# DYNAMIC CONTRACTING: An Asset Management Tool in Controlling Infrastructure Maintenance Activities

**PhD. Researcher Hatice Cigdem Demirel**

Faculty of Civil Engineering and Geosciences
Delft University of Technology
Stevinweg 1 2628 CN, Delft, The Netherlands
h.c.demirel@tudelft.nl
Telephone: 0031152784774

**Prof. Dr. Ir. Hennes De Ridder**

Faculty of Civil Engineering and Geosciences
Delft University of Technology
Stevinweg 1 2628 CN, Delft, The Netherlands
h.a.j.deridder@tudelft.nl
Telephone: 0031152784774

**Prof. Ir. Dr. Marcel Hertogh**

Faculty of Civil Engineering and Geosciences
Delft University of Technology
Stevinweg 1 2628 CN, Delft, The Netherlands
m.j.c.m.hertogh@tudelft.nl
Telephone: 0031152784774

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**ABSTRACT**

Infrastructure road network is a complex system in a fast changing complicated environment and therefore subject to change. The changes refer to demands, requirements, regulations and financial possibilities as well as advanced technologies. Therefore outsourcing maintenance activities are rather difficult. In result, increasing complexity and changes severely affects the asset management strategies of transportation agencies and reduces their ability to control the maintenance activities. In this case, current traditional contracting based on fixed price lack the capability of dealing with changes to provide improved level of services. The main question is how to do outsourcing of the maintenance activities in this context. Implementation of effective and efficient delivery of services could be mentioned as the goal of agencies for their assets. This paper summarizes and explains the key challenges and preliminary findings with respect to performance parameters of changing circumstances within process of controlling the maintenance activities of managing the outsourcing in the Dutch road network system. A framework is introduced to describe the dynamic behavior of the network that enables to support goal controlled dynamic interaction of network assets, performance measurements and changing circumstances.

## INTRODUCTION

In road network asset management system, neither infrastructural maintenance activities nor its environment are stable. In recent years road infrastructures are exposed to diverse changes from multitude of sources, requirements, demands, economy, technology and regulations. The constant changes in the field of maintenance are acknowledged to have enabled new and innovative developments in the field of maintenance science *(1)*. Changing complex systems and especially how they change in response to changes in the environment is extremely interesting *(2)*. In this case, the main question is how to do outsourcing of the maintenance activities in this context.

The main undesirable character of traditional contracting is early fixation of the project goals that avoid the innovation of maintenance activities. The traditional types of contracts (firm fixed price and pure cost reimbursement) were found to be an inadequate means of controlling the expenditure and management of such developments *(3)*. Road agencies and contractors need to realize that the project goals expressed in fixed performance and price, which will come into inefficient and uncontrolled mechanisms in future, is part of a perception problem of traditional contracting. Both parties have a conflict of controlling the ongoing maintenance activity. The client claims for a better performance of the product where he measures the actual performance below his initial expectations, the contractor claims a financial compensation for his extra efforts, which mainly originate from the fight against the consequences of unexpected events *(4)*.

In result, road agencies are struggling with increasing conflicts, complexities and being thought of as outdated, that increases when the duration of the contract increases. Nowadays countries are paying more attention to adapting their road network system to changing circumstances with new perspectives for design management and maintenance of infrastructures *(5)*. It can be stated that contracting play a key role in the control, development and implementation of the maintenance activities for outsourcing facilities in road network asset management system. Therefore, contracting mechanisms have to set up ambitious methods to cope with changes, to provide goal control systems and to avoid conflicts between principle and contractors.

Dynamic contracting mechanism is a very strong tool to control and improve maintenance activities dynamically in order to keep them adequate in the constant changes. In a rapid changing world, there are a great variety of difficulties to determine the required performance and to measure actual performance in road network systems. Dynamic contracting which is a mechanism can be dynamically applied and controlled the sequence of performances and price in time during the maintenance activities. This mechanism can be used to develop a set of requirements that establish goals to be met by control. Requirements are the basis for every project, defining what the stakeholders- users, customers, suppliers, developers, businesses- in a potential new system need from it, and also what the system must do in order to satisfy that need *(6)*. For effective control it is necessary to describe aspect requirements for a goal-controlled system with relation to the performance by using system theory. Regarding to system theory, the aim is to find an answer how the mechanism will meet the principle requirements to the maximum effectiveness in the changing circumstances and how to make an optimization between performance and price relation in maintenance activities.

