensively than railway, especially in North and South America. One of the characteristics is that long-term, performance-based contracting is highly utilized in these countries. When a contractor's skills and know-how are good, the advantage of PBC is maximized; as a result, both improved maintenance performance and cost reduction is achieved simultaneously. In general, highway maintenance outsourcing is much more advanced than that of the railway at this moment.

Performance Based Contracting and its Prerequisites

Well-skilled contractors, moderate competition among the contractors, and clear performance standards are the prerequisites for the successful PBC. Without any of these attributes, PBC would

fail. Moreover, incentive schemes match PBC well, because objective performance measurements are predetermined by mutual agreement among involved players. Both rewards and penalties are usually used to encourage contractors to improve their performance. A single-year contract is not appropriate for a maintenance contract, because the period of time is too short for contractors to be encouraged to invest for enhancing their resources to improve performance. A five year contract is average in this category.

Focus on Customer's Perspectives in Maintenance Activity

Customer satisfaction has been focused on in the maintenance area nowadays. In highway maintenance, outcomes that are directly connected to customer satisfaction are more highly weighed than others. Not focusing on internal goals, but looking at customers' needs and trying to meet them is a new movement among transportation infrastructure maintenance. This philosophy can be applied to railway maintenance, too.

Standard Contract Structure in Transportation Infrastructure Maintenance

A combination of a fixed-price and cost-plus contract is a common style as a maintenance contract. Maintenance work can be roughly divided into two parts; routine maintenance and emergency work; thus the routine part is usually covered by fix-cost, while an emergency is covered by cost-plus. This package is reasonable in the light of a wide variety of maintenance work and uncertainty associated with each segment of it.

7-2 Suggestions for Future Research

Lifecycle Cost Analysis in Transportation Infrastructure Maintenance

It is important to compare the estimated maintenance cost and the actual cost. At the construction phase, components and materials are supposed to be selected to minimize the total lifecycle cost, based on the estimation of traffic load and consideration of future environmental changes. In practice, especially in the case of old infrastructure, this discussion tends to be neglected. However, as noted before, maintenance activity is needed as long as the infrastructure is in use. Verification of actual maintenance cost by aggregating actual data is one of the suggestions for future research.

Innovative delivery methods that require much more involvement of the private party is becoming more commonplace; that includes BOT, DBOT, DBOM, and Turnkey. This trend will enhance the unity of construction and maintenance, which will stimulate studies about maintenance management

more than ever before.

Deterioration Modeling in Railway Infrastructure

Even though much research has been implemented on highway maintenance, such as pavement and bridge management, studies about railway infrastructure has not been well established yet. In particular, capturing the deterioration process using semi-Markov process will also be beneficial for practical maintenance management, especially for maintenance planning and budgeting. The complexity of the rail track deterioration process has been the bottleneck of this study; however, due to the recent development in computer technology, more accurate computer simulations would be possible.

Quantitative Risk Analysis about Railway Infrastructure Maintenance

What we could not clarify in this thesis is the quantitative risk analysis about highway and railway maintenance. Quantifying risks are important factors in determining the appropriate contractual structure; thus future research on this issue will not only satisfy academic interest of maintenance engineers, but will also contribute to the study of how to build appropriate maintenance contracts. Applying reliability engineering to railway infrastructure is suggested.

Effective Incentive Scheme in Infrastructure Maintenance

In most cases, the amount of incentive is currently established based on negotiations or experience. Emphasis on incentives with large penalties and rewards will attract some contractors, but not all. The primary objective of incentives is to increase the contractor's performance; thus owners should be careful about choosing an optimal degree of incentives, which should be figured out by estimating the contractor's utility function and risks involved in a contract. Moreover, incentives will affect the contractor's decision making about their investments for improving efficiency, because tradeoff analysis between investments and prospective gains by incentive will matter. Considering these points, it is worthwhile to be scrutinized.

Analysis about Cons of Long-term Maintenance Contract

Long-term contract is beneficial for infrastructure maintenance contracting as noted before. However, long-term contract can cause an unfavorable situation, especially for an owner, which is called 'asymmetric information' in contract economics. This situation is that only one party holds important information, which will bring a lot of disadvantage to the other party. At the end of the contract term,

due to the long period of contracting, most of all actual cost information will have accumulated on the contractor's side, but not the owner's side. This indicates that in the process of contract renewal, the contractor will be in a much more advantageous position than the owner because of this asymmetric information about cost. This disadvantage associated with long-term contract should be verified, and some solutions to avoid this need to be suggested.

Railways are complex and dynamic systems, and so is railway maintenance management. There is a lot of room for much research in this area to improve its total efficiency and service quality for customers.

APPENDIX

A. Example of Infrastructure Condition Ratings: Bridge Condition Rating Guide set by National Bridge Inventory

Bridge condition is divided into nine states as defined below.

| Rating | Category | Description |
|--------|----------------------------|---|
| 9 | Excellent Condition | |
| 8 | Very Good Condition | |
| 7 | Good Condition | No problems noted |
| 6 | Satisfactory Condition | Some minor problems |
| 5 | Fair Condition | All primary structural elements are sound but may have minor section loss, cracking, spalling, or scour. |
| 4 | Poor Condition | Advance section loss, deterioration, spalling or scour. |
| 3 | Serious Condition | Loss of section, deterioration, spalling, or scour have seriously affected primary structural components. Local failures are possible. Fatigue cracks in steel or shear cracks in concrete may be present. |
| 2 | Critical Condition | Advanced deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present or scour may have removed substructure support. Unless closely monitored, it may be necessary to close the bridge until corrective action is taken. |
| 1 | Imminent Failure Condition | Major deterioration or section loss present in critical structural components, or obvious loss present in critical structural components, or obvious vertical or horizontal movement affecting structure stability. Bridge is close to traffic but corrective action may put back in light service. |
| 0 | Failed Condition | Out of service; beyond corrective action. |

C. Performance indices used in Queensland Rail

| Key Result Area | Key Performance Indices (KPI's) |
|-------------------------|---|
| Safety | Injury down time rate |
| | *Lost time frequency rate |
| | Lost time injuries |
| | Public trespass accidents |
| | Public electrical accidents |
| | Public level crossing accidents |
| | Wildfires |
| Asset Reliability | Dewirements |
| | *Track/structures transit time delays |
| | Non-resettable trips per electrified kilometer |
| | *Running move derailments caused by infrastructure |
| | Signals restored in the face of trains |
| | Signals passed at danger |
| | Signaling/ communications transit time delays |
| Asset Condition | Buckles, pull-aparts |
| | Wayside faults reported |
| | Transformer condition |
| | *Track condition index (track geometry) |
| | Sleeper condemnation percentage |
| | Bridge timber condemnation numbers |
| | Rail wear |
| Maintenance Performance | Fault response time for traction power |
| | Fault response time for signals |
| | % of major trackside maintenance completed |
| | % of routine trackside maintenance completed |
| | Completed trackside isolation |
| | *Production against program for, re-sleeper, resurfacing, rail grinding, ballast cleaning, track geometry recording |
| *Cost Control | Current inventory value |
| | Cost per sleeper inserted |
| | Cost per kilometer resurfaced |
| | Cost per kilometer of rail ground |
| | Cost per kilometer of track ballast cleaned |
| | Cost per kilometer of track geometry recording |

*These six indices are chosen to represent the overall outcomes of maintenance group's work.

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