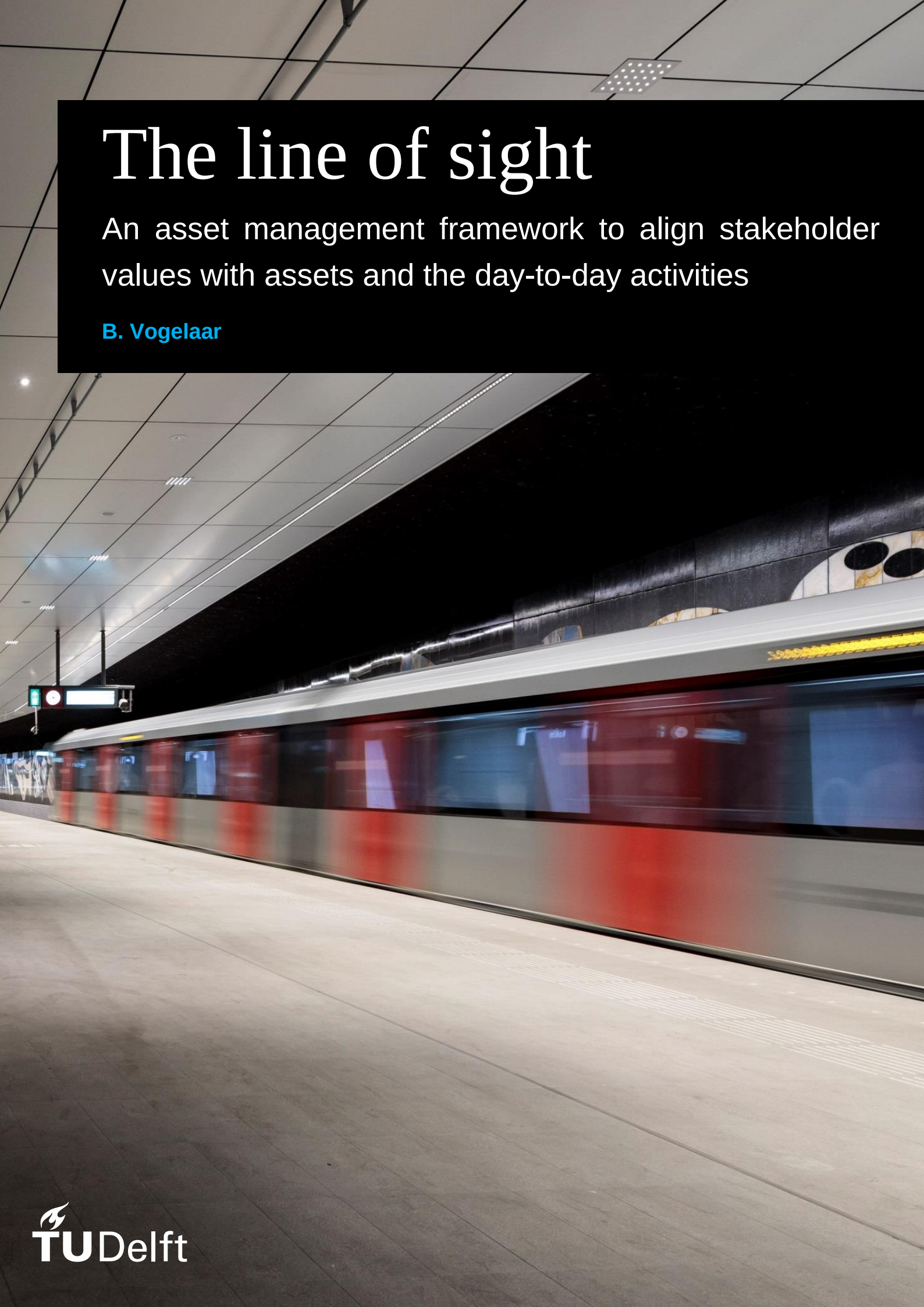

The line of sight

An asset management framework to align stakeholder values with assets and the day-to-day activities

B. Vogelaar

TU Delft

Front cover photo by Gé Dubbelman

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An asset management framework to align stakeholder values with assets and the day-to-day activities

By

Bart Vogelaar

Student number: 4412184

in partial fulfilment of the requirements for the degree of

Master of Science
in Engineering & Policy Analysis

Faculty of Technology, Policy and Management

at the Delft University of Technology,
to be defended publicly on Thursday March 22, 2018 at 15:00.

Graduation committee

Chair	Prof. mr. dr. J.A. de Bruijn	Multi-Actor Systems: Organisation and Governance
First supervisor	Dr. M.L.C de Bruijne	Multi-Actor Systems: Organisation and Governance
Second supervisor	Dr. J.A. Annema	Engineering Systems and Services: Transport and Logistics
External supervisor	Ir. D. de Mello	Royal HaskoningDHV, Transport & Planning

Preface

Perhaps the most frequently fired question at any graduate in the process of writing his or her thesis is something like: ‘when do you expect to finish?’ For some, including myself, a question that brings about a certain amount of discomfort and is preferably deflected with a grin or a joke. This question is often preceded by another obvious one: ‘what is your thesis about?’ When confronted with the latter question, I sighed internally and motivated myself to explain what the thesis was about as best as I could. Not that I was bothered by the genuine interest of those who asked, but because of the fact that the concept of a line of sight – let alone the definition of asset management – is not really something you explain within a few sentences.

Over the course of time my response would come to be how boardrooms and ‘the guys who do the maintenance’ do not always strive after the same thing and why this is not cool. The technically correct answer would have been: ‘seeking the connection in asset management between high level organisational objectives with physical assets and the activities surrounding these assets’, but hardly did this latter definition spoke to the imagination of those interested in my research project – and I cannot blame them.

Understanding the necessity of a line of sight in a broader context called asset management was personally quite a challenge for me. Simultaneously, delineating the scope of my research proved to be a task not too trivial. I would not claim asset management is rocket science, but a certain complexity is introduced through the proliferation of definitions and perspectives of this discipline. Asset management is arguably perhaps not a discipline on itself in the first place, but rather a fruit basket of multiple disciplines.

Nevertheless, it was an intellectual challenge to harmonize this abundance of perspectives that we call asset management today, although frustrating at times. The courses provided by my master’s degree proved to be valuable in creating structure out of chaos, in particular the course that taught me the principles of policy analysis. Unifying these mental images of managing physical assets has perhaps not been fully documented in this thesis alone, but rather something I did parallel to this research. All in all, I feel relieved that I managed to succeed in presenting a framework that I believe is easy to understand for outsiders and captures the essence of asset management.

Many people helped me in doing so. First of all, I would like to thank my external supervisor and colleagues at Royal HaskoningDHV that inspired me to start exploring the topic of my research and for facilitating me wherever they could. I also want to thank my graduation committee for their elaborate feedback and critical questioning that fundamentally helped shaping my theoretical understanding. In particular I would like to thank Metro and Tram for giving me the opportunity to research their organisation. Without the many hours of interviewing the experts of Metro and Tram I would not have come to substantial insights.

Bart Vogelaar,
Oud-Beijerland, March 2018

Abstract

Organisations managing large stocks of physical assets are increasingly under pressure of diminishing budgets and rising performance demands. In order to better fulfil a wide variety of stakeholder demands against the lowest low costs the management of physical assets has gradually professionalized by eliminating inefficiencies and enhancing performances. This professionalization is nowadays regarded to as asset management. Asset management is a relatively new discipline that aims to achieve organisational goals through the management of physical assets. A way to achieve operational excellence from the asset stock is by aligning the strategical organizational objectives with the operational activities.

The PAS55 asset management standard describes the alignment of organizational strategic direction with the day-to-day activities surrounding the assets as the 'line of sight'; the day-to-day activities being primarily maintenance. The PAS55 prescribes a planning system consisting out of a policy document, a strategy document and objectives amongst others, and states that, if this planning system is followed, it safeguards a line of sight.

In practice, many organisations struggle with establishing a line of sight. Although it is not sure why this is so, it is suspected that they have no clear framework that unambiguously tells them how to develop a line of sight. We at least found that the PAS55 planning system does not clearly define how policy and strategy, as envisioned by the PAS55, establish a line of sight.

No research has been performed on the consequences of not having a line of sight. Let alone that there is little research available on the topic of the line of sight within asset management. A Dutch professional asset management platform states that the benefits are increased efficiency, communicating strategy to personnel, performance monitoring and stimulating innovation.

Only a few research papers were found that related to the line of sight within asset management. Past research in the field of line of sight had a strong emphasis on performance measurement. It considered the line of sight as a linkage of objectives in a structured manner that needed to be monitored through performance measurement. However, some remarks can be made on this past research. The performance measurement frameworks that specifically focussed on the line of sight were analysed alongside past performance measurement frameworks on their suitability to serve as a line of sight framework. Although one of the frameworks that focussed on the topic of the line of sight was considered to be the best framework to date, we argue it to be insufficiently qualified to serve as a framework that establishes the connection between stakeholder values, assets and the day-to-day activities. For this reason it was chosen to develop a line of sight framework that is strongly inspired by the aforementioned performance measurement frameworks.

Research objective

As still little knowledge is available on the topic of the line of sight in asset management in scholarly literature, this research makes a contribution to the perspective of a line of sight as an entity on its own. The goal of this research is to develop a framework that helps organisations in the process of establishing a line of sight. This framework is consequently used and evaluated in a case study for the organisation that manages the light rail infrastructure in the Amsterdam region called Metro and Tram.

The knowledge produced in this research is meant as a stepping stone for further research and is not considered to be sufficiently covering the topic of the line of sight as such that the framework that is developed is generically applicable to organisations in various sectors and all sizes. The main research question of this document states:

How to design a line of sight for a public asset intensive organisation?

This main research question is answered through six sub research questions. The public and asset intensive characteristic of an organization proved to generate requirements to which no existing framework complied with.

Research design

The research can be regarded as a design science research. The product to be developed is tested against requirements from the environment for which the framework is developed and requirements from literature.

As the aforementioned frameworks were based on performance measurement literature, and these frameworks proved to be valuable in making a logical connection with the organizational strategic objectives and the operational processes, performance measurement literature was considered to be a useful theoretical basis.

Performance measurement literature was analysed to look for requirements and simultaneously discover what performance measurement frameworks are available. On the basis of the requirements from both the Metro and Tram environment and those found in literature a comparison could be made. None of the existing performance measurement frameworks was considered to be suitable enough to serve as a line of sight framework for a public asset intensive organisation, despite some of these frameworks were purposely designed to establish a line of sight. For this reason it was decided to build an own framework that is however strongly inspired by past works in the field of performance measurement.

Consequently the developed framework was evaluated in two ways. The first was by actually using it. Several lines of sight were developed for Metro and Tram. A second of evaluation, which was much more theoretical, compared the line of sight framework with the Metro and Tram policy and strategy document, and the performance measurement systems and the PAS55 planning system.

Findings

The developed line of sight framework consists of five separate layers. Each layer contains factors that pertain to a real world attribute of the asset system or the actions that can be undertaken that directly influence the asset system. The factors are connected with each other in a vertical matter and together form a causal chain. This way, stakeholder values are connected to improvement measures through assets and the activities surrounding these assets.

For each stakeholder value a separate line of sight is created. This research provided a method to identify the stakeholders and their interests and consequently distil these interests to generic values. This practical exercise of filling the line of sight framework led to the creation of several guidelines that help developing a line of sight; the structure of the line of sight framework does not always sufficiently guarantee a smooth design process. The line of sight framework proved to be an intuitive instrument for outsiders that generally was filled without too much difficulty. In many instances a connection could be made with the stakeholder values, the assets and the day-to-day activities.

The comparison of the line of sight framework with the Metro and Tram policy and strategy document and performance measurement system resulted in reciprocal insights. The Metro and Tram policy and strategy documents were found to have little to no line of sight embedded within. Reversely did the Metro and Tram policy and strategy document highlight the inability of the line of sight framework to cope with organizational amenities, such as information technologies and asset management competencies. These amenities do not directly affects the assets, but certainly do on a longer time span. A new layer for the line of sight framework was proposed in order to include these organizational aspects, but the expanded framework could not be put to practice.

A comparison with the Metro and Tram performance measurement system revealed that this system did not show much line of sight either. The line of sight not only proves to be useful for ensuring a logical causality of performance indicators, but also for harmonizing the policy and strategy documents and the performance measurement system. We argue that the line of sight is a separate entity on which policy and strategy can be formulated. Consequently the performance measurement system checks upon the objectives that are set in the policy and strategy documents. If thus policy and strategy are based on the line of sight, the performance measurement system will also display a line of sight. On the other hand the comparison with the performance measurement system made apparent the poor ability of the line of sight framework to cope with cross connections that run horizontally across the line of sight or between two or more separate lines of sight.

This research resulted in a line of sight framework, a method for finding the relevant stakeholder values, methods for the identification and selection of factors, guidelines on how to design a line of sight and an evaluation for the potential future use of the framework. Alongside these products, accountability for all of the made design choices has been provided.

The biggest weakness of the framework is its poor capability to cope with cross connections. Those are the connections between factors that run horizontally across the framework or in between two or more separate lines of sight. Especially the cross connections that run between two separate lines of sight can create the risk of sub optimization. Another weakness is that the framework can hardly incorporate organizational aspects such as collaboration that do not directly affect the assets, but do in a longer time span.

Recommendations

Like stated before, this research is considered to be a stepping stone to further research. Three areas for further research are identified for the advancement of knowledge on the line of sight. These are more naturalistic evaluation, the expansion of the line of sight framework in order to incorporate organizational aspects that indirectly influence assets and modifications of the framework to incorporate cross connections without harming the comprehensibility of the framework.

The more naturalistic evaluation is done for three reasons. The first is to better explore the connection of the framework with the actual maintenance processes, since this research was solely performed within an organisation that does not perform maintenance works themselves. The second reason is to gain more insights in the generic applicability of the framework for organisations in other sectors. The third reason is to better understand the application of the framework; it has not been tested for actual policy and strategy formulation or performance measurement after all.

The framework can be expanded with various layers that give room to incorporate factors that do not directly affect the assets as the day-to-day activities do. These factors are referred to as organizational aspects. A suggestion has already been made for a layer that allows the incorporation of improvement

measures in the field asset management competencies and information technology. What is considered to be more problematic are organizational aspects such as collaboration. The importance of collaboration is recognized as its outcome can have an influence on assets, although the time span is long and measuring the throughput of collaboration is difficult. Adjusting the framework so that collaboration can fit within requires serious thought.

Finally, methods need to be developed for the systematic identification of cross connections and the framework needs adjustments to visually display these cross connections between factors in separate lines of sight without harming the comprehensibility of the framework. The risk of cross connections is that of sub optimization.

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1 Introduction

This chapter presents a brief overview of changes within the world of maintenance. The perspective of maintenance has changed over the years and eventually evolved to become part of a broader discipline called asset management. The rise of asset management is briefly touched upon and consequently the term LoS is introduced. The LoS is a term introduced by the PAS55 asset management standard and states how organisations should align their objectives with the activities they perform. The LoS is a topic that has received little scholarly attention. It is not known what the consequences are of not having a LoS in place, let alone that there is hardly any recognition of the concept in academic literature; here we recognize a scientific gap.

1.1 A call for more efficiency

Our today's world is becoming increasingly more dependent on maintenance. As in the case with industries more and more production is automated with the help of machinery (Zuashkiani, Rahmandad, & Jardine, 2011). This brings about a shift in costs from labour expenditures towards capital expenditures that are in need of maintenance. Similarly, better service requirements such as availability are demanded from most of our infrastructures at the same costs – or sometimes even lower than the previous year's budget (Wijnia & Herder, 2010). Besides, infrastructure systems are becoming more integrated and complicated (Van der Lei, Herder, & Wijnia, 2012). Perhaps the biggest thriving force behind these developments is the ever growing competition that is caused by globalization (Van der Lei et al., 2012). Not only do manufactures need to produce more effectively and efficiently, but also the infrastructure they use to transport their products needs to excel simultaneously.

Most developed nations invested heavily in the construction of infrastructure in the second half of the 20th century. However, maintaining this capital stock proves to be difficult as the maintenance needs become evident concurrently since the infrastructure was built during the same period (Parlikad & Jafari, 2016). The amount of technical defects of tunnels, bridges and other pieces of infrastructure has doubled in 2016 in comparison with the year before in the Netherlands (Prenger, 2017). One of the most intriguing and relevant cases of hindrance due to malfunctioning infrastructure was the case of the Merwedebrug in 2016. The bridge contained cracks and as a consequence transport trucks were prohibited from crossing the bridge. According to the transport sector the economic damage amounted to half a million dollar per day (NRC, 2016). In 2014 the US spent 57% of its infrastructure budget on operation and maintenance while having already been raised by 6% in comparison with 2003, but still a general consensus prevails that this rise is not in line with actual maintenance demand resulting in worsening infrastructure conditions (Parlikad & Jafari, 2016). This becomes clear from the giant backlog the US is currently struggling with. The American Road and Transportation Builders Association found that 55,771 bridges needed to be repaired or replaced in the US (Houlihan, 2017). Besides the dilemma of high requirements and small budgets there is less public acceptance for outage of infrastructures as the information coverage in the media on these issues is immense. In

sum, this burdens those in control of the physical assets with high demands on the maintenance tasks to be performed: maintenance is expected not to impair the service and should be done at the lowest possible costs.

A change in maintenance philosophy

It may come as no surprise that maintenance professionalized alongside these incentives for better requirements. The perspective on maintenance has come to transform over the course of time as depicted in Figure 1. Initially it was viewed as a necessary evil that had to be tackled: repairs and replacements were performed when the defects became evident trough machinery failure. The first step forwards was that maintenance evolved to become a technical matter that could be optimized both in a technical and organisational sense. Not much later it developed into a profit contributor that had to cope with the flexibility of dynamics business environments. Finally, maintenance has become a partner in business strategy and is treated with the same amount of efforts as the production function within organisations. Maintenance is now considered to be an integral part of corporate strategy that attains organizational goals by fulfilling stakeholders' demands.

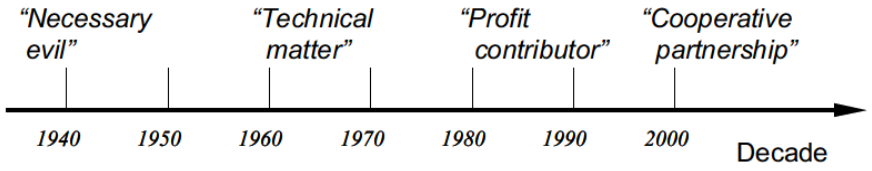


Figure 1: Changing perspective on maintenance over the years (Pintelon & Parodi-Herz, 2008)

Maintenance is nowadays often part of a broader discipline referred to as asset management. Asset management involves next to maintenance also the acquisition and replacement of new assets and thereby integrates maintenance and investment decisions. The PAS55 process standard defines asset management as (The Institute of Asset Management, 2008a):

"Systematic and coordinated activities and practices through which an organization optimally manages its physical assets, and their associated performances, risks and expenditures over their lifecycle for the purpose of achieving its organisational goals."

It is this discipline of asset management that systematically tries to link the eventual maintenance activities with the high level organizational objectives. Asset management is what makes maintenance the partner in business strategy. Two other features can be distilled from the above definition. Firstly, asset management is concerned with balancing performance, costs and risks against each other (Wijnia & Herder, 2010). Secondly, asset management stresses the need to consider the whole life cycle of assets. This coincides with the idea of integrating maintenance and investment decisions. Moreover it is wise to consider the life-cycle costs of infrastructures due to their long life span. Asset management has evolved from practice and is often considered as the professionalization of maintenance and repair actions (Wijnia & Herder, 2010). Professionalization in this context means, amongst others, the introduction of condition based maintenance, tools such as Failure Mode and Effect Analysis (FMEA) and life-cycle analysis considerations. Despite these advancements in the late 20th century, the focus was still on high reliability without questioning why this should be a goal per se. The ties with high level strategic objectives were weak and maintenance was not involved in investments decisions (Wijnia & Herder, 2010).

Many infrastructure investments and maintenance decisions in the past were made in accordance to tradition, intuition, personal experience, resource availability, and political considerations (Too & Tay,

2008). Logically, this gives room for inefficiency in prioritizing the already scarce budgets. To overcome this problem, many government agencies created their own sort of asset management system. In scientific terms the concept of asset management is relatively new as many industries and government agencies created their own asset management system from practical experiences (Too & Tay, 2008; Wijnia & De Croon, 2015). Although there was agreement on the past that asset management encompassed several disciplines (such as maintenance, information technology, human resource management, finance, etc.) there was often little integration between them. With the publication of the Publicly Available Specification 55-1 on asset management in 2004 a first step towards a univocal definition of asset management was made that aimed to integrate the various disciplines it contained. The latest widely used asset management standard is the ISO55000 that was released in January 2014. Both the ISO55000 standard and the newest PAS55 standard prescribe how optimally managing the assets should lead to fulfilling high level organisational objectives.

1.2 The line of sight

As we have seen from the previous paragraph asset management is about the management of physical assets as to achieve organisational goals. This is where the concept of line of sight (LoS) comes into play. The LoS is a term that is widely used although hardly *comprehensively* defined.

The PAS55 standard, who presumably coined the term and that was later adopted by many practitioners, describes the LoS as the connection between the organizational strategic direction and the day-to-day activities of manging assets (The Institute of Asset Management, 2008a). A Dutch knowledge platform on asset management (IAMPro) defines the LoS as *the connection between the strategic asset management goals and the operational activities* (IAMPro, 2017). Presumably they too adopted this definition from the PAS55 standard given its great similarity.

1.2.1 Problematic line of sight

Apart from the above definitions, the professional literature does not provide any tools as to build such a LoS, let alone further specify to what such a connection must qualify. Only the PAS55 says that through its planning system, consisting of asset management policy, asset management strategy and asset management objectives, a LoS is guaranteed. The newer ISO55000 standard provides a planning system that is very similar to that of the PAS55. Without using the word ‘LoS’ the ISO5500 standard describes how the organisational goals should be attained is adopted within the asset management policy.

How exactly these assets contribute to these organisational goals is not obvious for organisations as becomes apparent from both academic and professional literature on asset management. The LoS is a rather unknown phenomenon in academic literature and therefore there are hardly any empirical observations that describe a problematic LoS that prevails within organisations.

Literature on the combination of asset management and performance measurement however hints that a LoS does not come naturally. Attwater, Wang, Parlikad, and Russell (2014) noted that even though organisations have well-defined asset management systems, they are uncertain about how to measure the performance of these asset management systems. They argue that existing asset management frameworks should be extended with the impacts of the on-the-ground asset management activities, thereby clearly showing the link between these activities and the organisational objectives. This plea demonstrates that this link is not always clear. In other words, this could hint at the fact there is no clear LoS.