The purpose of this paper is to present and explain the key challenges and preliminary findings with respect to performance parameters of changing circumstances within process of controlling the maintenance activities of managing the outsourcing in the Dutch road network system.

## FRAMEWORK TO STUDY MAINTENANCE OUTSOURCING

An effective and efficient outsourcing is the backbone of the controlling maintenance actions in infrastructure asset management system. Recently, there has been tremendous pressure on civil infrastructural environment to control the various maintenance functions and to provide timely improvement. In general, complicated civil infrastructural environment comprise interrelated elements in a complex maintenance system. Controlling an optimal contract mechanism requires understanding the entire realization of outsourcing maintenance. A proper framework to study maintenance outsourcing from both client and contractor points of view involves several interlinked elements as indicated in Figure 1. *(1)*

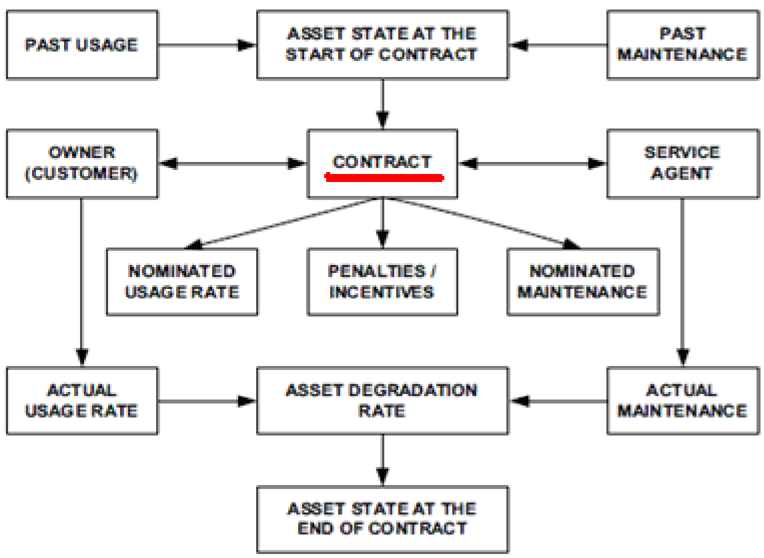


**FIGURE 1: Framework for study of maintenance outsourcing *(1)*.**

### Assets and Its Maintenance Activities

Infrastructure assets are systems or networks that serve define communities where the system as a whole is intended to be maintained indefinitely to a specified level of service by the continuing maintenance and replacements of its components *(7)*. Infrastructure assets and its maintenance activities play a key role in achieving organizational goals of transportation agencies. Owners of infrastructure networks have many physical elements (the assets) to maintain and to keep functioning *(8)*. Table 1 *(9)* provides an infrastructure inventory of Rijkswaterstaat (the executive agency of the ministry of infrastructure and environment in the Netherlands) to maintain its road network.

| | |
|---|---|
| **Primary road ways** | 3250 km |
| **Motorways** | > 2100 km |
| **Motorways with traffic signaling** | approx. 1000 km |
| **Tunnels** | 14 |
| **Traffic management offices** | 7 |
| **Dynamic traffic signaling systems** | 91 |
| **Ramp metering systems** | 51 |
| **Ecoducts (game passages)** | 5 |

**TABLE 1: Infrastructure inventory of Rijkswaterstaat (2004) *(9).***

Rijkswaterstaat will have to provide assets, comply with demands and maintain a performance obligation for the outsourcing of work for the Dutch road network system. In case of outsourcing maintenance for infrastructure assets, the goal is to achieve agreed level of services while keeping the desired functions available. An asset is said to be in failed state when it is no longer functioning properly *(1)*. Changing circumstances in infrastructure road network system causes complexity for outsourcing maintenance activities. The occurrence of failures and changes of infrastructure road network system can be controlled through contracting mechanism. To enable and choose appropriate maintenance actions in a road network system, dynamic contracting mechanism takes a central role. Dynamic contracting mechanism can be viewed as a use of suitable type of contract which deals with the set of failures and changes that client and contractors can control the maintenance activity period. Controlling the process of optimal contracting mechanism requires understanding the forms of maintenance activities.

