Infrastructure Management: dynamic control of assets

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Abstract
The infrastructure in the Netherlands is crucial for economic development on a national scale. Dramatic increases of transport and mobility accelerate ageing of infrastructure. The GNP of the Netherlands is strongly related to transport and to the two main ports (Port of Rotterdam and Amsterdam Airport Schiphol). The Netherlands is used to a high standard of infrastructure and expectations of the Dutch are that this will continue. But in the public mind new capital works are predominating and renewal of existing infrastructure is taken for granted. This paper focuses on the maintenance and renewal of existing infrastructure. The economic growth and finance conditions, that gave rise to its initial development, has changed and financing of renewal and acquisition of new projects needs to be accomplished in a new and more complex economic climate. In order to provide a reliable, well-manufactured infrastructure, which satisfies public expectations, planning of the necessary activities should be carried out on tactical as well as strategical levels. The research is based on systems theory, and conditions for effective control are developed. The conceptual model is validated in real life cases in the Netherlands. The result of the research could be used as a framework for controlled, tactical asset management processes. It involves the application of detailed asset management processes, procedures and standards. This allows development of sub-plans for the allocation of natural, physical and financial resources, which may serve to achieve strategic goals by meeting defined levels of service.

Key Words:
Infrastructure, assets, control, process, maintenance, traffic load, valuation, accounting standards

Introduction
Infrastructure assets are designed to function for several decades. This is in accordance with the design life of an object, that is the expected life of a construction from a designer’s point of view. In general the design life of infrastructure will be 50 to 80 years. But will the asset function well for such a period of time? The life of an asset will be shortened by wear and tear. At that point the technical life of the asset has ended, the construction cannot function at an acceptable level of performance anymore. If society still wants that functionality, the bridge will be renovated or replaced by a new one. Most of the time an asset’s useful life is shorter than the technical life. However, there are more factors that influence the life of infrastructure assets. Dynamic environments and the influence of stakeholders may have significant impact. Reasons are changing needs of society (better roads or facilities) or more traffic (transports, commuters) than initially planned. The bridge becomes obsolete. The asset does not fulfil its function in society anymore. In those cases we are stating that the economic life of a construction has come to an end. Should these structures be renewed, renovated, rebuild or replaced? The central question to be answered in this research will be:

How can the decision making process be optimized for the dynamic environment of road infrastructure?

Before answering the research question, a description is given of the integral management of infrastructures, including road infrastructure, as applied in the Netherlands. Developments in highway usage in the Netherlands are shown in the next paragraph. How the Dutch manage
those changes over time is illustrated in the paragraph with respect to governance.

There reforms in governance and management of public infrastructure are described. New management methods and techniques (New Public Management reforms) are introduced in the public office. For example an accrual accounting based financial administration is introduced in government agencies, followed by asset management, performance based contracting, and Economically Most Advantageous Tendering (EMAT) is strongly promoted. The question is "Will these reforms help to master dynamic changes?" Before answering this question the next paragraph describes the use of the road network in the Netherlands. The functioning of networks is evaluated by using a systems approach, yielding arguments to improve infrastructure management. This paper offers a framework for controlled asset management processes at a tactical level and will end with conclusions and recommendations concerning governance and management of road infrastructure.

**Road network usage**

After the Second World War the economy of the Netherlands grew enormously. Between 1950 and 1975 the yearly growth was about 7% [WL | Delft Hydraulics, 2005: p4]. Due to the economic growth and the growth of the population (11.6 million inhabitants in 1960 to 16.6 million in 2010), rapid urban development took place.

![Figure 1: Growth of highways length in the Netherlands](image)

The increase in economic activity, as well as the large number of inhabitants expanded requirements for transport of people and freight. This, in turn, necessitated more highway kilometres.

The network of highways became more complex and the number of structures (assets), like bridges, viaducts and tunnels, has increased as well. Especially in the years 1965 to 1975 a great number of viaducts was added to the road network capital stock. Therefore, the road network was extended because of changes in societal needs.

Desk research shows that conditions can differ in which infrastructure networks (roads) and structures (bridges, tunnels) have to function well. Therefore at all times the objects need to be in shape and fit for use, while meeting the public’s expectations. But is that the case? These changes can be categorised in social, political, societal and technical categories. In the 1970s and early 1980s, the number of cars increased at a huge pace due to an increased number of inhabitants and urban developments. New areas of industrial activity or urban development came up and had to be connected to our mainports (Rotterdam Harbour and Amsterdam Airport). An analysis of infrastructure planning indicates reasons for modifying the network and adding objects to it are [Ministerie van Infrastructuur en Milieu, 2012]:

- Urban developments with regard to living, working and recreation,
- Traffic: more vehicles, heavier loads,
- Accessibility: making industrial and urban areas better accessible,
- Improved technology (other type of vehicles or different technical solutions).