Attwater et al. (2014) also argue that too much attention is spent in vain on maturity models as these only assess the asset management capability (probably hinting at amenities such as information systems, human resources and the like) of the organisation, but do not account how asset management contributes to organisational performance.

Hartmann and Dewulf (2015) examined the effectiveness of infrastructure asset management at a Dutch provincial agency. They concluded that there is a missing link between the overall strategic objectives and the degree to which maintenance, renovation and reconstruction work achieve these objectives. This missing link consequently resulted in conflicting views on the budget and provision for these maintenance works.

In this research project the Metro and Tram (MaT) organisation of the Amsterdam municipality is examined. An example of how this LoS is absent within this organisation is provided by one of their policy spearheads that states that traveller comfort is a goal that MaT pursues. The strategy consequently makes no mention of how this comfort is provided through the assets or either the day-to-day activities.

Hestermann (2012), as an asset manager practitioner, vividly illustrates how executive boards have a clear overview of their human and financial resources. But when asked about their asset resources, what he refers to as non-human and non-financial (NHNF) resources, they do not even know what is present. He argues that a LoS between the top management/top boardroom and the NHNF resources is the core principle of the many asset management standards out there. Here we also see a pragmatic extension of the definition of the LoS as it can also relate to the connection between organisational objectives and the assets themselves, not just the day-to-day activities. But how exactly will the ISO55000 guarantee this LoS? Hestermann (2012) mocks the ISO55000 standard as he says it leaves us with nothing but quotes like:

> *Organizational responsibility reflects an organization's requirement for assigned individuals, from the top management to the lowest level in an organization, to bear the consequences for the failure and the success of their assets to perform as expected and deliver the desired outcomes.*
>
> *Asset management requires coherent direction and guidance from top management and delivery by appropriately empowered and competent people.*

It may be clear by now that, apart from the planning systems and woolly language, the asset management standards do not make any further effort to describe how a LoS should be designed and established within an organisation.

From the above we see that asset intensive organisations are not always capable of formulating a clear LoS throughout their hierarchies and the standards on asset management neither offer much help. Let alone that the definition is clearly delineated. But then what is a LoS? In order to enhance the readability of this document, we already provide a definition of the LoS as will be proven to be useful in later chapters. Our definition of the LoS therefore becomes the connection of the stakeholder requirements with asset and maintenance properties.

1.2.2 Problems of not having a line of sight

Many of the research attention now focusses on the perceived benefits of asset management systems as whole, which should include a LoS. No research directs its efforts on proving the benefits or costs

of having a LoS in place; let alone that there is recognition of the concept of a LoS in academic literature.

Perhaps the literature that pleas the most for an idea like the LoS, is the one on the interface of asset management and performance measurement. Attwater et al. (2014) argued that too much effort is spent in maturity models that relate to the facilitating amenities of asset management. There is no clear focus on how day-to-day activities contribute to organisational performance. Again, it is not hard to imagine how this leads to wasted efforts as there is no effectiveness in attaining organisational objectives.

Professional literature does state some advantages of having a clear LoS in place. IAMPro (2017) describes several advantages of having a LoS in place. The first advantage is efficiency: no activities may be forgotten and no unnecessary activities may be done. The LoS should make clear why we do something, it should make apparent whether activities truly contribute to these objectives upfront before undertaking action. Closely related to the first reason is that it can be used as a tool for evaluating. Monitoring will reveal whether goals have been reached or where possibly adjustment in the activities is needed: do the activities truly contribute to the goals set? A last reason is that IAMPro states that the LoS leads to creativity and innovation. They state that if you know *why* you are doing something, you are incentivized for looking for smarter ways to achieve these objectives, perhaps even outside the activities an organisation is currently undertaking. Still, these stated advantages are not empirically backed up as far as we know.

What exactly 'the costs' are of a problematic LoS therefore still remains rather speculative, just as the perceived benefits, as empirical data is still absent. But with a little imagination one can see how a municipal executive board, that is steering for a sustainable asset portfolio, is completely misunderstood by a maintenance department that is primarily focussed on Reliability, Availability, Maintainability and Safety (RAMS) criteria. On the basis of the LoS definition provided above, we can then say that the executive board does not know how to realise sustainability through asset and maintenance, while the maintenance department does not know what stakeholder requirements should be fulfilled. Problematic communication of objectives throughout an organisational hierarchy could potentially be resolved by a LoS, although this remains rather speculative. Parida (2012) underscores that high level organisational objectives are by definition subjective and this subjectivity disappears when moving to the lower, more functional, objectives of an organisation. A clear translation of abstract, subjective high level objectives to specific and objective functional tasks is what enables employees throughout the organisation 'to speak the same language'. Proper communication in both directions is of cornerstone importance when successfully achieving strategies: top down to specify the necessary objectives and bottom up in order to receive feedback. A LoS can be the missing link in communicating the objectives top down and the constraints bottom up within organisations.

1.2.3 Scientific gap

As was stated earlier repeatedly, the LoS is relative unknown phenomenon in academic literature. Line of sight is term that is frequently used in physics as to describe the unhindered propagation of electromagnetic waves. Searching in scientific databases on the term 'LoS' therefore proves to be useless as one will be buried with articles in engineering and natural sciences. When searching in Scopus on the combination of 'asset management' and 'LoS' in the article title, abstracts and keywords only 10 results are displayed. Of these results, 5 of them relate to the physical principal described above. Another 2 of these results use the word LoS in relation to asset management, but

they rather use it as principle in which there is a logical connection between elements in a process or system. One result specifically meant the LoS that connects the 'boardroom' with the assets. This was not a scientific article but a presentation document that hardy gave any explanation. Another article defined the LoS as complement key performance indicators with evidence-based causal relationships. This article was however not accessible. Only one result from this search query was both accessible and relevant for this research.

The English Highway agency carried out a mapping exercise where the organisational objectives are tried to be linked to the operational activities. This attempt is documented by Hatcher, Whittlestone, Sivorn, and Arrowsmith (2012). On the basis of corporate documents and expert panels they managed to setup a service framework for the British Highway Agency, as they argue that assets continuously provided services that reflect the purpose of the organisation. They define the service framework as the translation of business goals through strategies, through provided services that in turn are shaped by service measures and indicators. These measures and indicators are predominantly quantifiable, verifiable and relate to management activities, engineering function and physical condition of the assets. Here we again see that the lowest operational measures are not solely maintenance activities, but can also relate to asset conditions. It is this causality that forms the LoS within their service framework. For each of these elements performance indicators can be conceived that could potentially inform decision-makers to the degree to which each of the intermediate and final objectives are attained. A limitation that was set to the service framework was that each activity and/or service level could only be coupled to a single strategic outcome or activity. This resulted, in their words, into an 'informed debate' about what available measures contributed most to which of the strategic goals.

The article described above was cited by a more recent attempt on setting up a LoS. Through an asset performance measurement system, Arthur, Schoenmaker, Hodkiewicz, and Muruvan (2016) aim to establish a LoS for an Australian water utility. In their attempt they turn to existing performance management literature as to create a synthesis with the current asset management practices. They conclude that research is to be done validating their approach to other utilities and sectors. Albeit the authors note that a strong sense prevailed that the new asset management objectives have a much stronger connection with the high level objectives, they stated that an extensive discussion continued about the selection of specific performance indicators; which should be selected, how they are normalised and the targets set to them. In the process of setting up the AMPS they also encountered so called "sacred cow" relationship that exist within the minds of employees. These are beliefs about how the management of assets is ought to work in real world, but is however not supported by data. These findings and the informed debate mentioned in the previous paragraph might hint at the fact that setting up an AMPS is contested by nature. Finally, they address that the APMS created is dynamic to change, but it is not further specified what defines this dynamic character.

To date, these are the only two scientific articles that try to link organisational objectives with lower organisational operational activities and measures. The articles were found to be limited in size and do not describe sufficiently their working methods in order to recreate a similar LoS whether or not in the form of a PMS. On the basis of the literature search and the above articles we conclude there is still much room for research on the topic of the LoS in asset management. No research has elaborately documented how such a LoS framework looks like *and* how it can be used in practice. In the following chapter we will present the research objective, questions and methodology of this research.

2 Research design

From the previous chapter it became apparent that there is a scientific gap in asset management on the concept of the line of sight (LoS). We start of this chapter by stating the research objective and the context in which the research is performed to better understand the practical relevance of this research. Consequently the research questions are presented with the used methodology to answer these research questions. This research can be classified as a design science research project. Design science is a field of research that is concerned with the development of artefacts that are to be deployed within a real world environment. From this discipline structure is brought into the research by setting requirements to LoS framework and selecting the methods of evaluation. This chapter already identifies the requirements that are set from the Metro and Tram (MaT) organisation, next to the requirements that are identified from literature in the following chapter. The chapter concludes with a general research design that links the design and evaluation phases to the chapters in this document.

2.1 Research objective

In both academic and professional literature the concept of a LoS is not clearly defined nor exhaustively documented. With this research an initial attempt is made to find out what building blocks a LoS framework needs in order to establish a relationship between stakeholder values and assets and the day-to-day activities surrounding these assets. Generic guidelines on how to fill a LoS are distilled by building several lines of sight for an organisation that manages the Amsterdam light rail infrastructure. The idea is that organisations align their objectives from boardroom down to the work floor through a LoS. By comparing the made framework with policy and strategy documents and a PMS we try to get an idea of the potential applicability of a LoS. The knowledge produced in this research is not considered to be definitive but rather serves as a stepping stone for further research in the field of LoS. This research is performed within an asset managing organisation (which also happens to be the owner), but the service provider was not examined. The knowledge in this research is a stepwise method to build a LoS that can be used by (public) organisations that manage assets and that wish to align their organisational objectives with their assets and their day-to-day activities surrounding these assets.

2.2 The Amsterdam case study

Metro and Tram (MaT) is a department of the municipality of Amsterdam that is mandated to manage the Amsterdam metro and tram infrastructure on behalf of Transport Region Amsterdam (Vervoerregio Amsterdam). MaT states that it fulfils the role of asset owner and asset manager of the metro and tram infrastructure systems.

In the past GVB Rail Services was the asset owner, asset manager and service provider of the Amsterdam light rail infrastructure systems. The responsibilities of asset ownership and asset management were transferred to the Metro Service unit of the municipality (Dienst Metro) back in 2011 (Soetenhorst, 2011), which later became known as MaT. Within MaT there is a department called Property & Management (Eigendom & Beheer) that has the responsibility of managing the existing metro and tram infrastructure systems. One of the tasks of MaT is to control GVB Rail Services in its

maintenance of the infrastructure networks. For this purpose, MaT developed a performance measurement system (PMS).

MaT has two issues they would like to have tackled. The first is that they want to recalibrate their PMS to academic standards. Secondly, MaT expressed that there currently is insufficient connection between the strategical and tactical activities they perform, and the operational activities that are performed by the service provider GVB Rail Services. By developing a LoS for MaT it is aimed to contribute to resolving these issues. The added value of developing a LoS in this case study is that the applicability of the framework can be directly tested.

There are no hard requirements set other than that MaT is simply interested in a LoS specified for their organisation and the remarks there are to be made on their PMS. The PMS is examined by comparing the current system with the developed LoS framework. Moreover, MaT is interested to see how the connection between the strategical and the operational goals are made.

2.3 Research questions and scope

2.3.1 Research questions

Because little research exists about the concept of the LoS and even less research describes how to establish a LoS, the following generic main research question is formulated:

How to design a line of sight for a public asset intensive organisation?

This main research question is still quite generic and abstract. As the aim of the research is to contribute to the misalignment problems which are experienced by asset owners such as MaT, a research approach has been developed which seeks to provide a stepwise method that enables all asset owners to develop a LoS. A case study research is conducted in which a LoS for an asset intensive organisation will be built. To create this LoS the research is structured via the following sub research questions:

Sub research question 1: What requirements can be identified for a LoS framework that is to be applied for a public asset intensive organisation?
Literature on the interface of performance measurement and asset management already stressed the need of aligning organisational objectives with the asset management objectives. This led us to search in literature on performance measurement for a framework, or the building blocks of existing frameworks, that could serve as the basis for the LoS. The framework must at least be able to cope with assets properties and maintenance properties as these are often incorporated into the definition of the LoS as we saw in the previous chapter.

Sub research question 2: How to identify relevant stakeholder values for developing a LoS?
Through a stakeholder analysis the relevant stakeholders of the case study, for which the lines of sight will be developed, are identified. Several methods already exist to this end. The question is more what values should be incorporated in the to-be built lines of sight and how to formulate the values so that they are generic enough to serve as a starting point, but not to be too specific as to leave to little room to build a LoS.

Sub research question 3: How to fill a LoS framework?
On the basis of sub research question 1 a framework is chosen. The question then remains how to fill this LoS framework. Although this may seem trivial at first, there are still a lot of choices involved in

filling the LoS framework. Using the framework can help highlight areas that need to be better delineated or further defined. Besides, an order in which the framework can best be filled might exist. The idea is to develop a cookbook-like written instruction on how to fill a LoS in practice.

Sub research question 4: How does the LoS framework compare to professional literature?
The LoS framework will be compared to the PAS55 planning system for which it is said that it establishes a connection between the strategic organizational objectives and the day-to-day activities. Through a desk research the elements that essentially comprise the LoS will be juxtaposed with this planning system to see where these concepts differ from a theoretical perspective and where they could possibly supplement each other.

Sub research question 5: What is the role of a LoS with respect to policy and strategy formulation?
The policy and strategy documents of MaT are compared with the LoS framework to assess where they differ and could potentially complement each other. This evaluation is more naturalistic than the comparison with the PAS55 planning system as it is related to a real world context. More specifically, we examine the reasoning that the LoS could be first developed and formulate the asset management policy and strategy on the basis of this.

Sub research question 6: What is the role of a LoS with respect to performance measurement?
Not entirely unexpected the LoS framework is also compared with the MaT performance measurement system given the fact that the idea of objective alignment in asset management stems from performance measurement literature. We will examine what contribution the LoS can possibly make in the design of a performance measurement system.

2.3.2 Research scope

- The research is limited to the management of existing infrastructure systems. It is not concerned with the construction of new infrastructure. This also has its consequences for the terms of policy and strategy. Policy and strategy are, in light of this research, only concerned with how to optimally manage existing infrastructure networks.
- In the case study as a proof of concept, six lines of sight were developed for six stakeholder values. During the research it was noted however that some lines of sight could be further split into a separate LoS.
- This research focusses on PAS55 because this standard was adopted by many public asset owners. MaT also used the PAS55 standard and based their policy and strategy on it. We are aware however that the PAS55 is slowly replaced with the newer ISO55000 standard, although they are similar in many respects.
- For the LoS of ‘availability’ the focus was primarily on railway related maintenance. Other subsystems are not considered as railway maintenance takes up most of the maintenance time and costs.
- This research focussed on the technical processes of asset management, these either relate to the assets or the activities that directly influence these assets. Organizational processes such as back-office and administrative activities are not considered.
- The research limited itself to scrutinizing the MaT organisation. The service provider (GVB) could not be scrutinized.
- The LoS framework was limited to asset and activity layers. The activity layers could have been split into more separate layers, but this was not done because of limitations of time and the inability to examine the service provider.

2.4 Research methodology

2.4.1 Design science research

In contrary to the 'classical' explanatory sciences, design sciences are concerned with developing knowledge that the professional of a particular discipline can use to design solutions for their field problems (Van Aken, 2005). As the central research question of this thesis is about designing a conceptual framework and the generic guidelines on how to use it, the field of design sciences is believed to make a useful contribution to the research methodology of this thesis.

Van Aken (2005) describes how in management sciences the appliance of academic research products into practice – which is also referred to as relevance – is considered to be problematic. He argues there has been a scientific debate as to why management sciences have not yet been able to adequately bridge the relevance gap that prevails. The explanation for this is considered to lie in the difference between how research is performed. Two modes prevail. The fist, simply referred to as Mode 1 is purely academic and monodisciplinary. Knowledge is developed for knowledge's sake (Huff, 2000). Mode 2 on the contrary is multi-disciplinary and aims at solving complex and relevant field problems (Van Aken, 2005).

A research framework that addresses this relevance gap is provided by 'A Three Cycle View of Design Science Research' by Hevner (2007). He distinguishes three elements that function through three cycles. The three elements are the environment, the design science research and the knowledge base. The *environment* is the practical context where a problem prevails for which a solution needs to be sought. From this environment requirements are set against which the research product can be assessed and evaluated. The environment is connected to the *design science research* project through the relevance cycle. The product is fed into the environment and consequently practical insights on the applicability of the product are fed back to the design science research. Within the design science research there is the design cycle where the created design alternatives are evaluated on requirements that are drawn from the relevance cycle. The design and evaluation theories and methods however are obtained from the rigor cycle. The rigor cycle connects the design science research with the knowledge base. This is a base of scientific theories and engineering methods that provide the basis for the design science research. New knowledge produced in the design science research with respect to this knowledge base can considered to be extensions to the original theories and methods. In Figure 2 the framework is already adapted to this research context.

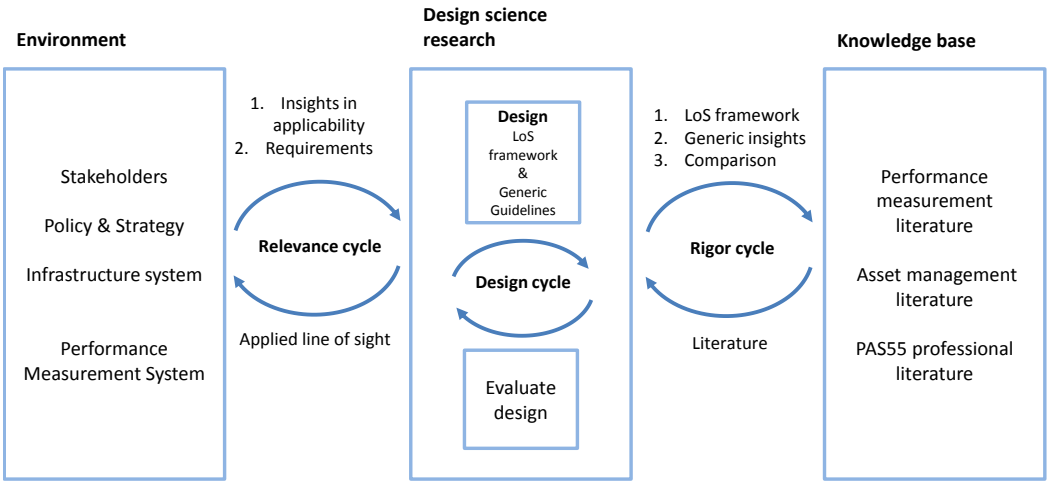


Figure 2: Research methodology from a high level perspective, adopted from Hevner (2007)

Three choices remain with respect to the selected design theory, the chosen requirements on which the design will be tested and the evaluation methods through which the design product is tested. The choices made on these three will be discussed below.

2.4.2 Design theory

As we saw in the previous chapter most of the literature within asset management that stressed the idea of a LoS interfaced with performance measurement. Arthur et al. (2016) stated that their asset management performance framework was based on the Balance Score Card (BSC), a performance measurement concept of introduced by Kaplan and Norton (1992). Initially the BSC was just a tool for performance measurement but soon evolved into an instrument for strategy development with the introduction of the strategy map (Kaplan & Norton, 2000). Also Hatcher et al. (2012) argue that their service framework sets the basis for measuring asset- and service performances.

The rationale for selecting performance measurement is thus that strategy development and performance measurement are closely connect to one another. In the next chapter existing performance measurement frameworks will be explored in order to assess to what degree these are suitable for establishing the connection between the organizational strategic objectives and the day-to-day activities and asset conditions. Initially it was tried to select an existing performance measurement framework that could serve as a LoS framework, but none of these qualified to all of the requirements that are covered in the remainder of this section and the next chapter.

2.4.3 Relevance requirements

As the case study zooms in on a public organisation, an additional requirement is introduced: the LoS framework needs to be suitable for public contexts. As we will see in the next chapter the focus of performance measurement literature is on commercial organisations that typically have a much narrower range of stakeholder values.

Next to that the framework should be able to cope with assets and the activities surrounding these assets – the majority of these activities are maintenance works. Much of the performance measurement literature focussed on the service industry where non-tangible assets have a more prominent role as we will see in the next chaper.

Finally, Hevner, March, Park, and Ram (2004) claim that an artefact (a design product in the field of information systems in their words) should qualify on the basis of utility, quality and efficacy. None of these but utility is actually defined; utility is defined as artefacts that are effective. We suspect that these terms are used interchangeably and all come down to the relevance of artefact with respect to the environment in which it is used. When the deputy director of MaT was asked to what a LoS framework should qualify to, he replied that he could only think of the requirement that the strategical aspects of his organisation should be connected to the operational aspects. This requirement strongly coincides with the definition of the LoS that is provided by the PAS55 standard.

Note that these are only the requirements found from relevance, i.e. the environment of MaT. In the next chapter we also find requirements from performance measurement literature that will be added to the LoS framework. We refer to these as the rigor requirements.

2.4.4 Evaluation methods

According to the Design Science Research (DSR) perspective proposed by Hevner (2007) evaluation takes a significant role in the DSR. Venable, Pries-Heje, and Baskerville (2016) present a framework

for evaluation strategies. Within this framework three questions are relevant, namely the 'why'-, 'when'- and 'how' question.

The 'why' question relates to the purpose of the evaluation. They distinguish between *formative* and *summative* evaluation. The 'why' question focusses on improving the artefact's effects within the environment of implementation. The summative evaluation on the other hand aims to create 'shared meanings about the evaluand [artefact] in the face of different contexts' (Venable et al., 2016, p. 78). Formative evaluation is thus related to the relevance cycle, whereas summative evaluation is concerned with the rigor cycle.

When to evaluate can be done in two ways: *ex ante* evaluations, beforehand, or *ex post* evaluations, after the artefact development is completed. Intuitively one might argue that ex post evaluations are always summative and ex ante and intermediate evaluations are formative. Venable et al. (2016) state that ex ante and ex post only refer to timing, not to purpose. They provide an example where a summative evaluation may be required on an ex ante basis. Stefanou argues that ex-ante evaluation is 'the predictive evaluation which is performed in order to estimate and evaluate the impact of future situations' (Stefanou, 2001, p. 206). In this case an ex ante evaluation has a summative character.

Finally, there remains the 'how' question. Here a distinction lies in naturalistic and artificial evaluation. Naturalistic evaluation relates to testing the artefact's performance in its real environment, artificial evaluation in simulated experiments that can include laboratory tests, simulations, criteria based, mathematical proofs or theoretical arguments (Venable et al., 2016). Artificial evaluations are argued to be the simplest, most straight forward and least costly.