**Definition of Maintenance and its Categories**

According to European standards *(10)* maintenance can be defined as the combination off 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. Murthy *(1)* shows that maintenance is categorized into 2 kinds;

*1. Corrective Maintenance:*

These are corrective actions performed when the asset has a failure and the most common form of corrective maintenance is "minimal repair" where the state of the asset after repair is nearly the same as that just before failure.

*2. Preventive Maintenance:*

In the case of equipment or consumer durables, preventive maintenance actions are carried out at component level where components are replaced on age, usage and/or condition. The degradation in the asset state can be controlled through use of preventive maintenance and, in the case of equipment, this involves regular monitoring and replacing of components before failure.

On the other hand, Schoenmaker *(11)* describes the maintenance as the whole set of activities that are needed for keeping the required functions available at the agreed level of service. There is variety of terms being used to determine the nature of maintenance. The maintenance activities grouped into 3 categories; *(12)*

*1. Execution of work based*:

Daily maintenance, small maintenance, structural maintenance, large maintenance

*2. Financial based:*

Fixed maintenance, variable maintenance

*3. Strategically based:*

Preventive and corrective

On the basis of strategically based maintenance, a choice can be made as shown figure 2 *(13)*.

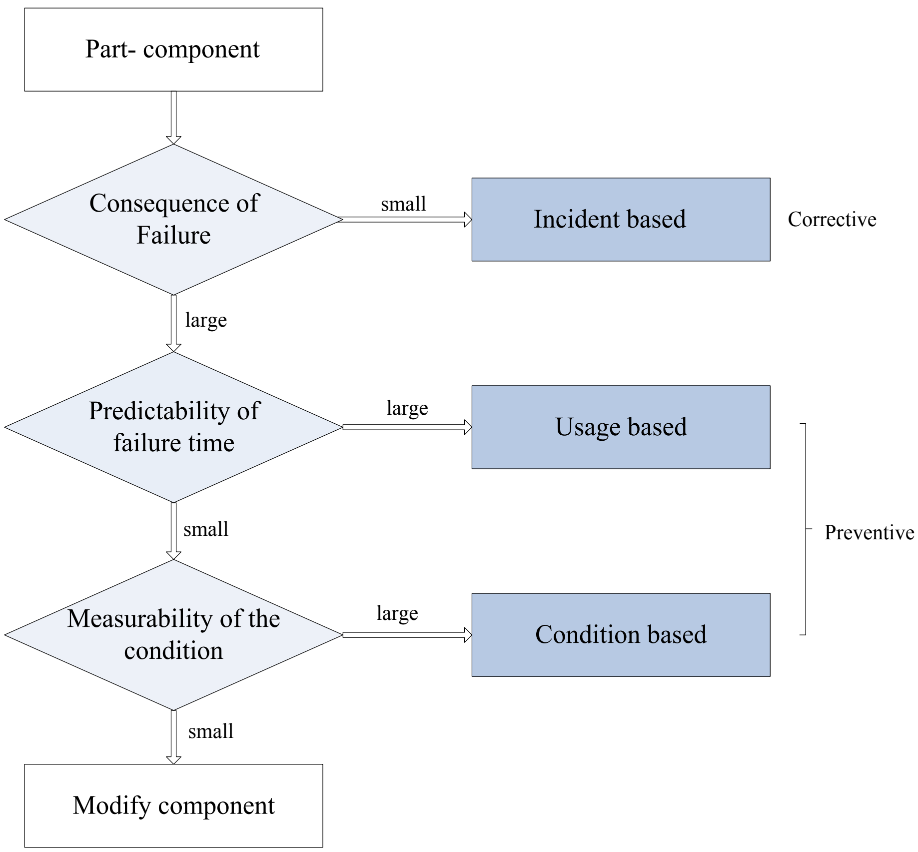


**FIGURE 2: Weighing of the function, the value and the risks of failure (Rijkswaterstaat, 2002)** ***(13)***

In addition to this definition it is essential that maintenance will be executed in an efficient and effective way by minimizing risks, restoring and preventing defects and minimizing life cycle cost *(11)*.