The above-mentioned reasons are related to the economic lifespan of networks and the structures in it. But we have to face technical problems as well. In the Netherlands over 1000 bridges and viaducts have technical problems in one way or another. A smaller number face the problem of serious fatigue, just because of the increase of the number of cars and the much heavier loads on the constructions (See Appendix A).

An explanation might be found in the following. In the period 1950-2010 freight transports on the Dutch road network increased dramatically.
In particular the number of heavy trucks (over 50-ton-carriers) increased significantly. Standards and regulations for the construction industry are adapted as a response to heavy usage of the network and in this way to changed needs of society. The assumption is that constructions (like bridges) are well designed and built, but the change in needs leads to another, more sophisticated level of infrastructure. This last level is hardly met nowadays.

The Netherlands possesses quite a number of infrastructure objects, like roads, bridges, and tunnels. Most of them are built in the 1960s/1970s or earlier.

Those infrastructure assets are built with materials and the construction knowledge of the time. It was assumed that the constructions were well planned, designed, built and maintained. Based on the traffic forecasts, building regulations and construction loads the life of those structures (that is the design life) was intended to be 60 to 80 years. Before 2040 no problems would occur. But in recent years not only the intensity of traffic is much higher, but car weights and axle loads have risen as well. That is one of the reasons that building codes are adapted to recent standards. That is why Rijkswaterstaat has started a project to investigate what the residual life of the old bridges might be. In general the economic life of existing structures has come to an end in about 40 years. That is less than intended. In a number of cases the economic life of the structure could be expanded and the object might function for another 20 years or more.

In most cases it is not the design, the building material used or the construction itself that lead to problems in proper functioning of the network. It is not the construction itself that causes technical problems but very often the changes in the environment will result in not delivering the performance asked. Other reasons for changed circumstances might be: number of vehicles, supply and demand of transport, societal needs, urban planning (living, working and recreation), improvements in technology (cars and bigger vehicles, bigger bridges) or changes in fiscal policy. In the Netherlands the building industry is confronted with process innovations, like integrated contracts (design, build, finance and maintenance in a single contract) or performance-based contracts. Even the procurement involved has changed from Lowest-bid in the ‘old days’ to EMAT (Economically Most Advantageous Tender) in more recent years.

Many bridges and viaducts were built in a relatively short period of time. That is why the Netherlands is confronted with the so-called “1000 bridges problem” caused by wear and tear on the one hand and/or changed circumstances in the environment of the bridges on the other. In most cases this is a technical problem and might be solved by reconstruction or renovation of the bridge. In recent years it seemed that these problems came all at once, but could Rijkswaterstaat have expected this? Is it possible to forecast these kinds of developments and react on that in advance? What conditions should be met to be able to deal adequately with those changes over time?

**Governance of road infrastructure**

All the infrastructure projects, reconstruction as well maintenance of the network, are financed from several budgets. At first it is the budget of the Ministry of Infrastructure and Environment, secondly it is the mentioned MIRT investment planning and thirdly there are the EU budgets. The total budget of Rijkswaterstaat was about €5,300 million in 2010. Of which €1,743 million was spent on road construction projects and €871 million on road maintenance and repair.
Most of the time the government will initiate the investments but private parties could be involved in financing infrastructure projects (Public Private Partnerships). Quite recently the Dutch minister ask pension funds to do so. In those PPP's the organisations involved have to deal with the trade-off between ROI (Return on Investment) and risks.

The decision making process for large construction projects can be very complex, especially when many stakeholders and lengthy procedures are involved. In this research the overall task in managing infrastructure is defined as Infrastructure Management (see figure 4). Very different types of infrastructure are involved: the road network, waterways, rail network and even airports. A great variety of policies were developed at a strategic level of infrastructure management. The tactical level is the level of the asset manager to develop programmes and projects to implement policies as far as concrete measures are involved (roads, bridges, tunnels). At the operational level the projects are really executed by (general) contractors. Most of the activities with respect to maintenance and repair are outsourced [Schoenmaker & Verlaan, 2013].

Nowadays the building industry is often an assembling sector. The contractor is interested in the design and the specifications of a project. This is a static approach of the building process. What is needed is a more dynamic concept that effectively manages demand (client’s value) and supply in an economic way through the whole life cycle of built facilities. For this ‘smart’ information is needed. ‘Smart’ means information that is correct (definitions), on time (agreements) and on the right location (procedures). A public sector that uses accrual accounting is one requirement for obtaining smart information.