From the sub research questions two evaluation phases can be identified that are preceded by the design phase. The first is the actual development of the lines of sight for the MaT organisation through interviewing experts and examining organisational documents. The second is the comparison between the LoS framework and the PAS55 planning system, and between the MaT policy, strategy and PMS. These different evaluation phases ask for different evaluation approaches. On the basis of the dimensions of naturalistic versus artificial and formative versus summative Venable et al. (2016) propose four prototype strategies. We will only elaborate on the strategies that are deemed suitable for the two evaluation phases.

The actual development of the LoS is considered to be a somewhat naturalistic evaluation. Developing the lines of sight is done by consulting experts on real world organisational substance after all; this is an immediate test to see whether the framework's logic appeals to the intuition of those have to co-develop it. As will turn out later, during the development process guidelines are distilled which help to consequently fill the LoS framework. These guidelines do not help to create a shared understanding, but rather aim to make the connection between the framework and its environment of appliance. Therefore this evaluation is considered to be formative and naturalistic. Evaluations of these kind are labelled as *Human Risk & Effectiveness* strategies (Venable et al., 2016).

The comparison of the LoS framework with the PAS55 planning system, and with the MaT policy, strategy and PMS have a summative and artificial character. The comparison is executed through desk research. The LoS framework is examined from a purely technical perspective without considering the social implications. This evaluation approach is best characterized as an *purely technical* strategy. The goal of this evaluation is to make a predictive statement about the potential use of the LoS framework in relation to policy and strategy formulation and the creation of a PMS.

So far, we have been discussing strategies and not the methods. Hevner et al. (2004) presents several methods for evaluation. It was stated that this research can be divided in three parts. The first part is identifying the requirements from practice and literature that can be set to the LoS framework and to consequently select a framework – this is considered to be the design phase. The second part is evaluation through filling the LoS framework in a *case study*. It is through using the LoS framework in the practical context of MaT that the applicability of the framework is tested and consequently evaluated. Finally, the last phase is also an evaluation phase where the framework is evaluated through *informed argument* by comparing it with the PAS55 professional model (that also claims to offer a LoS through its planning system) and the MaT policy and strategy, and the MaT line of sight. A summary of the evaluations is provided in Table 1.

Table 1: Summarization of the chosen evaluation with their evaluation strategy and method

Evaluation	Character	Evaluation strategy	Evaluation method
Developing lines of sight	Formative & naturalistic	Human risk & effectivness	Case study (interviews and desk research
Comparing lines of sight with existing documents	Summative & artificial	Purely technical	Informed argument (desk research)

2.5 General research design

Table 2 presents an overview of the research that is divided into three phases, with the respective goals, sub research questions and research methods. We purposely choose not to use the design cycles of Hevner (2007) as structure for this report, but the design phases according to the table below. Some design phases tap into several cycle simultaneously; this would make the structure of the research incomprehensible.

Table 2: The various phases of this research and the coupled goals, sub research questions and evaluation methods

Phase	Goal	Chapter	Sub RQ	Research method
1. Designing: Building the framework	(1) Setting up research design and (2) finding relevance requirements	2	1	Desk research
	Literature study: (1) Finding rigor requirements and (2) developing framework from theory	3	1	
2. Evaluation: Using the framework	Finding stakeholder values	4	2	Case study (interviews and desk research)
	Filling of framework	5	3	
3. Evaluation: Comparing the framework	Comparison with PAS55	6	4	Informed argument (desk research)
	Comparison with MaT policy & strategy	6	5	
	Comparison with MaT performance measurement system	7	6	

2.5.1 Designing (phase 1): building the framework

The design phase first starts with identifying requirements from both the environment of MaT (relevance requirements) and the knowledge base (rigor requirements) which is the performance measurement literature. Several performance measurement frameworks are analysed on the basis of these requirements and it is examined to what degree they are candidate to serve as a LoS framework. As we will see in chapter 3 none of the analysed framework suffices to all found

requirements simultaneously. Therefore an own LoS framework is developed that is strongly inspired by on existing performance measurement frameworks.

2.5.2 Evaluation (phase 2): using the framework

In this phase the framework that is selected is actually tested in practice by building various lines of sight for MaT. As part of developing the lines of sight for MaT it is important to identify the relevant stakeholder values that have to be considered. As a first step, a stakeholder analysis is performed for which a method was derived that helps identifying the relevant stakeholder values. As the LoS framework should be fit for public organisations it is an important step to make clear the relevant stakeholder values that are at stake. The stakeholder values found in the stakeholder analysis will be the starting point for developing the lines of sight for MaT. In the remainder of this document it is explained why for each stakeholder value a separate LoS will be developed.

The use of the framework actually comprises more than just filling it in with factors – these are the fundamental elements that comprise a LoS as we will see later. Using the framework actually leads to generic guidelines as how to fill the framework. It was during the exercise of filling the framework for MaT several generic guidelines could be distilled. Figure 3 presents an overview of the used method to conceive generic guidelines for a LoS. The LoS framework is filled through interviewing personnel of MaT on the relevant stakeholder values. For each separate stakeholder value a LoS is created.

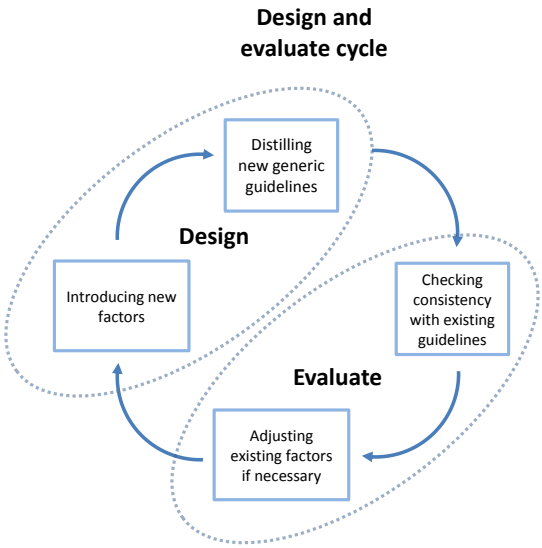


Figure 3: The design and evaluate cycle as used for filling the LoS framework

2.5.3 Evaluation (phase 3): comparing the framework

The second evaluation compares the LoS framework with three existing documents. Note that the comparison is done with the LoS framework developed in chapter 3, not the actual lines of sight that are developed for MaT. All comparisons in this phase are based upon the evaluation method of informed argument. Four documents are compared in various manners with each other. The goal of this evaluation is to make an estimation for the future potential use of the developed LoS framework in policy and strategy formulation and performance measurement. The LoS framework is compared with the (i) PAS55 planning system, (ii) the MaT policy and strategy document and (iii) the MaT line of sight.

Like stated before, the PAS55 standard claims that adapting its planning system ensures a LoS throughout the organisation. Therefore the LoS framework is compared with this planning system. The

MaT policy and strategy document are based upon this planning system. The LoS framework is also compared with the MaT policy and strategy to examine possible discrepancies with real world policy and strategy documents. It is out of the scope of this research to check to what degree MaT adhered to the PAS55 planning system when formulating their policy and strategy.

Finally, a comparison is performed with the PMS. The PMS serves to check the implementation of the objectives that are set in the policy and strategy documents. Since the PMS is a reflection of the policy and strategy documents it should contain similar elements as the policy and strategy documents.

Through this second evaluation the practical applicability of the LoS framework is evaluated from a theoretical perspective. To maintain oversight Figure 4 presents an overview of the various comparisons performed in the second evaluation. An explanation for the comparisons is provided in Table 3.

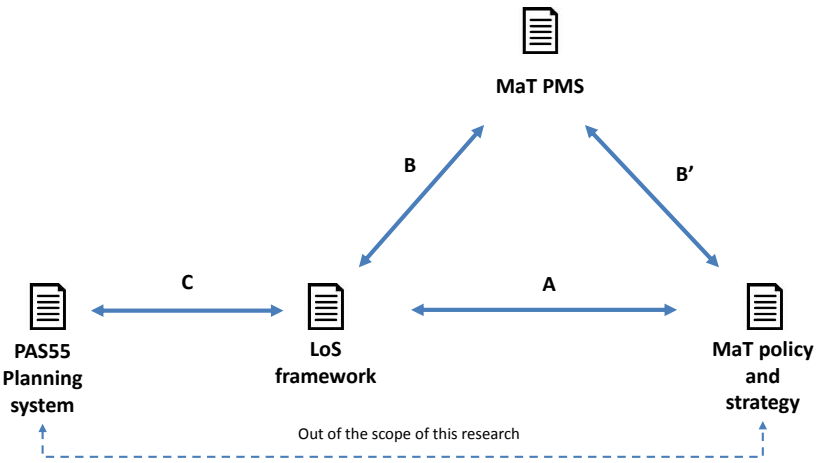


Figure 4: Comparison between various documents within this research

Table 3: Explanation for the various comparisons as depicted in Figure 4

Comparison	Explanation
A	The LoS is compared with the MaT policy and strategy. The LoS framework consists of several building blocks that form the basis of the framework. It is checked to what extent these building blocks are represented in the MaT policy and strategy. Reversely the LoS framework is evaluated on what elements it might be lacking that are contained within the MaT policy and strategy. This comparison relates to *sub research question 5*.
B	Given the fact that performance measurement should be a reflection of the policy and strategy we also check if a LoS can be found back in the MaT performance measurement system. This comparison relates to *sub research question 6*.
B'	One of the ways in which it is examined how LoS can contribute to performance measurement is ensuring an alignment between policy and strategy documents and the performance measurement system. This comparison relates to *sub research question 6*.
C	The LoS framework is compared with the PAS55 planning system. A similar comparison is performed as A. It is examined to what extent the building blocks, that are deemed essential for a LoS, are represented within the PAS55 planning system. This comparison relates to *sub research question 4*.

3 Theoretical perspective

In this chapter we start off with the link between performance measurement and the LoS, namely that the very little research that has been performed in the field of LoS is connected to performance measurement. The primary objective of this chapter is twofold; the first is to identify requirements for a potential LoS framework. The second reason is that we analyse existing performance measurement frameworks and consequently analyse them on the basis of the requirements found in this chapter and the ones that were found that were set by MaT. As will turn out, none of the existing performance measurement frameworks qualify to the requirements at once. For this reason, an own framework is designed that meets all of these requirements.

3.1 The link with performance measurement

Literature on the interface of asset management and performance measurement stressed the idea that day-to-day activities should contribute to overall organisational objectives (Arthur et al., 2016; Attwater et al., 2014). Arthur et al. (2016) developed their PMS on the basis of the work of Kaplan and Norton's balanced scorecard (BSC) and its complement the strategy map, two widely used performance measurement systems. Research suggests that between 30 and 60 per cent of the firms have adopted the BSC as their PMS (Neely, 2005).

The work of Arthur et al. (2016) proves to be a useful stepping stone in the development of a LoS framework. Their core idea is that the connection of asset management objectives through a strategy map provides a LoS in objectives from stakeholder level to the level of 'activities surrounding assets'. This research builds on their idea of making a LoS through the existing theories of performance measurement systems. Although the framework built by Arthur et al. (2016) is focussed on performance measurement, as it also operationalizes the objectives through performance indicators, it is the concept of linking various objectives together in a coherent matter that is considered to be the essence of a potential LoS framework. For this reason it is chosen to explore relevant performance measurement frameworks. In the remainder of this chapter we will elaborate more on the concepts of (amongst others) the BSC, the strategy map and the LoS framework as developed by Arthur et al. (2016).

To better understand the perspective of performance measurement a brief history of performance measurement will be explored as to get a grip on the developments that took place within performance measurement. Subsequently various contemporary performance frameworks are analysed to see what characteristics are useful for a LoS framework. Many of the lessons learned in the field of performance measurement are just as well applicable for a LoS framework, as we will see in the remained of this chapter. For this reason we can identify several requirements that can be set to a LoS framework from performance measurement literature. Once the *rigor* requirements are combined with the *relevance* requirements we have a set of requirements on the basis of which a LoS framework will be developed.

3.2 History of performance measurement frameworks

Selecting the right set of indicators as to gauge organisational performance may seem as a task not too difficult. Companies rarely suffer from having too few measures; the list of indicators is often long

in practice and grows every now and then with each worthwhile suggestion made (Kaplan & Norton, 1992). The other extreme is that organisations, in an attempt to keep oversight, try to compound as much as information into a single performance indicator. This can take the form of a ratio that is built up from multiple but relevant factors, each having their own weight depending on their relative importance (Kumar et al., 2013). Using a ratio and or compound indicators can be deceptive as they may remain approximately constant while in reality some of the indicators increase dramatically and others may decrease unnoticed.

These two (extreme) ways of setting up a performance measurement systems bear little coherence and it can be questioned in the first place whether one can speak of a 'system'. Building a line of sight is thus not a trivial task. Therefore, scholars have come up with performance measurement frameworks. These frameworks help in selecting the right indicators and ensure that some degree of coherence between them is achieved.

As of today, a wide array of performance measurement frameworks exist and subsequent literature reviews that describe the development, potential and shortcomings of these frameworks (Neely, Kennerly, & Adams, 2007; Parida, Kumar, Galar, & Stenström, 2015). To better grasp the current form of contemporary frameworks we briefly discuss the evolution of these frameworks over time. Through analysing these frameworks, their benefits and pitfalls will become evident.

The genesis of the performance measurement frameworks occurred in the early 20th century, when three DuPont cousins conceived a pyramid that links a variety of financial ratios together that eventually end up in the return on investment. It has an explicit hierarchical structure that decomposes the cost and asset build up. Although this model can give quick insights on how to influence financial performance this simultaneously is considered to be its pitfall (Bruns, 1998). The criticism reads that it focusses on past historical performance, which is consequently blamed to encourage short-termism. In order to understand the elements that shape these financial outcomes, managers started looking for measures that informed them about the internal processes within organisations. One of the first widespread frameworks that made progress on this aspect is the Performance Measurement Matrix of Keegan, Eiler, and Jones (1989). The matrix consist of two axes where one states the "costs" vs. "non-costs" and the other axis representing "internal" vs. "external" measures, where internal aspects relate to the parameters within the company and external relates to measures external to the company such as customer retention, market share or the competitive cost position. It simple design reflects a need for a more balanced selection of measures. A synthesis in hierarchy and a balanced set of measures was found in the SMART (Strategic Measurement And Reporting Technique) pyramid developed by Wang Laboratories as is shown in Figure 5.

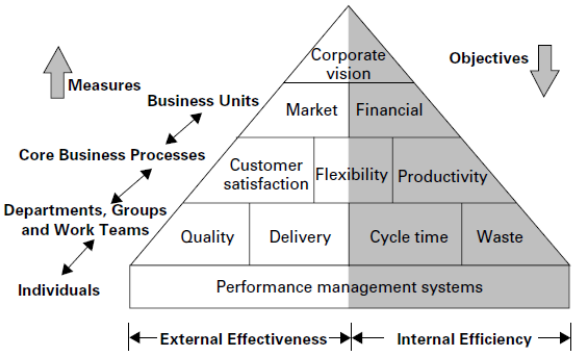


Figure 5: The SMART pyramid (Neely et al., 2007).

The measures conceived are connected to the various layers of a hierarchy of an organisation. This bolsters the idea that corporate objectives should be passed down into more functional task description that reversely contribute to the high level organisational objectives. From studying performance measurement in service industries, Fitzgerald, Johnston, Brignall, Silvestro, and Voss (1991) developed a framework constituting elemental aspects, namely measures that relate to results (competitiveness, financial performance) and those that relate to the determinants of those results (quality, flexibility, resource utilisation and innovation). The strength of this framework is that it implies causality between the results and the determinants that define the results, introducing the idea that today's business performances are the results of determinants nurtured in the past. In performance measurement literature the measures concerning results are called *lagging indicators*, while the determinants of performance are called *leading indicators*. This concept of causality was further developed by Brown (1996). His macro process model of the organization divides the business process into five distinct stages. These stages are defined as, in consecutive order, as inputs, processing system, outputs, outcomes and goals. They key idea is that each process is influenced by its predecessor, with the exception of inputs of course. This cascading effect of influence is according to Neely et al. (2007) an oversimplification of reality, although it is not specified why. We assume that a process is not only influenced by its predecessor, but also by the process before its predecessor.

3.3 Analysing performance measurement frameworks

The frameworks above are a brief summarization of early performance measurement frameworks. In the next section several performance measurement frameworks that are more relevant today, in the academic literature, will be elaborated in more detail. These frameworks are chosen for their relevance, popularity and for either its generic or specific applicability. The aim of this section is twofold. First, the requirements that authors of performance measurement frameworks in the past have set are identified. Second, all the frameworks that are covered in this section will be compared with each other's requirements plus the relevance requirements that were identified in the previous chapter.

Before analysing each of the frameworks an overview is provided in Table 4 of the rationale behind selecting each of the performance measurement frameworks for further analysis. The order of the table does not follow the order in which the framework are analysed in this section.

Table 4: An overview of the selected performance measurement framework and the reason why they are analysed

Performance measurement framework	Why is it analysed?
Asset planning performance measurement framework (Arthur et al., 2016)	This framework was found to be the most recent attempt in designing a LoS although it was coupled to the development to a PMS. Through this article many of the following frameworks were found.
Service framework (Hatcher et al., 2012)	The service framework was one of the first frameworks that tried to couple objectives through strategy to the actual asset services that are provided. Alongside with the framework of Arthur et al. (2016) this is perhaps the only framework that tries to realise the idea of a LoS.
Balanced scorecard (BSC) (Kaplan & Norton, 1992)	The BSC is the most popular performance measurement framework in the academic world and is estimated to be the most used performance measurement framework in practice.
Strategy map (Kaplan & Norton, 2000)	The strategy map can be seen as an enhancement of the BSC. Arthur et al. (2016) based their PMS on the strategy map.
The maintenance BSC (Alsyouf, 2006)	This adaptation makes modifications to the original BSC and is specifically applied to maintenance. This framework also includes societal values, next

	to commercial ones.
Multi-criteria hierarchical framework (Parida & Chattopadhyay, 2007)	This framework is built around the hierarchical order of strategical, tactical and operational levels which is commonly used in many asset management protocols. Besides, it also includes societal values.
Performance prism (Neely et al., 2007)	The performance prism wears strong resemblance with the BSC but includes the notion of stakeholder contribution.

3.3.1 The balanced scorecard

As from the 1980s on, the research focus within performance measurement was centred on short-termism (Neely, 2005). Nearly a decade later, Kaplan and Norton (1992) presented the Balanced Scorecard (BSC) as a solution to overcome myopic views within senior management functions. They argued that a limited focus on the traditional, financial measures would result in quickly attained but short-lived financial gains. Instead, measures about the customer's satisfaction, the internal processes and the organization's innovation and improvement activities are considered to be the drivers for future financial performance (Kaplan & Norton, 1992). They compare the necessity of the BSC to that of a cockpit with various indicators and signalling instruments. For pilots to fly and navigate their plane safely to a destination they rely on multiple aspects of the flight, for instance fuel availability, air speed, altitude and so on. Reliance on a single measure would become fatal. Similarly, the reliance on a single measure (or aspect) in organisations would be impossible in the contemporary complex operations of today's organisations. Over the course of decades, the BSC has become one of the most popular, if not the most popular, performance measurement framework due to its simplicity and effectivity.

The BSC forces managers to conceive measures beyond just the financial ones. It addresses four so called perspectives. For each of these perspectives goals must be set that are operationalized through indicators. To these indicators subsequently targets are attached that define when a goal has been achieved. The BSC is illustrated in Figure 6.

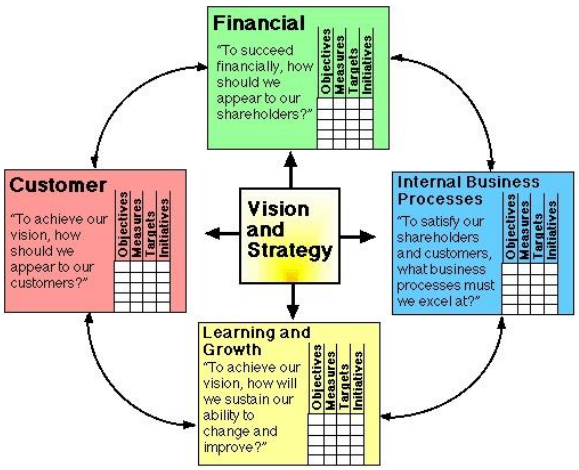


Figure 6: The balanced score card, adapted from Kaplan and Norton (1992)

The customer perspective concerns objectives and indicators that relate to the type of customer and market segments a company wants to target. Typically, this perspective includes generic measures like customer satisfaction, customer retention, customer acquisition, customer profitability and market and account share.

At the end of the day, the financial perspective is all what matters to companies. Despite the BSC's efforts to move away from a limited view of solely financial measures, all casual paths from all the measures on the BSC should eventually contribute to the financial objectives (Kaplan & Norton, 1996b). In many cases, shareholder value is the highest objective within the financial perspective, but several options exist as to how this goal can be achieved.

Within the internal business perspective, managers identify the internal business processes must excel as to fulfil the business strategy. It is through these internal business processes that value is delivered to customers. According to Kaplan and Norton (1996b), the BSC separates itself from the traditional approaches as the BSC usually identifies entirely new process at which the business must excel to meet customer expectations.

The perspective that is the most fundamental driver for change is the learning and growth perspective. It identifies the infrastructure that is needed to improve the business processes that deliver value to customers. Kaplan and Norton (1996b) identify three principal sources that can be subjected to innovation: people, systems and organizational procedures (processes). According to them the BSC will reveal discrepancies between existing capabilities of people, systems and procedures and what is needed to acquire breakthrough performance.

Kaplan and Norton state the BSC is not a replacement for an organization's day-to-day measurement system (Kaplan & Norton, 1996b). Instead, the measures on the scorecard are chosen as such that these are the critical success factors that lead to competitive breakthrough. Moreover, Kaplan and Norton (1996b) distinguish between *diagnostic measures* versus *strategic measures*. The former are used to monitor whether the business remains "in control", while the latter informs managers about the degree to which the strategy is attained.

According to Kaplan and Norton (1992) the BSC puts strategy and vision, not control, at the centre of the PMS. This suggests that the PMS moves away from a sanctioning system, to a system that measures to what extent the predefined strategy has been achieved, thus incentivizing innovative behaviour. As measures about the extent to which innovation goals, customer satisfaction attained are also adopted within the system this loosens the focus on just internal business process alone and how to cut on costs on this perspective, which is typical for short-term oriented management style.

3.3.2 The strategy map

After the introduction of the BSC in 1992, Kaplan and Norton performed further research on this topic in collaboration with hundreds of executive teams from various organisations, in both the private and public sector, and came to realise a common patterns prevails with regards to formulating strategy. As a result, they developed a visual framework, referred to as a strategy map, that explicitly states the cause and effect chain between the various drivers of performance and the desired outcomes that together make up the strategy (Kaplan & Norton, 2000).