For integrated contracts Pakkala *(14)* classify maintenance practices into 2 categories;

*1. Routine Maintenance:* Can be defined by those maintenance activities that occur every year on a routine basis or of a cyclic nature.

*2. Periodic Maintenance:* Can be defined as those activities that occur infrequently or every so often and can be termed as "upkeep and improvements".

Maintenance is complex work to achieve agreed level of services in a cost effective manner. In this complex system, dynamic contracting mechanism proposes to make a clear approach to be functionalistic and to achieve lower life cycle costs by giving contractors and client opportunity to choose appropriate contracts according to the type of maintenance activity needed.

## PERFORAMNCE REQUIREMENTS

The elicitation and delivery of requirements has long been problematic in construction sector *(15)*. Requirements are a key determinant of principle needs. These needs may be constraint by factors outside their control or may be influenced by other goals which themselves change in the course of time *(6)*. Where clarity of project requirements is low, or constraints are confusing and variable, research managers are more likely to believe that the probability of success is comparatively low *(16)*.

To control and manage maintenance activates successfully by a road authority depends on the well defined performance requirements. Some of the performance requirements are clustered in Table 2 for road network maintenance activities.

| Asset Owner | Asset Provider | Contactor |
|---|---|---|
| **Goals** | **Outcomes** | **Aspects** |
| - Costly effective projects | - Availability | - Flatness |
| - Fewer traffic jams | - Safety | - Roughness |
| - Safe roads | - Maintainability | - Light burning |
| - CO2 emission | - Accessibility | - Noise production |
| - Sustainable road network | - Functionality | - Resistance |
| | - Reliability | - Cleaning |
| | - Security | - Water drainage |
| | - Environment | - Road signs |
| | - Cost effectiveness | - Durability |
| | | - Snow removal |

**TABLE 2: Performance requirements for contracting mechanism in road network maintenance activities**

In order to identify suitable performance requirements that are widely applicable with the contracting mechanism, the challenge is dealing with changes and transferring the necessary assessment of system requirements. Pakkala's *(14)* international study on contracting practices reveals that there are some missing gaps between the higher level of performance measures and the performance measures that are used in the contracts.

The performance requirements in the different stages can be adjusted to each other, leading to optimal solutions from a system theory perspective. Dynamic contracting in general can be seen as the mechanism that support the changed approach by measuring the performance requirements and making the transfer of these requirements between parties and suggest further improvements for the maintenance outsourcing. (Figure 3)