Since the early 1990’s initiatives are undertaken to make the Dutch government administration more performance based. The output should be more effective and more efficient. The taxpayer should get more value for his money. That is not only the case in the Netherlands but a growing number of countries have taken action to strengthen accountability. Traditionally, governments use cash-based accounting systems. In the Netherlands, Rijkswaterstaat is the provider of the civil infrastructure on the national level. As a government agency, Rijkswaterstaat has the obligation to base her administration on the principles of accrual accounting. Accrual based accounting can provide better information to operate efficiently and effectively [Hoek 2005]. That could be a requirement for solid implementation of asset management as a subset of infrastructure management (see figure 4).

Infrastructure management might be seen as systems management this is the process of monitoring and controlling a system to achieve overall system objectives. Here, the management role is to ensure that all necessary disciplines and functional areas are involved to meet system requirements. For a road network, that could be "adequate and safe transport of people and goods" which is the mission statement of the of Rijkswaterstaat
business plan [Rijkswaterstaat, 2004]. Therefore infrastructure management includes all decision making and activities with respect to keep the infrastructure ‘fit-for-use’ and ‘up-to-date’ by using ‘state-of-the-art’ methods and techniques. In this integral vision all phases of providing infrastructure services are included from initial idea, conception to demolition at the end of the service life of the network objects (assets) and relations between them. Asset management is seen as a subset of infrastructure management and is related to all administrative activities mainly at the tactical level and all the physical activities at the operational level.

![Image](image.png)

**Figure 4: Levels of infrastructure management**

The World Road Association (PIARC) has adopted an OECD definition of asset management, which in turn was derived from a FHWA definition, viz:

"A systematic process of effectively maintaining, upgrading and operating assets, combining engineering principles with sound business practice and economic rationale, and providing the tools to facilitate a more organised and flexible approach to making decisions necessary to achieve the public's expectations."

This broad definition boils down to the following: road asset management means managing a road network (roads, bridges, traffic facilities, etc.) in order to satisfy the requirements of business and private road users, at the lowest possible cost over a long period of time [Verlaan & Ridder, 2008].

**Systems approach**

There are arguments to see infrastructure as a system. Firstly, because its focus is total system oriented and it emphasises achievement of the overall system mission and objectives (network requirements). Secondly, based on adequate information the asset manager takes decisions (the managers job) that optimise the overall-system rather than the subsystems. Thirdly, the systems approach recognises interaction and synergy among systems and subsystems. Systems management is used to ensure that organizations, responsibilities, knowledge and data are integrated towards achieving overall objectives. Asset management recognizes interactions and interdependencies between subsystems (and objects) and with the environment, and tries to account for them in making plans and taking action (e.g. prioritising activities) [Nicholas & Steyn, 2012: p288]. This is in contrast with the more typical management view, which is focussed strictly on individual functions and tasks and on the performance of individual departments, even if that is at the expense of the total organisation.

Asset management includes "systems thinking", a systems approach, which is a way of conceptualizing physical entities (infrastructural objects, the assets) and addressing problems with respect to building and maintaining infrastructure facilities. The main components of the systems approach are [Nicholas & Steyn, 2012: p62]:

1. **Description of the system**
2. **The objectives and performance criteria of the system**
3. **The system environment and constraints**
4. **The resources of the system**
5. **The elements of the system, their functions, attributes and performance measures**
6. **The interaction of the elements**
7. **The management of the system**

The systems approach is a way to visualize and analyse physical systems, but it also provides a framework for asset management. It is a way to systematically conceptualize problems and to structure information to take decisions as well.

The infrastructure as a system is defined here as related to transport, mainly roads and waterways and their objects like bridges, viaducts and tunnels included.

Because there is a tight linkage between infrastructure and economic growth it is of
The utmost importance that a country’s infrastructure functions well. Adam Smith was the first economist who really recognised the economic advantages of a good system of roads, canals and the like by diminishing the expenses of carriage and putting remote parts of the country relatively near to the town [Raphael & Smith, 2003]. By doing so monopolies were broken down and new markets were opened. After describing the infrastructure system the maintenance of infrastructure functions starts with the overall objectives of the system involved and performance criteria are set. In the Netherlands, this is done in so-called Service Level Agreements (SLA) between the Ministry of Infrastructure and Environment and Rijkswaterstaat, a governmental agency. Based on an integral analysis of transport by roads, waterways and rail the so-called MIRT-planning (Multi-year plan for Infrastructure, Public Space and Transport) prioritizes and assigns budgets to infrastructure projects new works for the upcoming years [Ministerie van Infrastructuur en Milieu, 2012]. This investment planning is based on a thorough cost-benefit analysis (CBA), Market-scan and Public Private Comparator (PPC) in which is investigated if partnerships between private and public entities are likely to be beneficial and what the most suitable contract form might be.