Put differently, a strategy can be conceived as 'a set of hypotheses about cause and effect' (Kaplan & Norton, 1996b). The strategy map can be considered to be an extension of the BSC. It takes the BSC one step further in that it approaches the selection of indicators in a more systematic matter than the BSC method does. As stated before, it links the various drivers of performance and desired outcomes with each other. Although the BSC acknowledges that internal processes, customer satisfaction and innovation and improvement activities are the determinants for future performance, the causal links are not made explicit.

An important design criterion is to build strategy maps top down. Organisations should first review their mission statement and their core value – why their company exists and what it believes in (Kaplan & Norton, 2000). This help shapes the vision that in turn defines the overall organisational goal. A strategy can then be made that helps reach this overall goal. For commercial companies the highest goal is often related to retaining or improving shareholder value. In the case of a commercial organisation, the strategy map typically starts with a financial perspective on top, followed by a customer perspective, then followed by the internal process perspective, to be concluded with an innovation and learning perspective. In this cascade of perspectives, the customer perspective answers the question *how* the financial perspective can be achieved. Reversely, the financial perspective answers *why* the customer perspective is desirable. Thus the linkage between the various perspectives is forged in terms of cause and effects. An example of a strategy map is presented in Figure 7 below.

According to Kaplan and Norton (2000) the greatest benefit of a strategy map might its ability to communication the strategy to the entire organisation. Employees throughout the organisation understand the strategy and consequently know how their activities contribute to high-level organisational goals. In turn, this enables employees at the tactical and operational levels to conceive new ideas about innovative processes or technology that can better achieve the organisational goals.

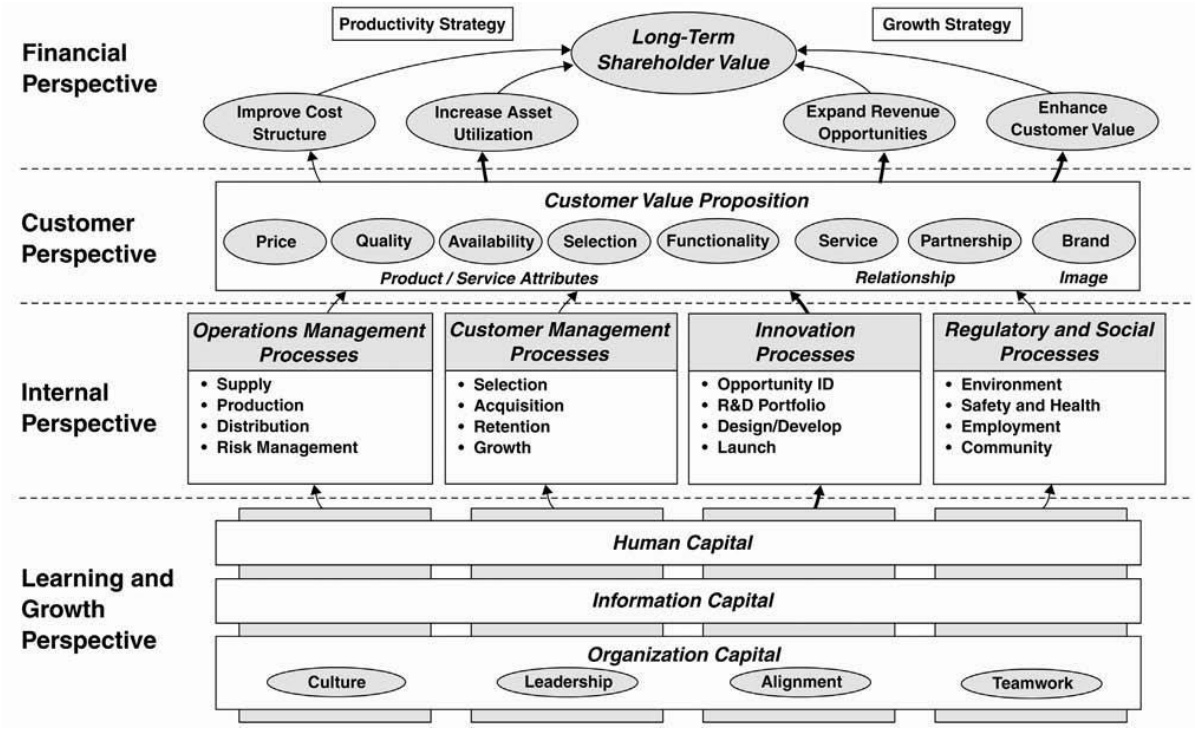


Figure 7: An example of a strategy map that shows the relationship between the various perspectives (Kaplan & Norton, 2004)

Despite this effort to rationalise the process of creating strategy maps, Kaplan and Norton (2000) state that formulating strategies is an art, and it will always remain so. What they meant to say, is that formulating strategies through a strategy map cannot be done by walking through a predefined clear-cut process. Strategies are tailor-made for each company with its internal context and the market environment in which it operates. As a consequence, the science of performance measurement can provide design principles at most, but for the larger part the creation of strategy maps, and thus a line of sight, is done with the help of the imagination of the analyst.

3.3.3 The maintenance BSC

Despite its widespread use and generic applicability the BSC has been criticized for (Atkinson, Waterhouse, & Wells, 1997; Neely, Gregory, & Platts, 1995; Parida & Chattopadhyay, 2007):

- It does not include a competitor perspective. To be more specific there are no measures included that relate to the competitive cost position, market share and customer retention and the like.
- It is limited to the customer perspective and does not include other potential stakeholders such as employees, society, local communities and suppliers. Although the BSC acknowledges employee contribution, it does not consider employee expectation. Employees are thus conceived as assets rather than stakeholders. Despite the BSC focus on attaining strategy, achieving employee satisfaction might very well be a good strategy in for example service industries.
- It does not consider environmental and safety perspectives. This point of critique is logical when considering that the BSC has not originated from industrial production sites.
- The second point of critique is relevant because the BSC does not acknowledge the reciprocal dependency between the organization owner's and stakeholders. Stakeholders make a (partial) contribution to the fulfilment of the primary objectives.

A drawback of the original BSC is its limited purpose of satisfying shareholder value through customer expectations. Atkinson et al. (1997) argue that 'what a company expects from and gives to each stakeholder group to achieve its primary objectives (organisational objectives) are its secondary objectives.' These secondary objectives thus help achieve the primary objectives. In a non-commercial setting, shareholder value might not be relevant in the first place. Public organisations do not have shareholder value as their top priority, but are rather focussed on a palette of values such as liveability and economic growth as their primary objectives.

The BSC adaptation of Alsyouf

Alsyouf (2006) slightly modifies the four perspectives of the original BSC. The new scorecard is displayed in the form of a strategy map in Figure 8. Roughly speaking the original four perspectives can still be identified in the adapted variant, but some of the perspectives are split up in several perspectives. The financial perspective and the innovation and growth perspective remain approximately the same. The customer perspective and the internal business process perspective are however split up in two separate perspectives. The customer perspective is complemented with a society perspective that includes objectives related to reducing environmental burden brought about by business operation. The customer perspective, the societal perspective and financial perspective together make up what Alsyouf (2006) calls the downstream organisation. The internal business perspective is split up into two separate perspectives, namely the production perspective and the maintenance perspective. The former relates primarily to production performances that are in turn influenced by maintenance performance that are included in the maintenance perspective. This divide between the two businesses processes enhance the insight how maintenance activities contribute to better production results. Although the learning and growth perspective is labelled the same as in the original BSC, its scope however considers a wider range of improvement possibilities. He argues that improvements in business processes (maintenance in this case) can be found in external resources such as collaboration with suppliers and research centres, improvements in product design, whereas the original BSC was restricted to training personnel, enhancing the information infrastructure (IT systems) and improving business protocols and procedures.

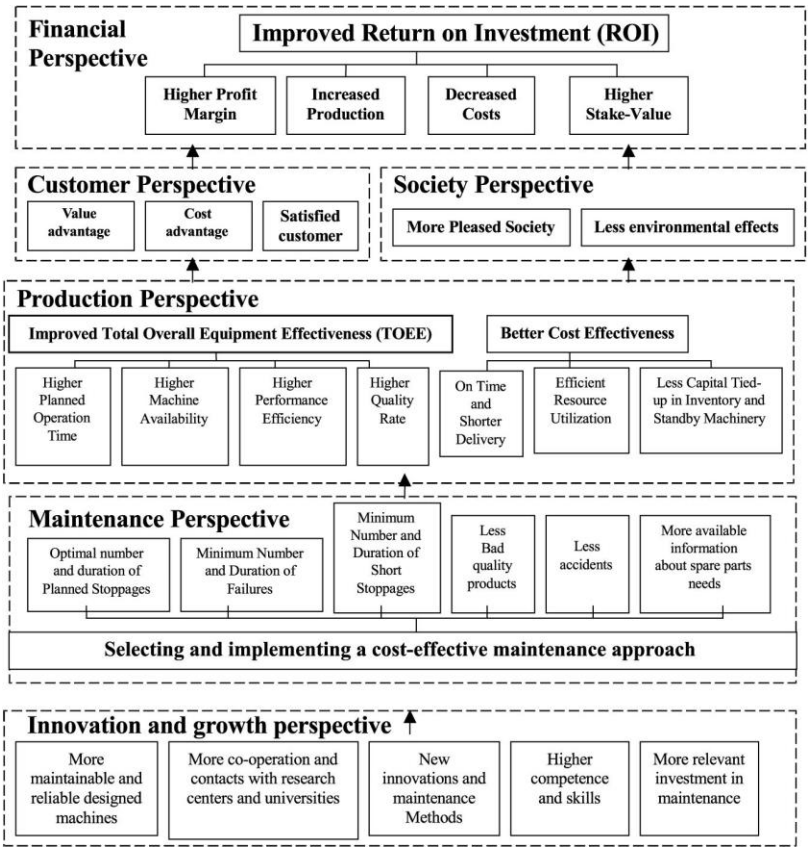
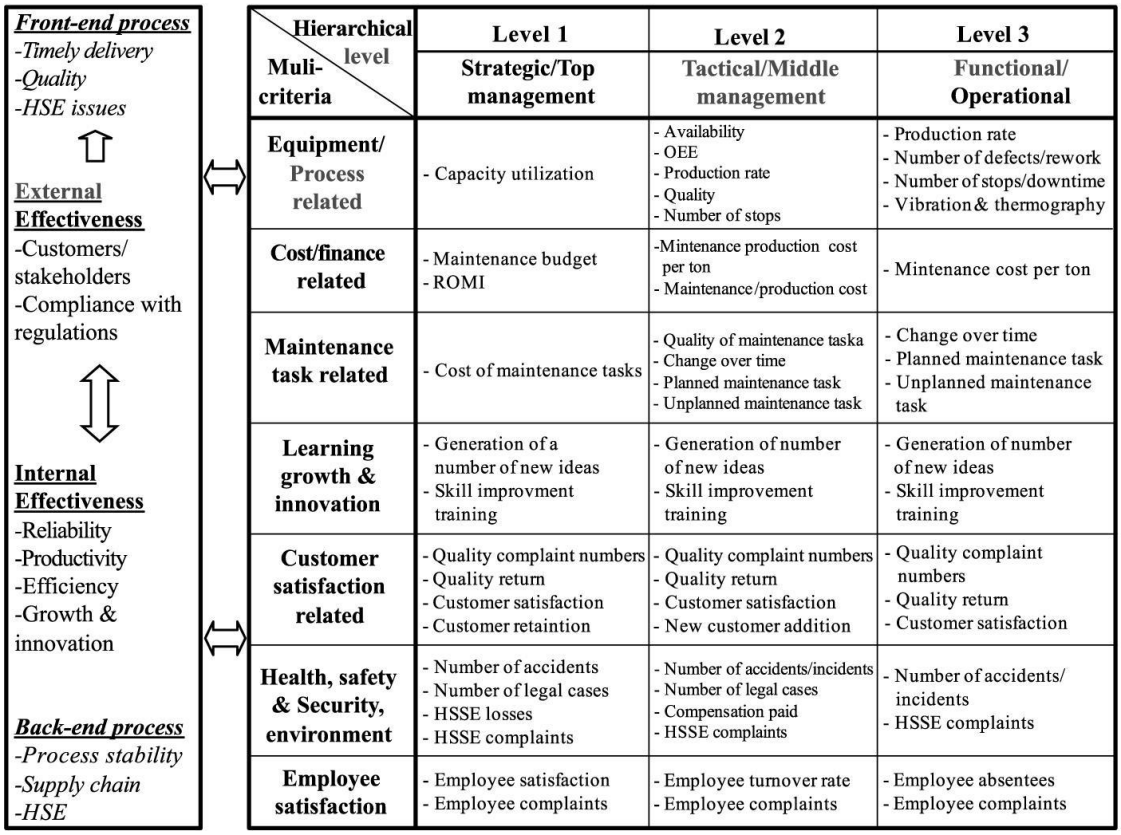


Figure 8: The BSC of Alsyouf (2006) that is specifically modified to maintenance contexts

Through this case study Alsyouf (2006) found that using this modified BSC it was possible to measure and identify the cause and effect relationship of using an maintenance strategy and assets it eventual impacts on the organisational objectives. The modified BSC made it easier for maintenance and production staff, that are technically oriented, to communicate with top management in terms that managers understand.

3.3.4 Multi-criteria hierarchical framework

Parida and Chattopadhyay (2007) propose a performance measurement framework that has two key characteristics. The first is that it considers more perspectives, or criteria in their words, than the BSC. Their framework is therefore extended with health, safety, security, environment and employee satisfaction considerations. With this extended scope of criteria they aim to better represent the stakeholders, a point for which the BSC was criticized. Secondly, they argue the necessity of performance indicators to be assigned to each layer of the organisational hierarchy. Generally speaking, organisation can be divided into three layers, namely strategical, tactical and operational. Sometimes, it might be necessary, depending on the organisational structure, to add more than three layers. Moreover, they argue that performance indicators at functional levels can be aggregated to form performance indicators at tactical level. This can repeatedly done for PI's at tactical levels as to arrive for PI's at strategic levels. The framework is displayed in Figure 9.



Hierarchical level / Muli-criteria	Level 1 Strategic/Top management	Level 2 Tactical/Middle management	Level 3 Functional/ Operational
Equipment/ Process related	- Capacity utilization	- Availability - OEE - Production rate - Quality - Number of stops	- Production rate - Number of defects/rework - Number of stops/downtime - Vibration & thermography
Cost/finance related	- Maintenance budget - ROMI	-Mintenance production cost per ton - Maintenance/production cost	- Mintenance cost per ton
Maintenance task related	- Cost of maintenance tasks	- Quality of maintenance taska - Change over time - Planned maintenance task - Unplanned maintenance task	- Change over time - Planned maintenance task - Unplanned maintenance task
Learning growth & innovation	- Generation of a number of new ideas - Skill improvment training	- Generation of number of new ideas - Skill improvement training	- Generation of number of new ideas - Skill improvement training
Customer satisfaction related	- Quality complaint numbers - Quality return - Customer satisfaction - Customer retaintion	- Quality complaint numbers - Quality return - Customer satisfaction - New customer addition	- Quality complaint numbers - Quality return - Customer satisfaction
Health, safety & Security, environment	- Number of accidents - Number of legal cases - HSSE losses - HSSE complaints	- Number of accidents/incidents - Number of legal cases - Compensation paid - HSSE complaints	- Number of accidents/ incidents - HSSE complaints
Employee satisfaction	- Employee satisfaction - Employee complaints	- Employee turnover rate - Employee complaints	- Employee absentees - Employee complaints

Figure 9: Filled in example of the multi-criteria hierarchical framework as proposed by Parida and Chattopadhyay (2007)

Albeit Parida and Chattopadhyay (2007) argue that it is important to link and integrate the overall objectives and the strategy of the company and state that with their framework a logical cause-and-effect structure has been created, this causal chain is not made explicit and goes against the logic of the original BSC at times. For example, the learning and innovation perspective is positioned in between all the perspectives, with the HSSE perspective right beneath it. To think that the HSSE perspective would contribute to innovation would be erroneous. Therefore the causality that is present within a strategy map is lost with this framework. This ambiguous way of portraying perspectives has an array of consequences. First of all the communicative character of the strategy map, and thus the strategy, is lost. Secondly, what indicators are leading and which are lagging is not clear anymore. The problem with this is that it is not sure how HSSE goals, for example, are attained. Although indicators are conceived they might be lagging indicators and not leading indicators which can steer the desired outcome. Moreover, the MCH framework starts with indicators instead of objectives. As a consequence, indicators are sought belonging to criteria while the question: 'why do we measure this?' is essentially skipped. This problem is reinforced by its inability to properly describe strategy.

3.3.5 The performance prism

Another popular performance measurement framework, called the performance prism, is developed by Neely et al. (2007). A key feature of this framework is its focus on both stakeholder *contribution* and *satisfaction*, i.e. 'what can stakeholder contribute?' and 'what do they expect in return for this?' respectively. Again, the reciprocal relationship between the organisation and the stakeholders is emphasized. They even go so far as to state that performance measures are not derived from strategy, but should be derived from the needs and wants of stakeholders, as strategy only serves to provide value to stakeholders. The performance prism has emerged from studying shortcomings of

existing frameworks and hence it tries to adopt the best of the existing frameworks. Neely et al. (2007) identified several key characteristics belong to performance measurement frameworks:

1. The framework should present a balanced picture of the organisation. The measures selected should be both financial and non-financial, and both internal and external.
2. A good framework is able to capture a succinct overview of the organisation's performance.
3. Performance measures should be multi-dimensional.
4. It should enhance comprehensiveness. The strategy needs to be mapped as such that omissions of important measures become visible.
5. Performances measures should both be integrated across the organization's functions (horizontally) and through its hierarchy (vertically).
6. The framework should explain how the results are an outcome of determinants.

They continue to state that their performance prism adopts all these characteristics. The starting point of this framework is that satisfying stakeholder expectations is the basis of achieving organisational objectives by contributions made by the stakeholders. Strategies as such are then focussed on satisfying stakeholders. It is not specified to what a strategy should qualify to or how it is constructed in the first place. These strategies are consequently achieved by internal organisational processes. These processes are subsequently facilitated by capabilities that can be defined as the combination of an organization's people (skills and talents), practices, technology and infrastructure that are collectively are able to create value for its stakeholders. A conceptual representation of the performance prism is provided in Figure 10. Ironically enough, the framework does not include measures for benchmarking; a point of critique earlier made by Neely et al. (1995) on the BSC.

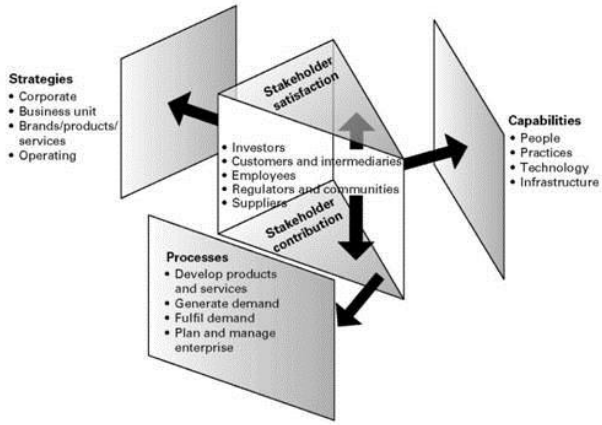


Figure 10: The conceptual representation performance of the prism by Neely et al. (2007)

3.3.6 Highway Agency service framework

Perhaps the first research article that tries to establish a LoS through a framework is that of Hatcher et al. (2012). In this paper they present the idea that asset performance directly contributes to a level of service that is expected by the stakeholders. This service level is gauged by what they call service measures – although using different jargon these are performance indicators in essence. These service level expectations are in turn defined by strategy, that is consequently based upon the organisational vision and goals.

The framework consequently exists of the following elements that are defined as follows (Hatcher et al., 2012):

- *Strategic goal*: Principle strategic goals
- *Service statement*: A statement of service in support of the strategic goal
- *Activities*: The activity being measured
- *Service measure*: A phrase describing the element of service being measured
- *Metric*: The actual measure of performance

The definition of these elements seems to be problematic. It is not clear what the distinction between a strategic goal and a service statement is, and the distinction between a service measure and a metric. Instead, there seems to be an overlap in definition and they rather service as a further specification.

Figure 11 shows a part of the worked out service framework for a particular strategic goal. Here we see that the service statement indeed serves as definition of the strategic goal, likewise the metric serves as a definition of the service measure. Here we also see that the lowest possible unit of measure is the availability of a particular technology. A particular asset property, namely the presence or absence of a certain piece of technology can contribute to stakeholder satisfaction. In this particular example the roll out a technology is adopted as an activity. In the light of the BSC this would more likely to be placed under the learning and innovation perspective, as it concerns a one-time activity. In this example the problematic definitions also lead to ambiguity. The service statement and the service measure merely describe the same thing. Besides, it is not clear how the maintenance of the traffic technology contributes to the availability of this very technology.

Strategic goal	Service statement	Activities	Service Measure	Metric
We provide a service that our customers can trust	Traffic technology assets are available to provide information to road users	Traffic technology equipment maintenance and replacement, roll-out of RTMCs	Availability of traffic technology	Regional technology maintenance contract (RTMC) aspect (PI 9)
				Technology availability via TTD's technology availability report

Figure 11: Example of a part of the service framework, adapted from Hatcher et al. (2012)

3.3.7 Asset planning performance measurement framework

The PMS developed by Arthur et al. (2016) was the framework that most resembled the idea of a LoS. In fact that authors state their very mission was to create a LoS between the organisational objectives and the asset management objectives. To this LoS they also link performance indicators. The framework thus becomes a line of sight. Similarly to the service framework of the Highway Agency this framework is specifically developed for a particular case study unlike the frameworks discussed above.

For the basis of this they use the idea of the BSC that was discussed above. More specifically they used the strategy map as to establish coherence between the various objectives. They made some adjustments to the original perspectives of the BSC. Through workshops a strategy map was created that could be aligned with the finance, internal process and the talent and teamwork perspective (they renamed the innovation and learning perspective), but the customer perspective was split into two.

The split was necessary to distinguish between strategies that impacted customers on the short term from that which had longer-term impacts on the community. As can be seen in Figure 12 the order of perspectives has also been reversed. The WA community is on top while the financial perspective is placed below. It is not described in what way the WA community differs from the customers, but what we do see is that the financial perspective is no longer the ultimate goal of the organizational as this concerns a public organisation. The WA community, customer and finance perspective answer *what* the Water Corporation wants to achieve, whereas the internal process and talent & teamwork perspective answer *how* this is going to be achieved.