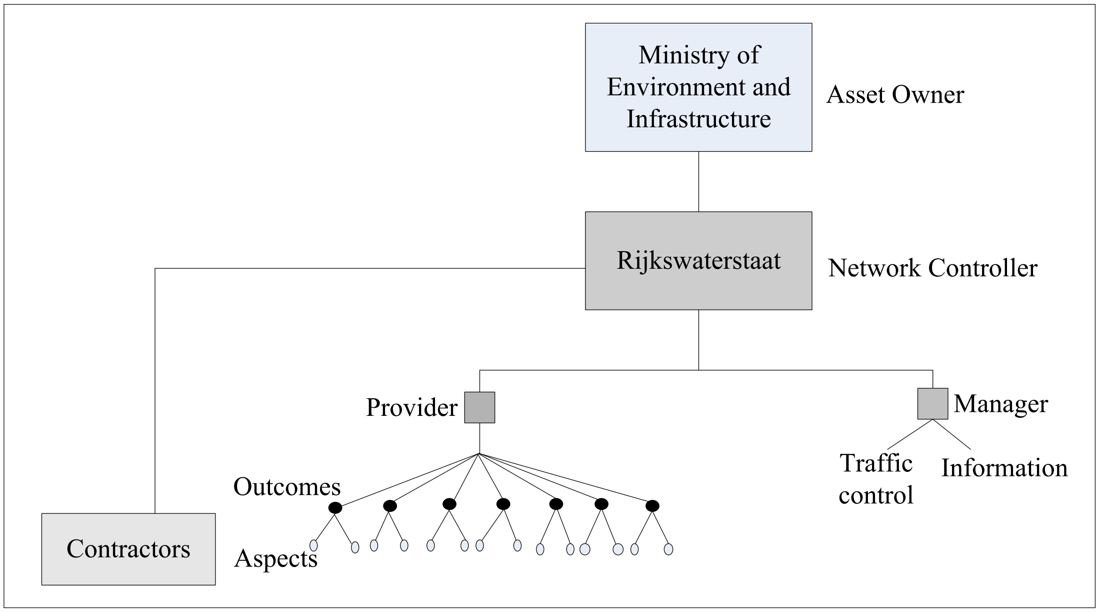


**Figure 3: Transformation of performance requirements**

## SYSTEM THEORY AND MAINTENANCE CONTROL

The vision of control paradigm stretches from system theory. It is of considerable importance to organizations that wish to have maintenance activities controlled that the variety of system knowledge have to be taken into account before any decisions can be made. The complexity of infrastructure networks limits our understanding of their behavior and, consequently, our options to effectively control and steer that behavior *(17)*. To be able to control infrastructure maintenance activities, system theory can be integrated into the organization's systems through the implementation of its strategies. The method proposed by systems theory is to model complex entities created by the multiple interaction of components by abstracting from certain details of structure and component, and concentrating on the dynamics that define the characteristic functions, properties, and relationships that are internal or external to the system *(18)*.

In terminology In't Veld *(19)* defined the system as "depending upon the objectives as defined by the analyst, a set of clearly distinguished elements within the total reality. These elements certainly have relations amongst themselves and may have relations with other elements of the total reality, where: elements are the smallest entities that the 'analyst wishes to consider in his analysis; relations are descriptions of the coherence between these elements. System approach also seeks to understand how they interact with one another and how they can be brought into proper relationship for the optimum solution of the problem *(20)*. An infrastructure can be seen as a large integrated system, which is built from objects (sub-systems) linked together in a system structure *(17)*.

**Effective Control of Maintenance Activities**

Outsourcing of infrastructure road network system can only be efficient if its maintenance activities are effectively and properly controlled. Transportation agencies want to move beyond the traditional contracting methods to growing use of new outsourcing methods in the effective control of infrastructural road maintenance activities. Controlling the maintenance activities play a vital role in contracting mechanism, where set of control rules assist the organizations towards its goals. Set of control rules occupies a very dominant position in the contracting mechanism of infrastructure asset management. This set of control rules is derived from a control paradigm as developed for the control of systems *(21)*. The control paradigm is defined as a class of abstract systems, each consisting of a controlled system, an environment and a controller.

The requirements for effective control have been developed by De Ridder *(22)* can be summarized as follows,
- Controller should specify a goal with respect to the controlled system
- Controller should have a model of the control system available
- Controller should have information available about the situation of the system parameters and influencing parameters of the environment as specified by the model
- Controller should have sufficient control variety available.

**Dynamic Control Model**

The control performance and process in any organization can be undertaken in three levels. These are; the strategic level, the management level and the operational level *(23)*.
- Strategic control: deals primarily with the broad questions of domain definition, direction setting, expression of the organization’s purpose, and other issues that impact the organization's long-term survival.
- Management control: deals with effective resource utilization, the state of competitiveness of the unit, and the translation of corporate goals into business unit objectives
- Operational control: is primarily concerned with efficiency issues. Occurring at very specific functional or sub-departmental levels of the organizational hierarchy, this mode of control generally conforms to traditional control models.

De Ridder *(24)* explores the levels of control by dynamic control model. (Figure 4) The vertical axis represents the control paradigm, whereas the horizontal axis represents the dynamic system behavior. In this dynamic control model the levels of control demonstrated where,
- Strategic control: is aimed at decision making about long term investments
- Tactical control: is aimed at programming interventions.
- Operational control: is aimed at delivery of network capacity and management of network flow. This contains operational goal control by the controller.