The dynamic aspects (changes over time) are frequently caused by the environment of the system, that is other related systems, a number of stakeholders (multi-actor system) and natural systems that might be affected by the infrastructure system. It is no easy matter to identify the environment of infrastructure, because those forces, external to the system, are not quite clear and sometimes hidden. Infrastructure objects (assets) will be there for 30 to 100 years, but changes might happen in a much shorter period of time. The resources used by systems management include capital, labour, materials, equipment and facilities. These resources are considered as available, but they might become constraints when depleted. Looking to the future, some questions might arise about likely changes (stakeholder needs) or innovations (technical advancements) caused in the environment.

The systems approach identifies two systems in interaction with the environment (strategic level, ministry), the controller and the controlled system (Figure 5).

![Figure 5: Systems behaviour, adapted from [Leeuw & Volberda, 1996]](image)

The controlled system (CS, infrastructure assets, society) and the controller (CS, management, RWS) communicate with each other by information (b) and control procedures (a) to produce a state-of-the-art network.

**Conditions for effective control**

Given the control paradigm of the previous paragraph (Figure 5), the conditions for effective control are [Ridder, 1994: p105]:

1. CR should specify a goal with respect to the CS,
2. CR should have a model of the CS available,
3. CR should have information available about the situation of the system parameters (CS) and influencing parameters of the environment (E) as specified by the model,
4. CR should have sufficient control variety available.

Ad 1: The controller did specify a goal with respect to the network in the mission statement at a strategic level, that is “adequate and safe transport on roads”,

Ad 2: The controller is searching for a model for asset management. Some ingredients are still there, but not all activities are involved yet,

Ad 3: Rijkswaterstaat does not have the resources and expertise yet to carry out asset management activities, necessary to provide accurate asset inventories and valuations. Asset information is therefore either minimal or fragmented and still difficult to access,

Ad 4: Two types of control can be distinguished, Internal control and external control aiming for influence of the controlled system and the environment respectively.
This leads us to the following framework (figure 6) in which Governance is related to a defined Service Level, to Investments and to Budgets (the dark oval in the middle). The grey marks are related to Management Information, that includes Planning, Monitoring and Auditing information. The white ovals in figure 6 have to do with the physical activities like Acquiring, Building, Maintaining and Replacing the assets.

![Fig. 6 Life Cycle Approach to Asset Management](Austroads, 2002)

Essential to the concept is the notion that the network requirements will change over time. That’s why a life cycle approach to road network asset management is needed as illustrated in Figure 6.

- The centre represents the main aim and focus of road network asset management, namely delivery of community benefits and satisfaction of stakeholder expectations at the lowest long term cost,
- The six elements (white) forming the inner loop represent the physical actions associated with asset management, and the ‘cradle-to-grave’ concept of asset management,
- The four elements (grey) in the middle circle represent the strategic activities that are essential for successful asset management, and
  - The outer circle represents the Integrated Asset Management Process, with three component parts (strategic planning process, the actions and performance feedback).

The integration of these three management processes in one framework might guarantee an effective treatment of dynamic circumstances. For the Dutch situation we reviewed the processes mentioned before. The MIRT procedures have a lot to do with information and consultation of stakeholders. That is why there are 5 steps to follow [Ministerie van Infrastructuur en Milieu, 2012]:

a) Consultation meetings of central government with local authorities; The Parliament is informed about the on-going process and decisions taken,

b) The Agenda for regional developments is actualised,

c) MIRT Research is executed for analysis of feasibility of short-term as well as long-term investments,

d) MIRT Rules should be followed for capital budgeting with respect to the initial phase, the design phase and the realisation phase of infrastructure projects (go/no go decisions are taken),

e) Priorities of MIRT projects are listed; description of problems, integral solutions, projects and planning of projects are described.

With respect to the conditions of effective control we state the following findings. The Ministry of Infrastructure and Environment (controller) did specify the goals in so-called policies. The MIRT procedure as described relates investment planning to policies of spatial planning and transport forecasts. With the procedures for consulting and decision making the controller has a model of the controlled system. As we have specified in figure 6 the information is available for making decisions on the three management levels of figure 3. The last condition is associated with control variety. In the Netherlands the functions needed in infrastructure management are owners of infrastructure, asset manager and asset providers. These functions are implemented at
the governmental level, but are not in the same agency.

Conclusion

The question to be answered is: How can the decision making process be optimized for the dynamic environment of road infrastructure?

As a result of researching literature and interviewing experts the following conclusions may be drawn about applying infrastructure management in the Netherlands:

a) The suggested framework for applying infrastructure management meets the conditions for effective control in the Netherlands;

b) There is substantial experience with infrastructure management in some countries, especially Australia and New Zealand that is used as reference for the Dutch situation;

c) An administration which is based on the principles of full accrual accounting, is a requirement for successful implementation of asset management methods and techniques in the Netherlands;

d) The MIRT projects in the Netherlands indicate that the transition of cash based administration towards an accrual accounting based administration will take more time than planned;

e) Improvements might be implemented when the developments with respect to road, rail and air can really be steered on a integral basis.

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