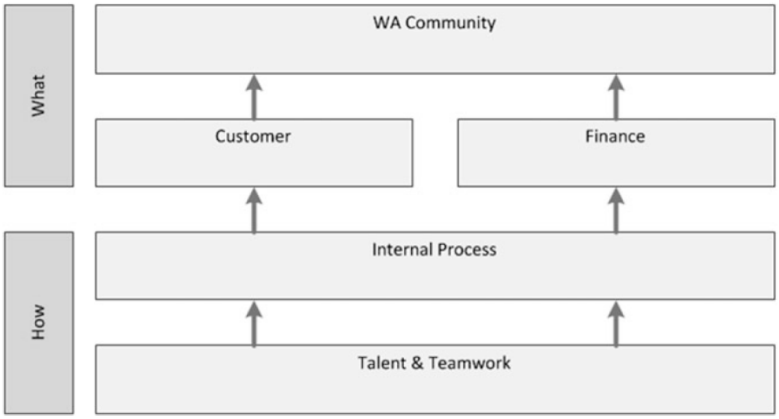


Figure 12: The perspectives as used by Arthur et al. (2016) in their strategy map.

Each of the perspective contained objectives to which one or more performance indicators were attached. Over time, it can be tested whether there is a relationship between the objectives. Although this is one of the first research papers that addresses the idea that LoS can be established through a strategy map that can consequently be operationalized in the form of a PMS it does not demonstrate its applicability nor provide deeper insights in how to build it. No explanation is provided as to why the perspectives are changed or what they actually comprise in the first place. Unlike the framework proposed by Alsyouf (2006), no changes are made to any of the perspectives that makes the strategy map explicitly applicable for maintenance activities or asset conditions or properties.

3.4 Evaluation of frameworks

The performance measurement framework can be useful for aiding the design of a LoS framework. The framework of Arthur et al. (2016) consisted of objectives that was operationalized to a PMS through performance indicators. In this research the goal is more the conceptualisation of a LoS than creating a working PMS. Although the line between a PMS and a LoS framework is therefore thin, the distinction lies in the operationalization through performance indicators. In this research we will solely look at the concepts of frameworks, not the issues surrounding the selection performance indicators.

Design science research prompts the use of requirements to evaluate a design. From the previous chapter the following requirements could be identified which we label as *relevance requirements*. Of course, what is recognized to be a relevance requirement today might become a rigor requirement tomorrow once its generic applicability is demonstrated. What now follows is a brief recapitulation of the requirements that are distilled from both the MeT environment and performance literature. At the end of the section the examined performance measurement frameworks will be juxtaposed with these requirements.

Relevance requirements

The relevance requirements are as follows. First of all, the framework has to be able to be (i) suitable for a public organisation. This means that a wide range of values can be included, unlike the performance measurement frameworks that place the financial perspective as the highest perspective. Not only is this interesting for public organisation, but also for businesses that increasingly have to comply with health, environment and safety concerns that are either demanded by a regulator or by labour unions or activist groups. This is especially relevant for asset intensive organisations as their actions can directly influence one of these aforementioned issues. Besides the framework needs to be able to (ii) include stakeholder requirements that are somehow connected to the activities surrounding assets and the actual assets themselves. The availability of a particular asset characteristic or an asset condition in some cases has a direct relationship with the level of service provided to a stakeholder. This in essence is what establishes the LoS.

Rigor requirements

From analysing the history of performance measurement frameworks and some contemporary performance frameworks other requirements were identified. These can be considered to be rigor requirements that originated from the knowledge base. The first and foremost is that performance measurement was focussed on financial results in the past. As a remedy the performance measurement systems were chosen in a balanced manner reflecting not only the financial performances, but also for instance the performances of internal processes.

Another requirement, and that partly overlaps with the previous one, is that of causality. Especially the strategy map emphasizes the need for coherence through causality between the various performance indicators. Performance literature distinguishes between leading and lagging indicators and stresses the need for a balance between both of them. This requirement of causality overlaps with the previous one because a balanced character will ensure to some degree the identification of both leading and lagging indicators.

Criticism to the BSC and the strategy map reads that it focusses too much on customer and shareholder demands, while too little emphasis is placed on stakeholders that are concerned with other issues than service or product quality and costs. Therefore a potential LoS framework should also be able to consider various values. This also coincides with the relevance requirement that the LoS framework should be eligible for public organisations.

Some authors plea that performance indicators should be integrated both vertically, through the hierarchy of an organisation, and horizontally, through the various departments and functions. For diagnostic reasons, that is to check whether departments and functions perform the tasks in accordance to what is specified, this is a reasonable thing to do. Kaplan and Norton (1996b) would argue however that it is the strategic measures that are important. The responsibilities that are assigned on a hierarchal basis are not concerned with what a stakeholder expects or how this expectation is fulfilled through either assets or the activities surrounding assets. The hierarchical structure of an organisation can hardly be reconciled with the concept of a LoS. This principle became clear when analysing the performance measurement framework of Parida and Chattopadhyay (2007). Although they managed to design a PMS conform organisational hierarchy, this displays little to no cause-and-effect relationships. Moreover did the framework try to link the various functional areas, but neither did this result in a logical causality.

Keegan et al. (1989) proposed a performance measurement framework that included external measures such as competitive cost position, market share and customer retention. These are measures that are relevant for businesses in commercial settings however. External may be more widely interpreted as it can also relate to stakeholder demands other than just service or product quality and cost with respect to that of the competitor. The usage of the Amsterdam infrastructure with respect to other transport modalities may be an interesting aspect to be considered however. This, however, is a diagnostic measure as it does not actually contribute to the stakeholder expectations. This leads us to conclude that the external orientation requirement is already sufficiently addressed by the requirement that LoS framework should be able to address more values than just shareholder value.

Finally, Atkinson et al. (1997) and Neely et al. (2007) argue that performance measurement frameworks should also include stakeholder contributions as these legitimatize an organisation's existence. Once could wonder in how far public organisations are dependent on the contribution of stakeholders as their ability to satisfy a stakeholder's expectation does not necessarily result in stakeholder contribution. In the case of MaT, their existence is dependent on a subsidy that is provided regardless of their stakeholder satisfaction. Therefore we discard this requirement.

Set of requirements

Some requirements are discarded, others overlap. Most of the rigor requirements coincided with the relevance requirements that are needed for the MaT organisation. The key concerns are that the framework should be eligible to address a palette of stakeholder values and that is should comprehend some form of causality in which the properties of physical assets and the activities surrounding these activities can be adopted.

> *Sub research question 1: What requirements can be identified for a LoS framework that is to be applied for a public asset intensive organisation?*
>
> The requirements can be summarized to the following list:
>
> 1. The framework should be able to address various stakeholder values. This makes it eligible for a public organisation
> 2. The framework should have causality of various perspectives. These perspectives contain objectives that all belong to that particular perspective
> 3. The framework should be able to include the properties of physical assets
> 4. The framework should be able to include the properties of activities surrounding assets

Table 5 shows all the frameworks that have been analysed so far with the found requirements.

Table 5: The various performance measurement frameworks with the requirements on which they are tested

Framework	Clear causality	Wide variety of values	Asset properties?	Activity properties?
BSC	No	No	No	Yes
Strategy map	Yes	No	No	Yes
Maintenance BSC (Alsyouf)	Yes	No	No	Yes
MCH	No	Yes	Yes	Yes

Performance prism	Yes	Yes	No	Yes
Australian water utility Framework	Yes	Yes	No	Yes
Service framework	No	Yes	Yes	Yes

Some peculiarities might become noticeable when inspecting the above table. The maintenance BSC of Alsyouf (2006) is considered to have a clear causality while the original BSC has not. The framework presented by Alsyouf (2006) actually bears strong resemblance to a strategy map. The MCH framework of Parida and Chattopadhyay (2007) is one of the few frameworks that actually includes asset properties in its framework, although they are not clearly separable from the activity properties (for instance maintenance frequency). There is no relationship between the two types of properties. Moreover, this framework does not provide the desired causality for establishing a LoS on a more general level as was discussed above.

Another framework that does include asset properties is that of Hatcher et al. (2012). Although they make the relationship of fulling stakeholder expectations and asset properties (i.e. the presence of certain technology) explicit, the causality of the total framework is unclear. This leads to double mentioning of objectives once the framework is filled in.

All frameworks that are adopted from the BSC include the internal process perspective. This perspective ensures that activity properties (that are primarily maintenance activities in the perspective of the selected case study) can be included.

The amount of times a framework scored ‘yes’ in Table 5 does not say anything about its usefulness to serve as a LoS framework. Perhaps because the most important requirement of all is the causality. The strategy map, the framework Alsyouf (2006) and that of Arthur et al. (2016) qualify the best in this respect. Nevertheless on these frameworks some remarks can be made. The strategy map places the financial perspective as the most highest perspective, thereby constraining the consideration of other stakeholder values. The same goes for the framework of Alsyouf (2006), although it does consider societal values this eventually is only to serve the financial perspective again. The framework of Arthur et al. (2016) places the community perspective on top, but does not elaborate what kind of values are comprised within.

A common point of critique for the three last named frameworks is that there are no explicit relationships demonstrated between the various objectives. Although the perspectives are linked, the objectives within these perspectives have no connection. This might be omitted because the sensitivity of information for those particular case studies. Although Arthur et al. (2016) are concerned with the right selection of performance indicators and the targets to be set for them, they are not really concerned with what objectives to set. We believe that the usefulness of a perspective is demonstrated through an applied case studies where there objectives between different perspectives are connected as this truly demonstrates a LoS.

Another point of critique is that none of these three aforementioned frameworks include objectives that can be set to the asset conditions. The Highway Agency framework and the MCH framework did include this, but presented no clear causality.

Having compared all these frameworks against the found requirements we conclude that although the frameworks provide a useful basis, there are still some modifications needed as to make it fit with the requirements.

3.5 The line of sight framework

After analysing all these frameworks the intention is to develop framework that suits the aforementioned requirements. The framework that stood out the most as the best possible candidate is the framework of Arthur et al. (2016). It placed the public value – although not defining what that exactly is – as the final perspective to which all other perspectives contribute. In essence the framework of Arthur et al. (2016) is based on the strategy map that was developed by Kaplan and Norton (2000). We choose the strategy map as a point of departure from which modifications are made. The LoS framework that is built in this section is made of various layers. These layers serve as a replacement for the perspectives that were initially introduced in the BSC. These layers contain factors that represent a real world characteristic of an object or an activity. The factors are connected with each other and together make up a causal chain. Several layers can be identified that together add up to several causalities of factors, which connect the stakeholder values with the assets and the activities surrounding these assets.

3.5.1 A layered framework

Value layer

The definition of the LoS according to the PAS55 standard is the connection between the organizational strategic direction and the day-to-day activities of manging assets (The Institute of Asset Management, 2008a). When looking at the frameworks that came after the BSC and the strategy map, most of them all had in common that stakeholder values should be pursued as the highest possible goal within performance measurement. One could argue that any organisation exists to serve a particular group of stakeholders, the organizational strategic direction and its inherent objectives should therefore always be focussed on stakeholder values we argue. One of the requirements found was that the LoS framework should be able to represent a wide variety of stakeholder values. For this reason we choose the stakeholder value to be the starting point of LoS framework. A public organisation is characterized by a wide variety of stakeholder values. In order to keep the LoS framework comprehensible it is therefore chosen to split the LoS framework into several distinct lines of sight, each for one stakeholder value.

Definition layer

The customer perspective of the BSC (and the strategy map) describes what exactly customers value in for example a product or service. This can be for example the quality, shipping time or the image of a product, but also the after sales services. In this example, the customer product valuation becomes explicitly defined. When dealing with public values such as liveability or RAMS criteria such as safety defining these values (or criteria) is also of great importance. Safety, for example, can come to mean many things to various stakeholders. A carrier of a light rail infrastructure is more likely to define safety as derailments, whereas the service providers that maintain the railway track first think of maintenance related accidents when talking about safety. For this reason it is important to define the stakeholder values in a separate definition layer.

Asset layer

A next logical question would be: how are these definitions established? What determines these definitions? If the definition layer is somewhat comparable to the customer perspective of the BSC, the

BSC would suggest this is done through internal organisational processes. Asset intensive organisations make products or deliver services on the basis of their assets. In many cases these stakeholder values, or rather the definitions thereof, are fulfilled through these assets. A particular asset property determines whether or not a stakeholder value is attained or the extent to which it is attained. For example, too much wear on the railway track can result in derailments. In the framework of Hatcher et al. (2012) the presence of certain traffic information availability contributed to the strategic goals. Whether it is the condition of the presence (or absence) of asset characteristics, they can generally be brought under asset properties.

Activity layer

In turn these asset characteristics are influenced by activities. When the continuing the parallel with the BSC, this layer can be best compared with the internal process perspective. The majority of activities surrounding assets relate to maintenance, but it is not solely excluded to maintenance however. Undesired acts of third parties can also influence an infrastructure system. For instance, trucks can hit the overhead line of the tram infrastructure. For this reason the activity layer is not labelled with the term maintenance as it is not solely restricted to maintenance activities. All activities that have a direct influence on asset property (asset factor) can be included in the activity layer. The PAS55 presumably spoke about this when it mentioned the term ‘day-to-day’ activities. Maintenance, exploitation of the infrastructure by the carrier and actions by third parties are the primary group of activities that are included in this layer. Processes such as collaboration do not fit within this layer as they do not directly influence the asset properties.

Not exclusively are stakeholder definitions directly established by asset properties. Sometimes, activity properties can also directly define the definitions. For instance, when safety is, amongst others, defined as maintenance related accidents, then it are activity properties, not asset properties, that shape the definition. In this case we the cascade of definition layer, asset layer and activity layer does not hold.

As all asset factors are asset properties and similarly all activity factors are properties, the terms factors and properties are used interchangeably in the remainder in this document when talking about assets or activities.

Improvement layer

When the LoS is made clear through definitions, asset properties and activity properties it is much more easier to attach existing improvements to them or conceive new improvements that connect somewhere in this causality. The learning and innovation perspective of the BSC is similar to this layer. Originally, this perspective in the BSC was primarily concerned with competencies, business processes and IT infrastructure.

An overview of the framework is displayed in Figure 13. The arrows are drawn in a downward direction, but the framework can be read in two directions. When reading top down one can ask the ‘how’ question, namely: ‘how is this realized?’ The factor in a layer below then provides the answer. The framework can also be read bottom up. In this scenario one can ask the ‘why’ question, namely: ‘why do we do this?’ The answer is then provided by a factor in the above layer. Note that (i) definitions can directly be shaped by activities and that (ii) the asset layer can also directly be connected to improvement layer, as improvements can also relate to asset properties.

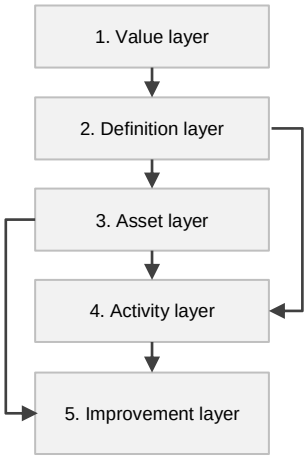


Figure 13: The LoS framework

In the framework of Arthur et al. (2016) the elements that together made up a perspective were referred to as objectives and had performance indicators attached to them with specific targets set. The LoS framework stays on a more conceptual level. We therefore refer to these objectives in the LoS framework as factors, as they are elements that have no performance indicators or targets attached to them. In the remainder of this document we will refer to the asset factors and the activity factors as the technical aspects.

The framework does not familiarize itself with the classical hierarchy of the strategical, tactical and operational layers that many asset management systems recognize. The stakeholder values and the definitions thereof, and the improvements measures can be considered to be strategical. The asset and activity properties can be considered to be operational on the other hand. This demonstrates that the layers in the framework do not follow the classical hierarchical order.

To help shape the understanding of the LoS a partial LoS is displayed in Figure 14 for the value of sustainability. In this example all layers are filled but this does not necessarily have to be case. The grey blocks in the figure are the factors. Together they connect the stakeholder value sustainability to an improvement measure.

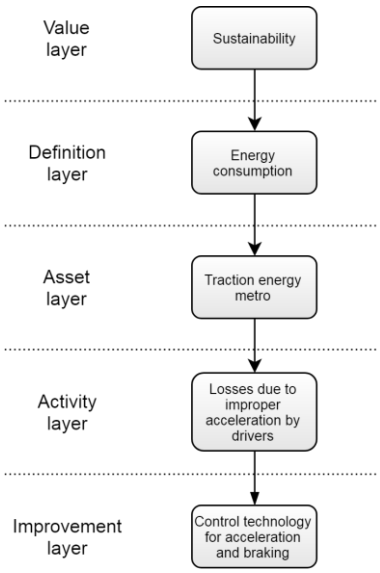


Figure 14: Example of a LoS for the value sustainability.

3.5.2. Purpose of the framework

The LoS offers organisations an overview of how the various stakeholder values are fulfilled through the assets and the activities surrounding these assets. The goal of the LoS is yet to be evaluated, but it is speculated to contribute to policy and strategy formulation and the design of a PMS. The LoS is at least, regardless of its application, an information instrument that can communicate the causal chains that establish stakeholder values to the employees on all levels in an organisation. Kaplan and Norton (2000) argued that their strategy map was a tool for communication. Logically this goes for the LoS framework as well, as it was strongly inspired by the strategy map after all.

In chapter 6 and 7 there will be an informed argument on the basis of the existing policy and strategy documents of MaT, and the PMS currently in use by MaT as to see what the potential use of the LoS framework can be and to evaluate eventual shortcomings. Note that we evaluate the LoS framework and not the lines of sight that are developed for MaT.

How to fill this framework will be covered in the coming chapters. In chapter 4 the stakeholders will be identified for MaT and their relevant values will be selected. This pertains to the question what values need to be considered and how to formulate them. The LoS framework was chosen to be split per stakeholder value. This will thus result in several separate lines of sight as they are developed for MaT. Chapter 5 will elaborate more on specific choices that can be made when filling the LoS framework. For instance, the question when something should be considered an asset factor or an activity factor. Several guidelines are found that help shape the consistency of developing a LoS. This chapter will also demonstrate ways to find factors in the first place, as this can be an unstructured process.

4 Stakeholder Analysis

In the previous chapter a LoS framework was proposed that recognized fulfilling a wide variety of stakeholder values as the starting point. These values are placed in the value layer of the LoS framework. Developing a LoS is done according to the bottom down principle, starting with stakeholder values at the top. The methods presented in this chapter serve to find the values that can be placed in the value layer of the LoS framework. This chapter consists of two sections. The first section elaborates on the used methods of stakeholder identification, filtering stakeholder interests and how these interests are translated to more generic values. The second section elaborates on the application of these methods and presents the results of the stakeholder analysis. The values found at the end of this chapter are placed in the value layer of the LoS.

4.1 Method

4.1.1 Identifying stakeholders

The identification of stakeholders is a crucial step within a stakeholder analysis. A mixture of several techniques has been used (Enserink et al., 2010, p. 85). In Table 6 below an overview of the various stakeholder identification techniques is provided. Enserink et al. (2010) describe that identifying stakeholders can be an iterative process where various techniques are being used. They are complementary to one another and partly overlapping at times. A mixed use is less likely to lead to the risk of omission of important stakeholders.

Table 6: Stakeholder identification techniques (Enserink et al., 2010)

Technique	Description
Imperative approach	Who feels strongly enough about the organisation's operations or who feels the consequences of the organisation's actions?
Positional approach	Uses existing formal hierarchies to see what stakeholders hold formal power or considerable resources.
Reputational approach	Ask stakeholders who are already identified what others stakeholders should be considered.
Social participation approach	Identifies stakeholders to the extent that they relate to activities surrounding a policy issue. For instance as part of committees, by attending meetings, or as part of platforms.
Opinion leadership approach	Identifies stakeholders who hold influential opinions.
Demographic approach	Identifies stakeholders by characteristics. Examples of which can be age, sex, occupation, level of education or residence.

In this research there was limited time scope to identify all stakeholders and research their interests in great detail. All stakeholders and their interests were identified within MaT as this saved time. Ideally all stakeholders should formulate their own interest. The available information resources within MaT were (i) a list stakeholder made by MaT, (ii) interviews with a member of the management team, (iii) a stakeholder analysis (not entirely identical to the first document) that was included in the MaT asset management strategy document and (iv) a descriptive document of a new regulation that governs the

administration of the metro and tram infrastructure in and surrounding the city of Amsterdam (SRA, 2015).

4.1.2 Filtering interests

In the first step of the stakeholder analysis the stakeholders, and their interests, are identified that are somehow involved in the management of the tram and metro infrastructure. It is questionable whether every interest is equally important for MaT to take into account. To this end several criteria have been distilled from the MaT case study that help filter which interests are relevant to include in the lines of sight. These criteria were found through consulting the management team by asking what they thought were important interests to account for. We do not claim that these criteria are generically applicable to other contexts, but they at least provided useful for the case study of this research – and more importantly they are in line with the scope of the LoS framework. In the next section the stakeholder interests are juxtaposed with these criteria as to see which are the most suitable. Now follows a brief elaboration of these criteria.

Dependence

The dependency of one stakeholder on a second stakeholder is shaped by (i) the resources held by the second actor, (ii) the degree to which this resource is replaceable by other resources and (iii) (Enserink et al., 2010). The dependency criterion thus relies on the dependency MaT has towards other stakeholders.

Importance

When performing a stakeholder analysis for a public organisation it is wise to investigate the dependencies the second stakeholder has on the first. Although there may be nothing to be gained for the first stakeholder, a public organisation's intention is to serve the relevant societal groups. Of course, when a particular interest the second stakeholder has in the first it not of great importance, one could ask if it should be considered in the first place if they are many other competing interests that deserve more priority.

Influence

This criterion of influence relates to the extent by which the organisation can influence the interest of a stakeholder. One might argue that if the organisation cannot influence an interest then it is not their responsibility. Sometimes, an organisation is only partly responsible or cannot influence an interest directly.

Relevance

The LoS was defined as the connection between the high level organizational objectives and the assets and the activities surrounding them. An organisation undertakes many activities but not all of these fall within the scope of the LoS. The LoS tries to establish the connection between the strategical and operational, and there are many activities an organisation under takes. Therefore we say that if the interest can be directly influenced by the assets or activity properties it is considered to be relevant.

If one of these above criteria are not met it is wise to not adopt the interests within the LoS.

4.1.3 Translating interests

Consequently interests need to be translated to values as they can be too specific to a particular context. We take the example of sound nuisance and property damage. Both these two interests relate to the same value of liveability. Finding out what the underlying value of the interests is can be done

by asking the ‘why’ question. De Haan and De Heer (2012) provide an example of an entrepreneur who has as its goals to make more profit. Asking him why he wants to do that he answers: ‘to continue business’ To ask him why he wants to continue business is not sensible as this is discussing the ‘being’ of an entrepreneur. This interest is so abstract and is always present regardless of any problem perceived that we refer to it as a value. The value is a high level interest that is always present independent of any problems perceived.