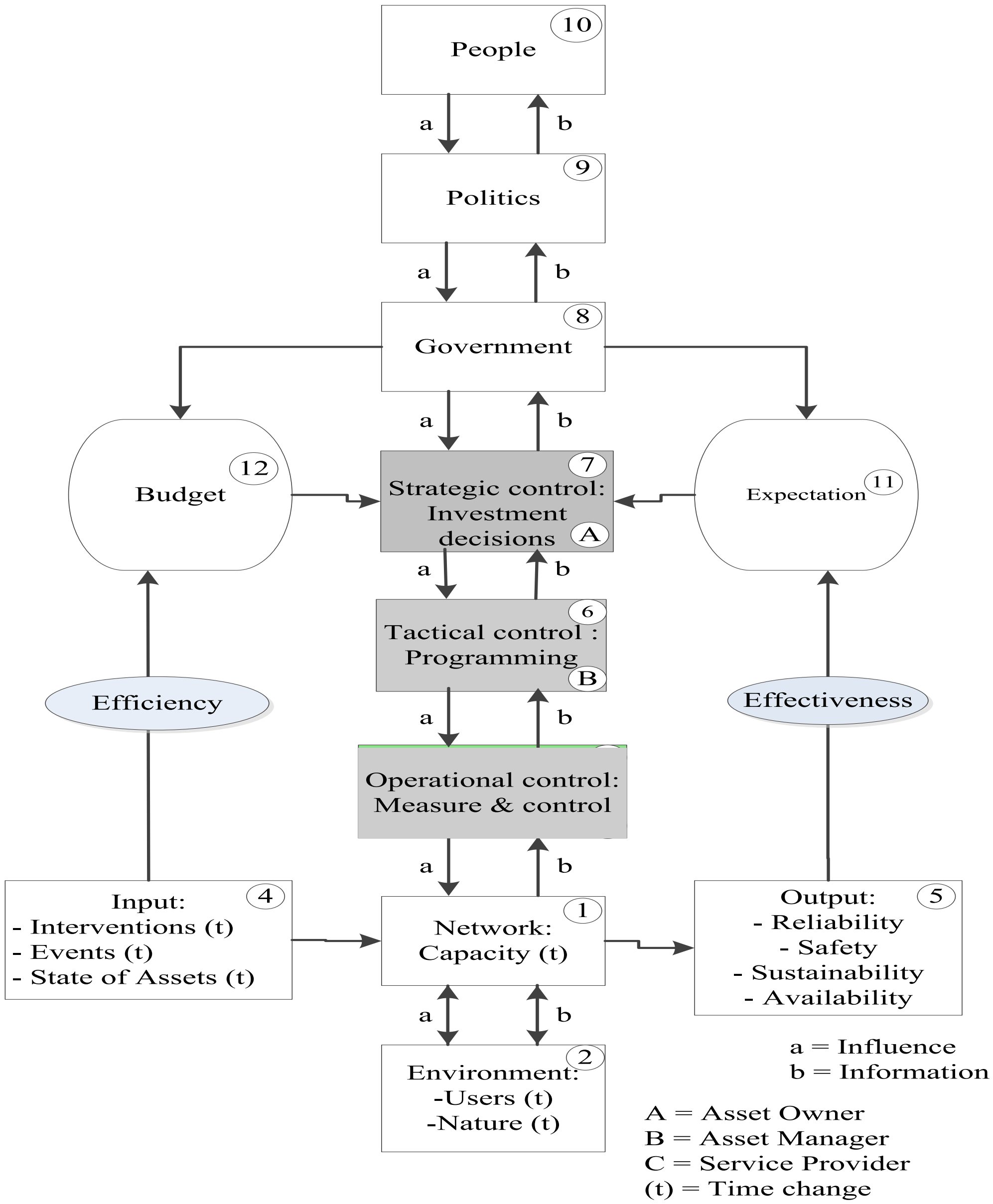


**FIGURE 4: Dynamic control model**

It can be seen that effectiveness of control is measured by comparison of the expectations at one side with the output at the other side and the efficiency as result of control is measured by comparison the allocated budget at one side with the input at the other side *(24)*. Consequently this conceptualization of dynamic control model can be used to deal with complex maintenance infrastructure activities.