Values can be rather vague, but this does not pose to be a problem as it can be broadly defined in the definition layer. In this layer the value is becoming more operationalized and can this way be connected to asset and activity properties. In other scenarios the value is specific and even measurable, like is the case with availability. The definition layer then serves as a further specification of the value.

4.2 Application

4.2.1 Identifying the Amsterdam light rail stakeholders

Primarily three methods have been used to identify the stakeholders and their interests in the MaT case study, namely the imperative approach, the positional approach and the reputational approach. By performing these three methods an overlap was often the case but also led to a more comprehensive analysis.

The initial stakeholder identification was done by analysing the descriptive text of the Act Local Railways. This best suits the *positional approach* as the text describes the formal responsibilities of many of the stakeholders involved in the Amsterdam light rail environment.

Consequently, the stakeholder documents that were already made by MaT were examined and a member of the management team was interviewed, as to complement the first approach. Especially interviewing a member of the management and asking him what stakeholder should be considered can be regarded as the *reputational approach*.

Finally, through *the imperative approach* the municipality of Amsterdam was recognized as a stakeholder. The municipality set targets with regards to the sustainable development of all of their activities, thus also including the transit system. In the MaT asset management strategy there was a brief stakeholder analysis adopted. This stakeholder analysis did not adopt the Amsterdam residents as stakeholders however. By asking the question who felt the consequences of the organisation’s actions, this stakeholder immediately came to the front. In Table 7 the complete stakeholder analysis is presented.

Table 7: The identified stakeholders in the Amsterdam light rail context and the reciprocal interests between MaT and the stakeholders

Stakeholder	Interest MaT has in stakeholder	Interests towards MaT
Vervoersregio Amsterdam	Authorized to delegate, subsidy	• Attaining RAMS criteria and quality criteria • A cost efficient infrastructure system
GVB Exploitatie	Exploitation according to usage agreement	High infrastructure availability
GVB Infra	Performing maintenance according to BORI agreement	Wants to be supplied with much as possible work and financial resources from MaT
Wethouder Verkeer, Vervoer en Luchtkwaliteit	Political backing	• Wants to be informed timely and justly • No negative publicity relating to metro

		and tram services • Preserving economical value of rail infrastructure
V&OR	• High availability of interfacing infrastructure on which the tram is dependent • Should take into account wishes and demands of MaT regarding changes to the rail infrastructure network • Should take into account feasibility with respect to finances and planning when it comes to maintenance and construction projects that have to be carried out by MaT	• Input for their transit policy • Wants to know when maintenance is planned in order to coordinate maintenance works of interfacing parties
Users	Good traveller ratings on the aspects that can be influenced by MaT	Comfort, reliable transport and good accessibility on the aspects that can be influenced by MaT
Amsterdam residents	No complaints	No nuisance, no property damage, little impediments in neighbourhood
Inspectie Leefomgeving en Transport	License-to-operate	Safe transport: regulatory compliance

4.2.2 Filtering relevant interests

In the previous section the four criteria of dependence, importance, influence and relevance were discussed. Now that the stakeholders of the Amsterdam light rail and their interests have been identified, the found interests can be juxtaposed with the criteria. In many cases much of the interests are overlapping. For instance, both the Transport Region and GVB Exploitation want high infrastructure availability. The interests that were not adopted in the LoS were either rejected because they either could not be directly influenced or were directly related to operations. An overview of the interests that are adopted in the lines of sight of MaT is presented in Table 8.

Table 8: The found interests juxtaposed with the four criteria of adoption

Stakeholder	Stakeholder interest	Is MaT highly dependent?	Highly important for stakeholder?	Can interest be influenced directly by MaT?	Is directly related to technical aspects?	Interest included in the lines of sight?
Vervoersregio	RAMS and quality criteria	✓	✓	✓	✓	Yes
	Cost efficient infrastructure system		✓	✓	✓	Yes
Municipal executive board	No negative publicity relating to metro and tram services	✓	✓	x	x	No
	Timely and justly information supply		✓	✓	x	No
	Preserving economic value of infrastructure		✓	✓	✓	Yes
	Sustainable		✓	✓	✓	Yes

	management of infrastructure system					
GVB Exploitatie	High availability	✓	✓	✓	✓	Yes
GVB Infra	Wants to be supplied with much as possible work and financial resources from MaT	✓	✓	x	✓	No
V&OR	Input for transit policy	x	✓	✓	x	No
	Wants to when maintenance needs to be done		✓	x	✓	No
Users	Comfortable, reliable and accessible transport	✓	✓	✓	✓	Yes
Amsterdam residents	No nuisance, no property damage, little impediment to local neighbourhood	✓	✓	✓	✓	Yes
Inspectie Leefomgeving en Transport	Safe transport	✓	✓	✓	✓	Yes

Note that the above table is merely supportive. It is often because several criteria are not complied with at once that the interest is chosen not to be included. The interests that are not adopted within the lines of sight are briefly elaborated.

The first interest that cannot be influenced directly is that of negative publicity. Negative publicity is always the consequence of excessive failing performances. For instance, this can be a safety incident or a long lasting disruption. As the values of safety and availability are already included via other stakeholder's interests, the interest of absent negative publicity is omitted.

Although informing the alderman justly and timely can be influenced by MaT it has too weak ties with the operational aspects to fit within the LoS framework. Therefore it is not included.

The interest of GVB Rail Services wanting enough work and financial resources to perform this work can also hardly be influenced directly by MaT. It is the municipal executive board in the first place who makes a decision about the selected service provider. Finally, the Transport Region allocates the financial resources by which maintenance should be performed. Although MaT can lobby for an increase of maintenance budget or an alleviation of austerity measures, they do not decide themselves on the annual maintenance budget.

VO&R wants to be supplied with information by MaT about the feasibility of large renewal and construction projects. This however does not relate to day-to-day operations and maintenance, and therefore is argued to not fit well within the LoS framework. Another interest V&OR has with respect to MaT is that they want to know when MaT plans to perform its maintenance, so that it can be coordinated with the maintenance works of other infrastructure managing parties. Here the problem is

that MaT can hardly steer when maintenance work needs to be performed: assets age according to particular usage. Moreover it is not known for MaT which time slot is preferred by V&OR.

4.2.3 Translating stakeholder interests to values

In order to reduce the number of lines of sight as much as possible generic values are extracted from the stakeholder interests, from which a LoS can be made.

The interests of RAMS and quality criteria and the preservation of the economic value of the infrastructure system are explained in more detail. In the 2013-2024 covenant between the Transport Region and the municipality of Amsterdam there are several criteria adopted, namely RAMS and quality criteria (SRA, 2013). The RAMS criteria, although including reliability and maintainability, are reduced to solely availability and safety. The quality criteria include a wide variety of such as the cleanliness of the stations, the travel comfort that is determined by the rail alignment, the accessibility for disabled people and the like. These quality criteria all contribute to the value of traveller's experience. In the next chapter the values will again be defined and many of these interests will be reintroduced as definition of the value traveller's experience. Similarly to the quality criteria, preserving the economic value of the infrastructure is a mere definition of the value cost efficiency.

Table 9 presents an overview of the translation of interests to generic values. Sometimes different actors value the same thing.

Table 9: Stakeholder interests translated to generic values

Interests	Value
RAMS and quality criteria	Availability
	Safety
	Traveller's experience
Cost efficiency infrastructure system	Cost efficiency
Preserving economic value of infrastructure system	Cost efficiency
Sustainable management of infrastructure system	Sustainability
High availability	Availability
Comfortable, reliable and accessible transport	Traveller's experience
No nuisance, no property damage, little impediment to local neighbourhood	Liveability
Safe transport	Safety

During the process of building the lines of sight it was found that splitting the lines of sight per value was more workable in order to retain oversight. It are thus the values of availability, safety, cost efficiency, traveller's experience, sustainability and liveability for which six separate lines of sight will be developed for MaT.

On a more generic level, a method was found for the identification, filtration and translation of stakeholder interests. With this method values are found that can be placed in the value layer of the LoS framework.

Sub research question 2: How to identify relevant stakeholder values for developing a LoS?

The method for finding relevant stakeholder interests consists of three steps.

1. Identifying stakeholders and their interests: several approaches to identify stakeholders were provided.
2. Filtering interests: this step selects the interests that comply with the scope of the LoS, namely those that relate to the technical aspects and where there is at least a dependency of a stakeholder with respect to the organisation.
3. Translating interests to generic values: the stakeholder interests are grouped into generic values by asking the ‘why’ question with regards to the stakeholder interests.

5 Developing lines of sight

This chapter will describe in detail how the lines of sight are developed for MaT in consultation with the experts for the various stakeholder values that were identified in the previous chapter. In this chapter the factors for the definition layer, the asset layer and the activity layer are found for the MaT case study. Filling the lines of sight for the MaT context is considered to be an evaluation of the applicability of the LoS framework. We start the chapter with describing the used working method of developing the lines of sight in consultations with experts from MaT. Some methods are provided for finding factors and how to attain the right level of detail and scope, amongst others. All of these insights were found while making the LoS and have a rather pragmatic substantiation rather than that they are based on scientific insights. Although no validation has been performed on the developed lines of sight, we briefly touch upon this subject. The chapter is concluded with a reflection of the developed lines of sight. Although the lines of sight are tailor-made for MaT there are however generic lessons to learned from this developing exercise.

5.1 Working method

Filling the LoS framework was considered to be a form of evaluating the LoS framework on its applicability. Kaplan and Norton (2000) recommended a top down working method when making a strategy map. The starting point of a LoS is therefore one of the values that were identified in chapter 4. These values are placed in the value layer. For each vale a separate LoS is developed in order to attain clarity. In this chapter the following three layers of the LoS framework are filled, namely the definition layer, the asset layer and the activity layer. This section describes on a general level the working method how this three consequent layers are filled through consulting experts.

Figure 15 shows the outline of how a single LoS is filled by consulting an expert on a particular stakeholder value. The LoS framework that was designed in chapter 3 is filled in an iterative matter primarily through interviews with experts. As a rule of thumb, generally three interviews were required to construct a LoS. The interview consisted of a real-life meeting with the particular expert where an A3-size paper, with the LoS framework printed on it, was filled in an iterative manner. When the LoS was considered to be finished a final validation was done where the expert was asked whether he agreed with the developed LoS.

The found factors in the LoS frameworks primarily stems from interviews with experts on a particular area, but in some cases were complemented by organisational documents. The research was only performed within MaT that claims to be the asset managing organisation, but not within GVB, the service provider of the Amsterdam light rail context.

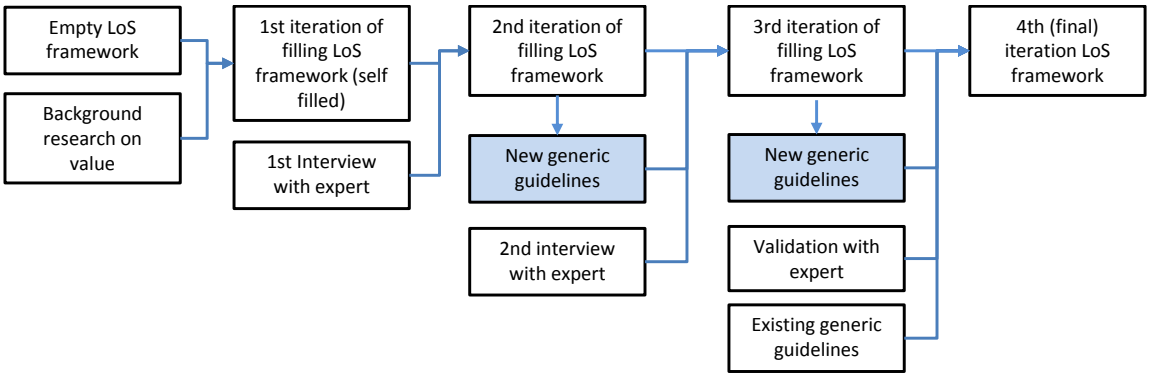


Figure 15: Iterative method of designing and evaluating the LoS

The LoS framework on itself may not always result in a smooth designing process that results in an actual LoS. When filling the frameworks several clashes were encountered at time where it was not apparent whether a factor should be adopted, or in what layer it should be placed. For this reason, several design guidelines were developed that help streamlining the design process. Figure 16 displays the process of designing and evaluating these design guidelines. Generally speaking, when new factors were introduced a clash could occur. Although the factor could eventually be fitted in, it was necessary to create a guideline as where to place it, because this creates consistency throughout the LoS and between the lines of sight. When the guideline was found it was tested with several other existing or hypothetical factors. When all these factors conformed to the guideline it was adopted. Eventual existing factors that were already in one of the lines of sight that had a similar problem but not yet conformed to the new guideline were adjust in such a way that they now conformed. Only a small amount of the factors were subjected to these guidelines.

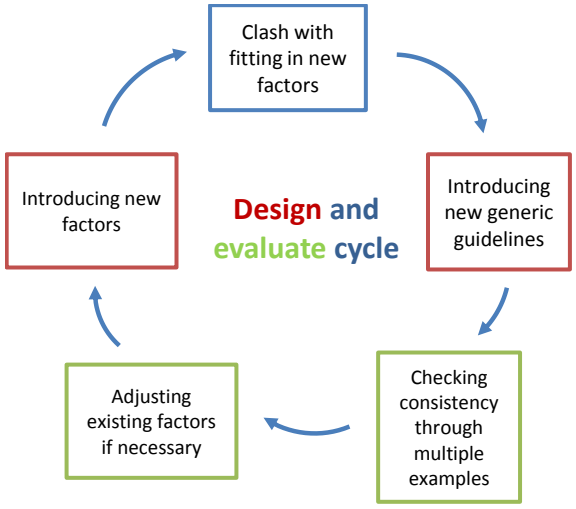


Figure 16: The design and evaluate process of the guidelines that belong to a LoS framework

5.2 The elements of a line of sight

5.2.1 Factors

The main building blocks of the LoS are called factors. The definition of a factor is 'a fact or a situation that influence the result of something'[1]. In this case that 'something' are other factors. Factors thus influence each other. Between these factors there is thus a causality.

The LoS framework consists of various layers. For each of these layers a specific type of factor exists. Hence there are definition factors, asset factors, activity factors and improvement factors.

The factors in the definition layer form the link between an (abstract) value and the operational factors. These factors help define the values. Values are often immeasurable because of their rather abstract definition. There is no obligation for the definition factor to be either an asset or activity property. These factors on the definition layer, however, need to be made measurable per definition, but for the rest they can come to mean anything. For instance, in the liveability LoS there is the factor 'traffic hindrance experienced by road users'. This factor does not relate to the assets or the activities surrounding them. Another example is 'material inflow' under sustainability.

They are the most important checks on whether a certain value has been attained. For some values, such as traveller's experience in MaT case study, the definition factors are rather difficult to measure although they are measurable through surveys. What further complicates the definitions of traveller's experience is that the degree of comfort provided by MaT should clearly be separated from the level of comfort as offered by the carrier.

The factors in the asset layer are asset properties. They tell something about a physical characteristic an asset has. Examples of which can be the condition of an asset or the availability or absence of dynamic traveller's information.

Factors in the activity layer are activity properties. Similarly to asset properties, they are a characteristic of an action a person undertakes that can somehow influence the assets. Generally speaking, most of the activities in the activity layer relate to maintenance actions undertaken by maintenance personnel in an asset management context. Activities are not solely reserved to the actions of maintenance personnel: other examples of activities can be the damaging of the infrastructure system by third parties or administrative processes (such as financing) that enable the equipment of stations with particular technology. Examples of activity factors can be, but are surely not limited to, the frequency, the price, the quality (quality is rather ambiguous term that often needs further clarification) or the time period (day or night) in which the activity take place.

Furthermore, some exceptions exist to factors within the same layer. As the LoS was created for both the metro and tram, it is convenient to create one image where both the factors for metro and tram are displayed. For this reason, tram specific and metro factors were highlighted with a separate colour.

Improvement factors

Improvement can be elaborated plans that can consist of the aggregation of multiple measures. Although no effort was spent on identifying improvement measures it is good to split improvement programmes consisting of several measures into pieces and show how each of these measures influences each of the asset and property factors.

[1] http://dictionary.cambridge.org/dictionary/english/factor

Reference factor

In some occasions causalities exists between factors that do not respect the top down causality. An example of which are definition factors that influence one another. In the LoS framework factors can only be connected with one another vertically, and not horizontally. It was chosen this way in order to enhance the comprehensibility of the LoS framework. Some of these horizontal relationships are so important that they cannot be omitted. There can also be a causality between factors of different lines of sight. For this reason, a reference factor is introduced. The reference factor is a factor that refers to an already existing factor. As a reference factor can come to mean anything, it often does not fit within the layers of the LoS framework. For convenience purposes, reference factors can be placed in layers to which they have no logical relation.

Proxy factor

Furthermore, there are factors that serve as proxy for other factors. An example of which is the factor 'average grade for safety culture'[2]. Empirical research suggests that a connection exists between the safety culture and the accidents and dangerous situations (Fernández-Muñiz, Montes-Peón, & Vázquez-Ordás, 2007; Milczarek & Najmiec, 2004). Accidents may not have happened purely by chance, but this does not imply that a working environment is safe. Measuring safety by the number of accidents can therefore be undesired by its time delay effect. In this case the proxy indicator *safety culture* could be a more actual representation of the safety level than the number of incidents. Although the 'average grade for safety culture' was already considered to be a performance indicator in the current PMS, it is unknown whether this relationship has also been demonstrated in the Amsterdam light rail context. In this example the reference factor is used in the definition layer, although it might also be used in other layers.

The legend of all factors used in the lines of sight is shown in Figure 17. The definition, asset and activity factors look all the same in order to keep the lines of sight comprehensive (indicated as 'factor' in the figure).

Figure 17: A legend of the various factors that exist

5.2.2 Guidelines for factors

Measurability

Do all factors need to be measurable? With the exception of the values, they should, including those in the improvement layer. The roots of the framework lie within Kaplan & Norton's strategy map. They refer to the strategy map as a set of hypotheses about cause and effect. To this end, the manager must verify whether the chosen strategy works effectively. A strategy in that sense is the set of hypotheses of causes and effects that can be verified by measurable factors.

Some definition factors cannot be measured directly such as accessibility. Several options exist on how to measure accessibility. Examples can be the number of complaints, making a compound

[2] This also happens to be the only proxy factor identified in this research

measure based on the underlying factors or surveying travellers about their satisfaction with the platform accessibility. Although remarks can be made on the suitability of each of these performance indicators, this lies outside the scope of this research. For now it is important that the designer of a LoS needs to be aware that the factor should be able to be quantified. This serves to ensure that factors are measurable and hence become formulated in clearly definable way.

A typical factor that needs further specification is quality. Quality can come to mean many things. In the LoSs created there was one type of quality found and that was of the maintenance. This quality has been defined through so called measurable Output Specifications that are set up for the assets on component level. In this case, using quality can be an effective way of working in building the LoS, but the creator of the LoS should first define how this quality can be measured before proceeding using this term.

Related to technical aspects

In the previous chapter it was found that some stakeholder values do not fit within the scope of the LoS, as not all values are related to the technical aspects. Similarly, some factors did not fit well within the LoS because of similar reasons. Especially those that relate to activity properties and that are abstract and ambiguous by nature. Typically these factors are also hard to measure and hard to specify. Activities that are hardly measurable are collaboration and negotiation. Attempts of quantifying collaboration have been performed in the past (Thomson, Perry, & Miller, 2007), but these still recognize that they merely offer 'a partial view of reality'. In the previous chapter we identified that stakeholders interests needed to be directly related to the technical aspects. Collaboration is considered to have weak ties with the technical aspects, although the effects of collaboration can indirectly influence assets or the activities that influence assets. This issue pertains to the scope of the LoS. Factors should therefore, just like the stakeholder interests, fall within the scope of the LoS and have a direct connection with either the assets or the activities surrounding these assets. Collaboration is considered to be too disassociated with these operational aspects and therefore does not fall well within the scope of the LoS.

Influence

Do factors all factors need to be able to be steered? Not per se. Sometimes it can be useful to include factors that are labelled as external factors; they are explanatory for how performances come about. An example in the MaT case is the energy production through solar panels that is strongly dependent on the payback time. The payback time is determined by technological innovation of solar panels and is therefore thus recognized as an external factor; this factor cannot be influenced by MaT. Another example is the passed tonnage: the more tonnage, the more maintenance needs to be performed. This is a factor that cannot be influenced by MaT, but can strongly define their performances. Factors that are considered to be external today may be influenced tomorrow, however. Therefore, adopting factors that cannot be influenced now, may prove useful later, or they can be used for explanatory purposes.

Measuring possibilities and constraints

Factors should not be excluded from the LoS because there is not data available for them. It is the very purpose of the LoS to inform management on what data should be available. Organisations put tremendous efforts in collecting various kinds of data and compose dozens of KPI's and there is little to no coherence (Kaplan & Norton, 1992); as a consequence oversight is lost. The LoS can help focus on the collection of data in a coherent matter with the specific goal of demonstrating a hypothesized

causal chain of cause and effect. When finding the asset and activity factors the designer of the LoS should not be hindered by the current data availability.

5.2.3 Relationships between factors

The lines between the factors in the LoS make up the causal relationships between factors. If a LoS is read top down, the (partial) cause of one factor is usually a factor in a lower layer. The number of relationships a factor may hold with factors in a lower layer is endless, but for the purposes of comprehensiveness it is wise to limit the number of relationships to the most significant influences. Determining whether something is significant can best be done with the help of an expert or through data.

The definition-asset-activity causality as the LoS framework presupposes does not always hold true in this consecutive order. It can also be that a definition factor is directly influenced by some activity property. In that case, the asset layer is skipped. It can also be that a definition factor is only influenced by some asset property and that this asset property is not influenced by any activity factor in turn.

The improvement factors directly influence either an asset or activity factor. The improvement factor cannot influence a definition factor. If one wishes to do so, this might be an indication there are missing asset or activity factors.

The relationship between the factors can be of course be quantified through a function if the factors can be expressed in terms of variables, although this lies outside the scope of this research.

5.3 Finding factors

5.3.1 Methods for finding definition factors

The LoS framework starts with the stakeholder values in the value layer. These values were consequently clarified in the stakeholder analysis in chapter 4. What happens to be convenient is that MaT has experts working on the various values that were identified from chapter 4. It is no coincidence that the tasks are divided among the various values within MaT. From a professional point of view this makes assigning responsibilities more clear. Not only from a professional point of view it is convenient to split functions per value, but the same principle hold true for the LoS as well. Working on a single value at a time helps focussing on all factors that are relevant for that particular value. The factors identified then all contribute to this value.

Going from abstract values to asset properties and activity properties is difficult, if not impossible. Hence, the first step taken when all the values are mapped is that they need to be further defined. Defining values is important as values are abstract and ambiguous concepts that cannot be quantified and can come to mean many things to different people. Several methods were used for finding these value definitions. Below five methods are provided but they are surely not limited to these ones.

Method 1: Adopting from the existing PMS

The starting point was to use as many existing performance indicators. Some of the PI's were identified to be lagging indicators rather than leading indicators, they serve as good definitions as they are considered to be the last measurable element before turning to values. The definition factors serve as a check to see whether a value has been attained, as value themselves are often not quantifiable. Although no sound criteria can be provided for when something is said to be a lagging indicator,

typically performance indicators that can express the value of a stakeholder almost directly is a sign that the indicator is a lagging one.

Method 2: Consulting experts
Consulting an expert in particular area is a fast way to gain oversight in the scope definition of the particular value. The drawback however is that what the expert is not aware of is not included in the definition. If, for example, the programme manager of traveller's experience is unaware of the subjective safety feeling (which was absolutely not the case at MaT) then he or she will never define subjective safety feeling as a defining factor for traveller's experience.

Method 3: Organisational documents
Another fast way finding definition factors of using organisational documents. In many cases, important values such as availability have readily available definitions. Two problems are identified with this method however. The first is that documents may not be up to date and therefore have a limited scope. The second problem is identical when consulting experts, namely that the scope is not complete for some reasons because of lacking expertise. This method may coincide with method 1, as the PMS can also be regarded as an organisational document.

Method 4: External resources
Consulting external information resources is unique with respect to the former three as the information comes from outside the organisation. An advantage of this method is that it can identify scope where experts or documents within the organisation are unaware of. Simultaneously the pitfall may be that the scope of values is very specific and in this case consulting external information resources falls short. For instance, the availability for tram in Amsterdam is partly dependent on events in the city. This might be a peculiarity for Amsterdam specifically that typical literature about infrastructure availability does not cover.

Method 5: Regrouping
A last method of finding definition factors is rather a pragmatic one. What happened during building the LoS was that at times new definition factors were defined because many of the asset and/or activity factors together signalled that there was a need for a new definition factor.

It is recommended to use a mixture of all of the above methods. This way, none of the recognized disadvantages remain. Because of the limited time scope, this was however not done in all cases. In particular no external resources were consulted. This is acknowledged as a shortcoming in this research. The methods are summarized in Table 10.

Table 10: Methods for finding definition factors

Method	Advantage	Disadvantage
1. Adopting from existing PMS	• Efforts are already made in measuring this factor • Reflects current focus of organisation accurately	• Current performance measures may not be aligned with the organisational goals that are really important
2. Consulting experts	• Always up to date information • Fastest way of gaining overview	• Blind spots will not be noticed • What is considered to be true for one employee may not be true for the others
3. Organisational documents	• Often (but not always) consensus on the content of documents	• Documents may be outdated

4. External resources	• Includes factors that personnel is not aware of	• Context specific factors are not included
5. Regrouping	• Definition factors found this way are irrefutably needed as they are found by doing	• Are found on the run: cannot be thought of before hand

5.3.2 Finding definition factors for the Amsterdam context

As definition factors are harder to select because they are very case specific we could not create an universal method that always work for selecting them. Therefore a brief elaboration for some values is provided in order to give an idea of the rationale behind selecting the definition factors.

Availability

MaT defines availability through what they call 'the availability number'. Several factors are included in this performance index: the train frequency per hour over a certain trace, the speed of the train over this trace and the hours the trace is affected by this reduction in availability.

The formula for availability was as follow

$$A = f \cdot v \cdot d \cdot l \cdot t$$

Where

A	The availability number
f	Train frequency per hour
v	Train speed
d	Number of directions (either 1 or 2)
l	Length of track
t	Service hours of exploitation

There were two options in defining availability in this instance. The first one was on the basis of the left-hand side, while the other was on the basis of the right-hand side. The latter proved to be rather difficult as this would require a very detailed analysis of how each maintenance work impacts each of the variables on the right-hand side. Therefore it was, chosen to continue with the definition as used in the left-hand side, that is the availability number.

Although this availability number already is measurable, it is good to further break it down because there are numerous of factors that influence availability. Again several choices were possible. The first option was to break down the availability by the various segments in which the metro or tram network is divided. The metro is divided into traces while the tram network is divided into a grid like structure. This would require two separate lines of sight as the network layout varies for both of these infrastructure systems.

The second option was to create definition factors according to the categories of the complement of availability, that is non-availability. This turned out to be useful for two reasons. The first was that the availability for both metro and tram could be mapped into a single LoS. A difference in causes of non-availability for metro and tram can consequently be marked through colouring a factor as metro specific or tram specific, as was explained at in the previous section. The second reason is that the non-availability was already categorized and registered when calculating the actual availability.

Safety

Defining safety was done through using the existing performance indicators as much as possible as these sufficiently covered all types of possible safety incidents. The intrinsic factors are the lowest possible unit of measurement in the hierarchy of the MaT PMS and these were chosen as definition factors as these are clearly measurable. Safety was defined through the following intrinsic factors:

1. Amount of derailments and collisions resulting from poor infrastructure condition
2. Other safety incidents than derailments and collisions
3. Maintenance incidents

The first two relate to incidents that occur during operations, while the latter relates to incidents during maintenance. The remaining intrinsic factors were identified to be determinants (or leading indicators) of the definition factors and were therefore placed in the asset and activity layer. Lagging indicators are often more eligible to serve as a definition factor as they directly represent the values of stakeholders.

Cost efficiency

The term cost efficiency already hints at the fact that not the absolute costs are central, but the relative costs. The problem with scrutinizing absolute maintenance costs is that the maintenance backlog may vary over the course of time. When steering on absolute costs it is thus not fair to ignore the maintenance backlog as this gives a poor image of the reality. Therefore, it is more useful to steer on the relative costs. For materials and maintenance this boils down to unit prices.

Next to that, investigating cost deviations also provides insight in cost efficiency. The factors brought under this definition factor primarily relate to individual maintenance works that exceed their budgets. From an aggregate perspective the budget might be in check while budgets of individual maintenance works are structurally exceeded.

Finally, it is also important to investigate costs from a life cycle and system perspective; those are the Life Cycle Costs (LCC) and Total Cost of Ownership (TCO), respectively. The asset management policy of MaT states that they strive to make as much as possible investment decision on the basis of LCC and TCO analyses. Attaining one does not automatically guarantee the other. This is why they were chosen as separate definition factors.

Lessons learned

There are still a lot of choices to be made when conceiving definition factors. The researcher needs to think thoroughly about what choices there are to be made. Choosing the definition factors is perhaps more complex than choosing asset factors and activity factors because they need to suit the specific context. Some definition factors were all defined through a single method, as was the case with safety, while others, such as traveller's experience, were defined through various documents and an interview with the expert. Of course did experts agreed upon the definitions that were chosen if these were found outside the interviews with them. In this case study most of the definition factors were found through either consulting the experts or from the organisational documents.

5.3.3 Finding asset and activity factors

Unlike finding definition factors, finding the asset and activity factors is much more unstructured and is likely to result in several iterations, whereas definition factors were often found in a single search iteration. This process repeated itself typically with a maximum of three iterations as was discussed in section 5.1. The same methods as stated in Table 10 can be used to find asset and activity factors.

Because the number of asset and activity factors is more exhaustive than the definition factors, some tips and tools are provided to bring structure in the search for these factors. When trying to find asset and activity factors do not be too critical initially. It should be rather seen as a brainstorm session. In the next section guidelines are provided about what factors should be included or removed.

Generally speaking, finding activity factors was more difficult than asset factors in this case study. This is however a logical consequence because the case study was solely conducted at MaT. MaT is a management organisation that does not execute the maintenance themselves and therefore has limited knowledge on the maintenance process. Experts at MaT were in many instances aware of the shortcoming of assets or new innovative technologies that had yet to be introduced. Therefore finding assets factors was typically not a problem. The one-sided emphasis on asset factors in this research is recognized as a short coming. For a more complete overview of the LoS, multiple interviews with experts from the service provider would have been beneficial.

Finding factors with experts

The interviews with experts on particular values were rather unstructured. None of the interviews were recorded because there was no preparation in questions. It was found that conceiving questions beforehand proved to be rather difficult as there was no background information on the subject in many instances. Learning from the expert about the topic and then distilling the right factors was how the LoS was filled. This requires a great deal of attention and the ability for immediate improvisation. Nevertheless, it is hardly possible to create one LoS in a single interview session. What factors proved to be useful and what factors did not will be covered in the next section. The focus in this section is on identifying factors.

There was a strong reliance on the (partly filled) LoS framework. The building sessions centred around these templates. Typically before starting the interview most of the definition factors were found or at least some of them through organisational documents. Besides, some asset factors and activity factors were already placed in this template in order to illustrate the purpose behind the LoS to the interviewee.

The lines of sight are constituted of factors with relationships between them. In many cases the relationships are straightforward to understand and do not comprise some sophisticated, complex background; but they were numerous. The interviews were therefore very exhaustive and voluminous with much superficial information. This proved to be another reason why making up interview questions was pointless.

Nevertheless, this simplicity in the relationships made it comprehensive for people outside the field of MaT. This simultaneously proves to be the power of the LoS as it is a simple yet effective way of communicating the hypothesized causality between factors within and outside an organisation.

The preference was given to start off with much as possible asset factors, and then move towards activity factors. Once again it is stated that is very well possible to go directly from the definition factors towards the activity factors. To ‘kick start’ these building sessions the format of Table 11 was sometimes used. The right column ‘biggest influencers’ was filled by the particular expert through email before the interview. This way the expert was not burdened with making a differentiation between asset or activity factors.

Table 11: Format used to quickly find asset and activity factors

Definition factor	Biggest influencers
Ontsporingen botsingen verwijtbaar aan gebreken in de infrastructuur	1. Slijtage spoor
	2. Vuil in wissels
	3. Afwijkingen ten opzichte van de gestelde eisen, dit kan zowel de spoorstaaf zijn, als de wissels, als de verharding tussen de sporen.
	4. Meest voorkomend: groefrails, hartstukken en niet aanliggen van de wisseltongen
Ongelukken anders dan ontsporingen en botsingen	1. Uitglijden op perron
	2. Bovenleiding niet op gewenste hoogte (geregeld door defecten aan ophanging of kapottrekken door derden)
	3. Onjuist seinbeeld van het beveiligingsysteem (1x in de afgelopen 3 jaar)
	4. Een storing in een beveiligingsysteem is zeer waarschijnlijk niet van invloed op de veiligheid aangezien dit soort systemen 'fail-safe' zijn. Bij falen komen ze in een veilige toestand. In de afgelopen 3 jaar is het eenmalig voorgekomen dat er een onjuist seinbeeld kon worden getoond tijdens de reset van een verstoring, dit heeft ook tot een incident kunnen leiden doordat de trambestuurder niet de gegeven opdracht heeft uitgevoerd (behandel het betreffende sein als stoptonend, onafhankelijk van de getoonde status)
Ongelukken in onderhoud	1. Foutieve uitvoering
	2. Foutief gebruik van gereedschap
	3. Aantal meldingen niet naleving van het veiligheidsmanagement programma
	4. -

Below an elaboration follows of how two tools, that are typically present within asset intensive organisations, can be used to quickly identify asset and activity factors.

Bowtie method

In the case when asset factors are related with events such as disruptions or malfunctions, the bowtie method proves to be useful in searching for the causes of these events. These causes can consequently be included as factors. The bowtie method places events central. Events can be triggered by threats. Once triggered, these events will have several consequences. The bowtie principle is illustrated in Figure 18.

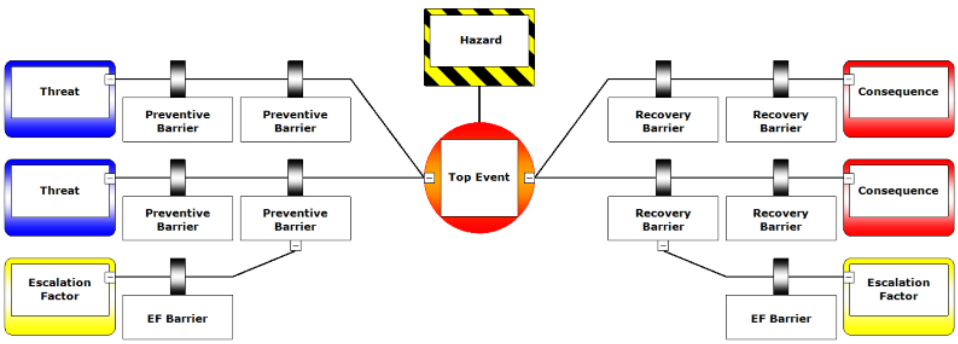


Figure 18: The bowtie method visualized (courtesy of CGE Risk Management Solutions)

These consequences can be adopted as an asset factor within the asset layer. Threats are probabilistic and the chance of occurrence can be decreased through so called preventive barriers.

The consequences of events can be affected by recovery barriers that may completely remove or alleviate the consequences. These preventive and recovery barriers can be adopted as either asset or activity factors. Although this method is useful, it was only discovered halfway through. Impacts of events in the form of disruptions or safety incidents are well suited for such analyses.

A more elaborate variant of the bowtie method is a Failure Mode and Effects Analysis (FMEA). Even more refined techniques are those of Fault Tree Analysis (FTA). The LoS can thus incorporate information of existing documents. The intention should not be, however, to embed an entire FMEA into the LoS. The LoS should embed the most problematic events where improvement efforts should consequently focus on. What is considered to be problematic and should deserve attention through improvement efforts can be done in consultation with experts. Ideally this should be based on quantitative data.

In the case study of MaT no risk analysis methods were available except a document that registered the most frequent causes of technical disruptions. It did not provide any further clarification on what components were problematic.

Work break down structure

In project management, objectives and deliverables that have to be attained are broken down into well-defined work activities with the help of a Work Breakdown Structure as is shown in Figure 19. Similarly, an infrastructure system can also be thought of as a deliverable that can be cut up into pieces of work called work packages.

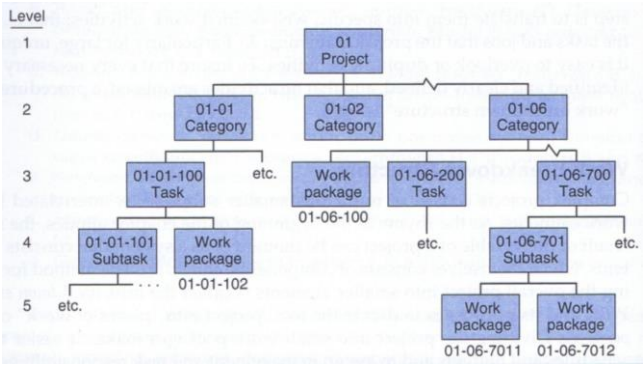


Figure 19: Schematic view of a work breakdown structure (Nicholas & Steyn, 2017)

The infrastructure system can be broken down into subsystems (rail, electrical, station, etc.) that in turn consist of components. Each of these components needs a specialised maintenance plan. These plans in turn consist of various work packages. These are the lowest distinguishable actions that can be performed in terms of maintenance. It are consequently these work packages that can be monitored in terms of time and costs, for instance. This way, the contribution of maintenance to the stakeholder values of availability and cost efficiency can be mapped. Ironically enough, the work breakdown structure already shows strong similarities with a LoS. Nevertheless it is not the meaning to adopt an entire work breakdown structure into the LoS. Once again, just as in the case with adopting from the FMEA, the most strategic elements should be selected where there is the most room for improvement.

It can be seen that the LoS can make use of various documents an organisation typically already has in place. In this research, the strongest reliance was nevertheless found to be on the expertise of the MaT personnel.

5.4 Selecting and placing factors

Finding factors is one thing, but sensibly selecting what factor should be included in the LoS and in what layer they should be placed is another step. For this purpose, several design guidelines have been developed. The method of finding these design guidelines was briefly elaborated at the beginning of this chapter. The necessity of these guidelines came to the front when filling the LoS frameworks with factors. Sometimes a clash occurred that urged the need for a guideline that was generally applicable for all the existing factors that were already placed in the lines of sight. In the coming subsections each of these guidelines will be elaborated.

5.4.1 Asset or activity factor

Perhaps the most prevalent hesitation that arises when filling the LoS framework is whether something should be considered to be an asset or an activity factor. To better illustrate this several examples are provided.

- Slipping (related to activity) or icing on the platforms (related to assets)
- Persons on the railway: the action is performed by persons, but the condition of the railway can be considered to be blocked
- Emission of particles: the particles are emitted by the infrastructure (for instance copper particles from the overhead lines), but this is caused by exploitation
- Sufficing to output specifications: the output specifications prescribe a certain asset condition but the process of sufficing to them is an activity

As these factors can be an asset factor or an activity factor the following rule was decided:

The factor should preferably always be placed as high as possible within the LoS framework.

The reason for this is demonstrated through an example. When the factor ‘persons on the railway’ is selected to be an activity factor, and one argues that placing a fence around the railway track should prevent this from happening, this fence then happens to be an asset factor. The causality in the framework is then lost, because the order then becomes: definition factor, activity factor and finally an asset factor. Reformulating the factor in such a way that it describes a blocked condition of the railway can make it fit as an asset factor. This is illustrated in Figure 20. Here we see the causality of the LoS framework is retained as the order now becomes: definition factor, asset factor, and finally an asset factor – this fence measure is then placed in the second asset layer of the framework. This example shows that the ambiguous factor can now still be influenced by yet another asset factor, while still fitting in the causality of the LoS framework.

Definition factor		Activity factor		Asset factor
Exogenous disruptions	→	Persons walking on railway	→	Absence of fence

Definition factor		Asset factor		Asset factor
Exogenous disruptions	→	Railway blocked due to persons walking on track	→	Absence of fence

Figure 20: The 'persons on the railway' example elaborated. In the above example the wrong causality is presented, and in the lower example the causality of the LoS framework is respected.

This principle works for the other cases where it is not clear at first sight whether the factor should belong to the asset or the activity layer. If we choose icing on the platforms (thus choose it to be an asset factor and not an activity factor), it can be influenced by yet another asset factor, namely a slide gradient of the station platforms for drainage. Of course, these factors that are selected to be asset factors can in turn also be influenced by activity factors.

Temporary versus permanent measures
Sometimes physical measures can be taken that have a temporary effect. An example of which are noise barriers. For certain maintenance work, temporary noise barriers can be set up. In other occasions permanent noise barriers are placed to counter the noise produced by operations of the carrier. For such cases the following guideline is provided:

> *Temporary measures that for the purposes of temporary activities such as maintenance are considered to be activity factor, whereas permanent measures are considered to be asset factors.*

5.4.2 The right causality

Another frequent problem encountered was defining the causality in accordance with the structure of the LoS framework. Sometimes the initial causality one conceives does not fit the LoS framework. The consequences of postponement of maintenance are used to illustrate this problem. In Figure 21 two causal chains are depicted. The upper chain was directly adopted from an interview about how cost deviations come about. To save costs on the short run, Type-B maintenance (replacement and renovation maintenance) is postponed. The postponement of Type-B maintenance leads to assets that are in a worse condition and that will show more defects. This increase in defects needs to be compensated with more Type-A maintenance that in turn leads to higher costs. The problem however is that the postponement of maintenance comes before the increased maintenance needs of the asset. The order of factors then becomes: definition factor, activity factor, asset factor and is eventually concluded with an activity factor.

The causality can also be reversed to make it fit within the LoS. Why do we have cost deviations? Because assets have an increased Type-A maintenance need. Why is this the case? Because the Type-B maintenance was postponed. This way of reasoning is depicted as the lower causal chain in Figure 21. The additional cost of the Type-A maintenance are now included in the definition factor ‘cost deviations’. In this example the additional costs from the increase in Type-A maintenance is brought under the costs deviations definition factor.

Definition factor		Activity factor		Asset factor		Activity factor
Cost deviation	→	Postponed Type-B maintenance	→	Increased Type-A maintenance need	→	Additional costs Type-A maintenance

Definition factor		Asset factor		Activity factor
Cost deviation	→	Increased Type-A maintenance need	→	Postponed Type-B maintenance

Figure 21: An example of how a causality can be fitted with that of the LoS framework. Above is the causality as directly adopted from the interview, below the causality is made fit conform the LoS framework

The rule provided is that:

The causal order of the LoS framework must always be retained.

This is done for two reasons. The first is that the functions of the assets and the activities remain clear this way. In many cases it are the assets that somehow fulfil, or influence negatively depending on their conditions, the values of stakeholders. In turn, it are the activities that keep the assets in good condition, or could actually harm the assets. When asset factors and activity factors run through each other the linkage with the stakeholder values easily gets lost. The second reason is one of comprehensibility. Just as Kaplan and Norton (2000) argue that their strategy map is a tool for communicating strategy, we argue that the LoS is a tool to inform management and other stakeholders in a concise and consistent matter on the levers there are to be pulled when it comes to influencing stakeholders values.

5.4.3 What to include and what not?

Not all factors which are ought to be of significant influence, are sensible to include in the LoS. While drawing up the lines of sight it was found that two categories exist when it comes to the output of variables by which a decision can be made on the inclusion of factors in the LoS. The first is whether the performance or the 'variable value' of a factor is fixed or may vary over time (on the long run), after it had been achieved according to the goals or norm set. The second category is whether the goal or norm of something is attained in the first place. It is not these categories on themselves, but the combination of them that determine whether factors are useful to adopt in the LoS.

Generally speaking, it is not sensible to include factors for which their performances are according to the goals set and remain so. For example, dynamic traveller's information is a factor that is identified to contribute to traveller's comfort. Metro platforms and the tram stops are already provided with dynamic traveller's information and it is not likely that this service will vary over the course of the years. This is an example of goal that has been attained and for which the performance is fixed.

For at least the factors for which the performance can vary over time it is useful to adopt them in the LoS; for both the factors that are performing according to the set goals and those that do not. Not only those which are performing badly now, because those who perform well today, may not perform well tomorrow. If for instance the entry gap between the platforms and the wagons is sufficient this year, it may be insufficient for the next years.

Finally, there are factors that are not yet completed, but for which their performance is fixed once completed. MaT also desires that dynamic traveller's information is available in the metro stations halls, not only the platform. This can be then included as factor for which the performance is not yet attained, but once attained it is fixed.

In Table 12 a matrix is provided that advises whether to include factors in the LoS or not.

Table 12: Criteria for adopting a factor into the LoS

	Performance fixed	Performance may vary
Goal completed	Do not include	Include
Goal not completed	Include	Include

5.4.4 Setting the scope through the width and depth

The width in a LoS is primarily applied through the number of definition factors that are selected. The depth, on the other hand, is applied through the number of asset and activity layers.