The systems needs to be adaptive *(25)*, because with a duration of the maintenance contract of 20 years or more not everything can be known in advance. In short: complex systems are adaptive when they can learn and evolve; they have the ability to improve.

Uncertainty as a characteristic and not something which has to be resolved beforehand in fixed contracts.

**A PROPESED APPROACH TO OPTIMAL CONTRACTING MECHANISM FOR CONTROL MAINTENANCE ACTIVITIES**

The transportation construction industry needs mechanisms for letting and managing construction projects through which optimal product performance can be realized throughout it's service life *(26)*.

The traditional contracting strategies often do not lead satisfactory results in their service life. State and provincial transportation agencies are faced with growing needs and limited resources to maintain the highway network *(27)*.

The key findings of challenges in Rijkswaterstaat maintenance contracts; *(28)*.

- Often resulting in conflict situations
- Low management attention for this type of work
- Insufficient initial data and data management
- Insufficient contract control capability
- Contract procured on lowest price

The resulting challenges have motivated these agencies to expand the amount of contracting they do *(27)*. The objective of a preventive and corrective maintenance contract should be to ensure that mechanism plan and accommodate expectations, control activities, formulate asset strategies and asses adequate functionality throughout its service life cost effectively. Road asset managers are therefore encouraged to adapt their ongoing provisions and facilities of maintenance activities.

Within system theory, a dynamic control model is a better understanding of the process of contracting mechanism in maintenance infrastructures. The conceptualism of dynamic contracting mechanism gives the collaboration model between contractors and clients for maintenance activities of road networks with their associated assets by using performance indicators and dynamic control model. (Figure 5)

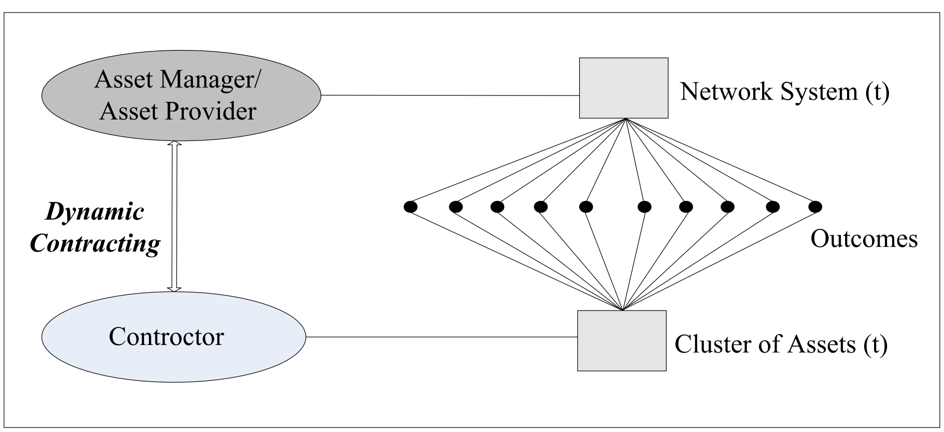


**FIGURE 5: Dynamic contracting**

**CONCLUSION**

The fast changing complicated environment and complex maintenance infrastructure systems require a contracting mechanism, which is dynamically controlled.

The key principles of dynamic contracting mechanism:

- Enables to controllers to keep maintenance facilities up to date
- Provide effective control of complex system in fast changing complicated environment
- Optimization of performance over the entire network per time step
- Maintaining level of asset performance through the execution of corrective and preventive maintenance
- Dealing with changing circumstances in a cost effective manner
- Ensuring performance (availability, safety, environment, etc.) requirements
- Ensuring flow of traffic
- Potential control on performance and costs
- Control transformation of risks between parties
- Choosing an appropriate type of contracting mechanism
- Is a tool for decision making

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