In the case of MaT two layers of each of these was found to be workable. More than one asset layer proved to be useful for several reasons. The first is that an asset factor this way can be influenced by yet another asset factor. In the above example of a blocked railway due to persons walking on the track can be influenced through another asset factor by placing a fence, for instance. A second reason for two asset layers can be clustering. This greatly enhances the readability of the LoS. For instance, several measures can enhance the reachability of a metro station: kiss and ride parking spots, bicycle parking, park and ride, and so on. All of these are examples of 'before and after transport' facilities. When brought under the factor 'before and after transport facilities' they can be clustered. This clustering is displayed in Figure 22.

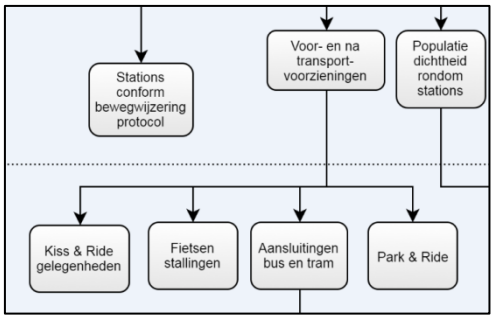


Figure 22: Example of clustering

On the other hand, when there is too much detail in the LoS, by bringing in too much layers, the LoS can become too complex and comprehensibility is lost; discouraging the further use of it. Through trial and error it was found that two layers for both the assets and activities worked good in attaining the right level of detail. It is expected that the danger of feeling the need to fill all layers might arise when too much layers introduced. This was already found to be case with two asset and activity layers in the exercise of drawing the LoS, but is even more likely to occur with three layers. When the LoS template looks blank this might urge a designer to fill it with needless factors that hardly contribute or where there effective causality is uncertain, in other words: does the factor truly influence?

Despite having chosen for two asset layers and two activity layers, the framework might need some adjustment. Especially the activities are more complex than is often portrayed in the developed lines of sight. It was not possible to scrutinize GVB Rail Services in this research and this is recognized as a limitation. The maintenance work performed by the service provider is what requires more sophisticated analysis in order to discover levers for improvement.

The width of a LoS is primarily determined by the amount of definition factors that are chosen. Here there is less choice for the designer of a LoS because the amount of definitions factors are often a given. Of course, an organisation can have a particular focus in attaining a particular stakeholder value. For instance, the CO_2 footprint of the organisational activities can be reduced through smarter energy management as part of the organisational strategy because this is cheaper per unit of reduced CO_2 output than investing in smarter waste management. Nevertheless it is wise to include the definition factors that are not part of the focus in the strategy initially as in future scenarios these definitions might become interesting.

Arguably, an additional improvement layer would also be recommendable in the case the improvements consist of large programmes like the safety management system that is used in the Amsterdam light rail casus. The safety programme can then be split up in several layers, the upper layers containing the most concrete changes that influence either the asset properties or the assets properties, and the lower improvement layers contains the clusters of improvement measures.

5.4.5 Aggregation or detailing

The LoS is meant as a management tool to gain a general overview. Another question is what level of detail to apply when choosing factors, considering the fact that the LoS should be a tool for overview.

Some factors have a wide variety of factors that can influence them. When detailing, it is wise to select the factors that are the most influential and provide room for improvement in order to keep the LoS comprehensible. For example, when looking at the endogenous malfunctions (technical malfunctions) it was chosen to include the malfunctions in the LoS that cause the most non-availability. To this end, it is necessary to have data on these kinds of failure patterns. In the case of endogenous malfunctions, there was easily identified a top three. But for other factors there is much more dispersion: there are a lot of factors that influence them. Let us say that in extreme scenario factor A is influenced by factors B until U that all have a share of 5% in terms of influence with respect to A; then which of these factors to include? Luckily, situations like these are exceptionally rare, but if this is the case this might hint at the fact that a separate LoS can be created just for factor A, also depending on how important factor A is in relation to the stakeholder value it belongs to.

The function repair time is chosen to be an aggregated factor, while it actually has a strong dispersion of influential factors. It requires a more thorough analysis of experts in the field of maintenance to analyse what the influencers of the function repair time are. Logically, this depends on many questions, like ‘what is the subsystem that is malfunctioning?’ and ‘what component caused this malfunction?’ Also one could question what repairs are worthwhile improving – some components are quickly fixed so little improvement is to be gained. The point here is that there are perhaps hundreds of combinations possible of subsystems having components that each ask for a different improvement actions as to improve the function repair time It would be senseless to try to fit all of these specialised improvement actions into the LoS of availability. A more strategical selection of factors is therefore desired. Two options exist: pick the components in subsystems that cause the most unavailability: a method that was already advocated in the identification of factors through analysing risk analysis document such as FMEA, or find common factors that all of the corrective repair actions have like for instance the response time. This latter matter was chosen although no further analysis was performed.

Similarly the work breakdown structure of maintenance could be analysed to see what maintenance activities are time consuming and are suitable for possible optimization, as it would not be sensible to include every maintenance action performed. Again, a strategical selection has to be made from the maintenance actions leave room for improvement. This is best done in consultation with the expert on that area. In the case study of the Amsterdam light rail there was however no possibility to scrutinize the service provider on his maintenance activities.

Nevertheless we argue that as a general rule to apply enough detail, while maintaining oversight we suggest:

> *Select the top 3 most influential factors. If the dispersion of influential factors is large then this might hint at the fact that the designer might opt for a separate LoS for just this factor, depending on how important this factor is in the first place.*

5.5 Validating a line of sight

5.5.1 Objectives of validation

Validating the LoS serves two objectives. The first is testing the correctness of the assumed causalities between the factors. The second is the scope of LoS. Although distinguishable, they are, however, interrelated. Not only can there be dissension about the topics that need to be included in a LoS, but also about the hypothesized causal relationships that might exist between factors that have not yet been proven significant by data. If one person believes a hypothesized relationship to be insignificant, he is not likely to include it in the LoS and therewith also changes the scope of the LoS.

The first objective of validation is to test the hypothesized relationships between factors. As these causal chains lean largely on tacit knowledge that is in the heads of the personnel, later adjustments to the lines of sight are certainly possible. The causal chains should not be taken for granted and validation should be sought. To this end, it is recommended to scrutinize the hypothesized relationships with the help of data analysis. Reversely, relationships between factors that have always been assumed to be there, that Arthur et al. (2016) refer to as “sacred cow” relationships, might be challenged. This is likely to result in an incremental approach to designing a LoS that is brought about due to a change in consensus or new insights from data analysis.

The second objective of validation lies within the scope of the LoS, in other words: when is the LoS finished? The scope can be defined in both the depth (the amount of layers) and the width (the amount of factors). It would be naïve to think that the LoS can capture the entire asset management situation of an organisation. We already saw this when identifying the stakeholder values and selecting factors: the values and factors within the LoS must deal with the technical aspects only but the issues that were not included certainly can pertain to asset management. When it comes to the scope of the LoS, the validation becomes much more subjective. The LoS is said be finished in terms of scope when all the involved parties agree on whether it is deemed fit for the intended purpose. What this purpose may be varies for its application and context. Scenarios might also arise where a factor is found to be influential but cannot be influenced by the organisation. It is up to the organisation whether to include such a factor to the LoS as it might be a good explainer for performances or ways can be sought to gain influence in the future.

5.5.2 Methods of validation

As there are two objectives of validation, we identified two methods for validation. The first is considered to be quick and simple, but less reliable, namely workshop validation. The developed lines of sight can be checked in a group meeting with the stakeholders that are relevant for that particular value. How these workshops are organized is dependent on the application and context we argue. If the LoS is used for policy and strategy formulation it would be wise to let the management team (that formulates the policy and strategy) and the particular expert on a value come to an agreement on the design of the LoS. Such a process could be facilitated by the designer of the LoS. The expert inputs his ideas of how he or she thinks the causal chains pertain to reality. The management team can then look what factors can be identified as strategical levers that offer room for improvement. The management team provides purpose, the expert provides context. Other relevant external stakeholder might also be invited in the development of the LoS as they hold different views of how real world mechanisms operate than what the expert believes. Of course, building the LoS directly with all of the relevant stakeholders forms an immediate check, but as building a LoS can be a time consuming process that sometimes takes multiple iterations it can be difficult to organize one or multiple workshops where a lot of stakeholders have to be present at once. This validation can both check the

correctness of the assumed causalities and determine the scope, although we argue this validation method is better for the latter.

The second method, we already discussed, is done through data analysis. This method can be considered the most objective. The downside is that the desired data is not always present and colleting it might be costly. Data analysis might prove or disprove assumed causalities or even highlight new causalities. Similarly to the previous validation method, data analysis also fulfils both validation objectives, although the accent is on testing the correctness of the causalities rather than defining the scope. Like stated before, if some assumed causalities prove to be false or correct eventually, this also changes the scope as a consequence because factors are either omitted or included in the LoS.

Because of limitations in time it was not possible to validate the developed lines of sight of MaT through any of the above validation methods.

The third sub research question is then answered as follows:

> *Sub research question 3: How to fill a LoS framework?*
>
> - For the identification of factors several methods have been presented.
> - Factors also need to qualify to certain criteria just as the stakeholder interests needed to qualify to certain criteria.
> - Additionally guidelines are provided that help streamlining the design process. This way, the LoS framework is filled in a consistent matter; primarily the choice whether something is an asset or an activity factor proved to be troublesome at times.
> - Filling a LoS is recognized to be a rather unstructured process that takes places in several iterations.
> - Validating the developed lines of sight can be on the basis of workshops with various parties or through data analysis.

5.6 Reflection on the developed lines of sight

The made lines of sight for MaT can be found in Appendix C. In this section some reflection is provided on the developed lines of sight. Although they have been developed for the MaT organisation we believe some generic lessons are to be learned upon reflection. The lines of sight were also made as a practical exercise to see whether the framework is sensible. Although at times it was not clear how to select or place factors, it was generally found to be an intuitive framework that appealed to the interviewers and which they thought of as logical.

Incomplete lines of sight
The developed lines of sight are considered to be incomplete for two reasons. The first is that the service provider (GVB Railservices) could not be interviewed in the process of developing the actual lines of sight. We suspected that there might be a need for more than just two activity layers as the maintenance processes, that are contained within these layers, can be broken down in a variety of work packages that each potentially show room for improvement. Moreover, it could be that new

problems might occur in placing activity factors that would be typical for just these activity layers and hence call for additional guidelines.

Secondly, there was a limited source of documents. In this chapter we discussed the potential use of Failure Mode and Effect Analyses and Fault Tree Analyses for mapping the root causes of the most prevalent technical disruptions. These were however not available. Especially the values of availability and safety suffered from this absence of documents and the inclusion of the service provider in developing the LoS.

Collaboration

In the LoS of traveller's experience collaboration was identified as an important activity factor that contributed to asset factors albeit not in a direct matter. What proves to be problematic is that collaboration cannot be further specified nor can it be measured; often these two go hand in hand. Factually speaking collaboration does not relate to the technical aspects; although the outcome of collaboration can affect the technical aspects the process of collaboration is not technical as it does not directly influence an asset such as maintenance and exploitation do. Nevertheless, we feel that collaboration is a significant factor that needs further attention. Therefore we will pay attention to collaboration in the remainder of this research and discuss how it potentially could be included in the LoS.

Cross connections

Incidentally connections between factors were encountered that were deemed significant but that did not run across the LoS framework in a vertical matter, but that influenced factors in the same layer in the same LoS or between two lines of sight. We refer to these connections as cross connections.

For instance, in the sustainability LoS a definition factor helped contribute to another definition factor. When the movement of a factor in the desired direction helps another factor to also move in the desired direction we refer to this as a univocal influence. There were also factors that cross connected but had an ambivalent influence: they had a positive influence on one factor as they increased and simultaneously a negative influence another factor when they increased. This essentially is sub optimization.

On the basis of the above we can make a matrix with two categories: (i) cross connections within the same LoS and cross connections between two or more lines of sight and (ii) cross connections with an univocal influence or an ambivalent influence. In Table 13 an overview of the possible combinations is shown and whether these combinations pose to be problematic. In Figure 23 a visual overview of the various cross connection that exist is presented. The letters in Figure 23 correspond with those in Table 13. One particular type of cross connection proves to be problematic, namely the combination of cross connections that run between two lines of sight and that have an ambivalent influence. This cross connection is labelled with the letter B.

Table 13: Various type of cross connections; the letters behind each cross connection corresponds with those in Figure 23.

	Univocal influence	Ambivalent influence
Within same LoS	Not problematic (D)	Not problematic (A)
Across LoS	Not problematic (C)	Problematic (B)

The cross connection of type A, C and D are considered to be not problematic. The univocal influences move the factor that is 'side-effected' also in the desired direction. Ambivalent cross

connections within the same LoS have less risks of sub optimization because the factors are visually close to one another: they are in the same LoS and in the same layer. Only the cross connections that have an undesired effect on a factor in another LoS (labelled as B) cannot be displayed in such a matter that it becomes apparent for someone who reads the LoS that there is a danger of sub optimization. In later chapters of this research we will readdress the issue of cross connections.

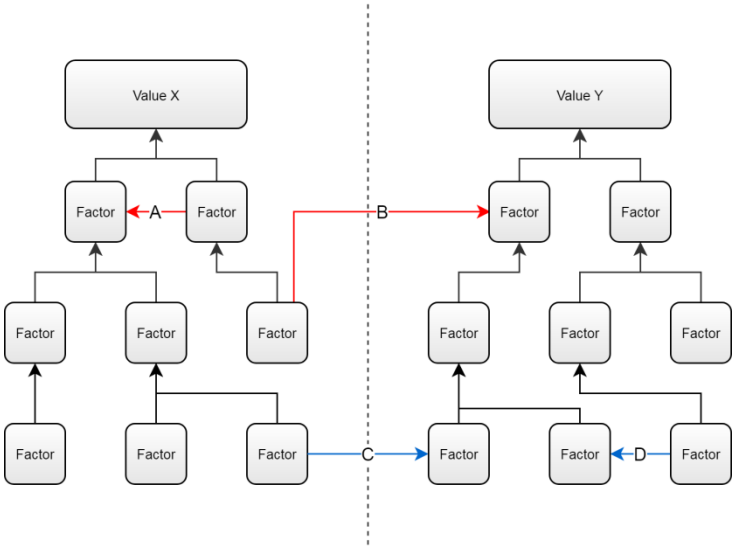


Figure 23: The various types of cross connections visually displayed in two simplified lines of sight.

Accent on asset or activity factors

Some lines of sight had a specific accent on either asset or activity factors. The LoS on availability had a strong emphasis on activity factors as availability is majorly affected by maintenance works. It must be noted that the LoS on availability was however incomplete because of the lacking risk analysis documents and the inability to scrutinize the service provider. The lines of sight on sustainability and traveller's experience on the other hand leaned strongly on asset factors that related to properties of the metro stations or tram stops. It is not known whether the accent of asset factors or activity factors is a peculiarity of the specific stakeholder value, or whether the development of the particular LoS was incomplete.

Further evaluation

The evaluation that is performed in the coming chapter is considered to be purely technical and not naturalistic. The developed lines of sight are not further used in the research for evaluation purposes because they are considered to be insufficiently complete as the service provider was not involved in the development of the lines of sight. Although the naturalistic evaluation is considered to be more useful, the evaluation self is much more costly in time and scope. This could not be fitted within the timeframe of this research. The exercise of actually developing the lines of sight for MaT has been to demonstrate the usability of the framework: to show that the framework can establish a connection with stakeholder values, assets and the activities surrounding those assets. We argue that the framework is intuitive to work with and can easily be understood by outsiders.

6 Policy and strategy

As part of the evaluation of the LoS framework a comparison is done between the framework and the PAS55 planning system, and between the LoS framework and the MaT policy and strategy documents. The goal of both evaluations is to predict the usefulness of the LoS framework in relation to the formulation of policy and strategy. We deliberately compare the LoS framework with the PAS55 planning system, as it is this system that is said to incorporate a LoS into the policy and strategy documents that are part of the planning system. Besides, a comparison was chosen with the MaT policy and strategy documents as well in order to make the comparison more naturalistic. Therefore the sub research questions 4 and 5 are both addressed in this chapter. The PAS55 planning system and the MaT policy and strategy are compared with the so called building blocks that are considered to be the essential elements that establish a LoS. Policy and strategy were found to be ambiguous concepts that have a variety of definitions. For this purpose, we start of this chapter by examining the definitions of policy and strategy.

6.1 The definition of policy and strategy

6.1.1 Policy

The word policy is handled with great variety. Trying to define policy proves to be rather difficult as many definitions circulate in both academic literature and documents released by governmental, non-governmental organisations and businesses. In the field of public policy a consensus lacks among scholars on the definition of public policy (Birkland, 2014). In Table 14 below various definitions of (public) policy are provided.

Table 14: Various definitions of (public) policy

Definition	Source
Policy: The basic principles by which a government is guided	Business dictionary[3]
Principles (in relation to the above definition): Fundamental norms, rules or values that represent what is desirable and positive for a person, group, organization, or community, and help it in determining the rightfulness or wrongfulness of its actions.	Business dictionary[4]
Public policy: "The term public policy always refers to the actions of government and the intentions that determine those actions."	(Cochran, Mayer, Carr, Cayer, & McKenzie, 2015)
Public policy: "… public policy seeks to achieve a desired goal that is considered to be in the best interest of all members of society."	(Torjman, 2005)
Public policy: "Whatever governments choose to do or not to do"	(Dye, 1995)
Policy: "… we can provisionally define a policy as a set of decisions which are oriented	(Sandford, 1985)

[3] http://www.businessdictionary.com/definition/policy.html
[4] http://www.businessdictionary.com/definition/principles.html

towards a long-term purpose or to a particular problem."	
Policy: "I define a policy as a statement by government – at whatever level – of what it intends to do about a public problem"	(Birkland, 2014)

We see that several elements come to the front in these definitions: principles, actions, intentions, goals, things one can do, decisions and problems. Generally speaking three generic elements can be distilled from these definitions, namely interests (principles), goals (objectives) and means (actions, decisions). Objectives fulfil interests through certain means. This terminology coincides with that of De Haan and De Heer (2012). Interests are the most general form of a goal of an actor that usually is too abstract to serve as a basis for criteria – in other words it is non-measurable (De Haan & De Heer, 2012). The interest is always present regardless whether there is a perceived problem. We speak of policy problem if (Enserink et al., 2010):

1. There is a gap between an existing or an expected situation and the desired situation; the desired situation serves the interest
2. There is a dilemma: there are one or more solutions at hand, but it is not readily apparent how best to proceed

Goals and means can easily get mixed up. Some means serve goals that are in turn means for a higher goal. This way of thinking is also used in the lines of sight.

What all of these policy definitions have at least in common is that they represent the interests of stakeholders and the goals set in order to eliminate or alleviate problems that harm their interests. What should be consequently done about these problems, or how they should be solved is where a distinction is made. Some policy definitions strictly focus on these how questions. For this purpose, we will also investigate the definition of strategy as to see where there is overlap and where a clear distinction can be made.

Next to stakeholder requirements, a policy document often states the legal and regulatory requirements. For the specific context of MaT this is placed outside the scope of this research.

6.1.2 Strategy

Strategy is also a concept that leaves much room for interpretation. On a general level, when practising executives are asked how they would define strategy they said "how I could achieve my company's objectives" (Markides, 2004). Although this seems to be a technically correct definition of strategy this still leaves many questions, like, 'what elements are relevant for a good strategy?' Much of the literature on strategy stems from business sciences, and therefore deals with questions on how to attain better customer satisfaction and improve costs structures. It is amongst others about the question how a company can distinguish itself from its competitors through product differentiation. Arguably the customer can said to be the second most important stakeholder after the shareholders for commercial organisations. A much more elaborate definition of (corporate) strategy is provided by Andrews (1971):

> *[…] is the pattern of decisions in a company that determines and reveals its objectives, purposes or goals, produces the principal policies and plans for achieving those goals, and defines the range of business the company is to pursue, the kind of economic and non-economic contribution it intends to make to its shareholders, employees, customers and communities.*

Here strategy is portrayed as the connection between the high level objectives and the plans for achieving these objectives. Simultaneously, the scope of activities by which the goals are achieved is determined within the strategy. Still this proves to be a woolly definition. Nickols (2012) effectively complements the definition of strategy as:

> *[…] the bridge between policy or high-order goals on the one hand and tactics or concrete actions on the other. Strategy and tactics together straddle the gap between ends and means.*

Moreover, Nickols (2012) states that:

> *Strategy, then, has no existence apart from the ends sought. It is a general framework that provides guidance for action to be taken and, at the same time, is shaped by the actions taken. This means that the necessary precondition for formulation strategy is a clear and widespread understand of the ends to be obtained. Without these ends in view, action is purely tactical and can quickly degeneration nothing more than a flailing about.*

In sum, the strategy is not specifically the actions to be taken, but can be rather seen as a general framework that provides guidance for the actions to be taken. Inevitably strategy deals with the 'how' question, but on more abstract level; describing high level principles that are fulfilled through concrete actions. Kaplan and Norton (1996a) defined strategy as a set of hypotheses about cause and effect. If viewed this way, strategy can be seen as the linkage of causes and effects that connects means and ends. Indisputably, strategy is always related to the 'how' question. The definitions of policy and strategy are thus intertwined at times. This 'how question' is answered by several scholars or governmental organisations in their policy documents as was noted in the previous subsection. Including a strategy inside the policy document is just a mere choice of preference or tradition.

6.2 The line of sight in PAS55

Sub research question 4 seeks the comparison between the LoS framework and the professional literature, which is in this case the PAS55 standard. This comparison with the PAS55 standard is considered to be an evaluation on the applicability of the LoS framework with regard to policy and strategy formulation. It was the PAS55 standard after all that states that its planning system provides a LoS and it consists primarily out of a policy and strategy document. The PAS55 standard and the newer ISO55000 standard are to date the only documents that provide handles on how to establish a LoS in professional literature. The LoS framework is built up of certain building blocks – not to be confused with the factors – that are deemed essential for the connection between the stakeholder values, through a causal chain of technical aspects, that can consequently be influenced by improvements. It is compared to what extent these building blocks appear in the PAS55 standard.

An elaborate analysis of the PAS55 planning system with its various objects is included in Appendix A. In the remainder of this section we will discuss the discrepancies between the PAS55 planning system and the LoS framework.

In the previous section it was discussed how within the research field of policy and strategy no consensus prevails on what precisely defines policy and strategy. This seems to be a reoccurring issue within the PAS55 as the separation between policy and strategy is not always evident. The policy and strategy used in the PAS55 planning system were found to be ambiguously defined and intertwined, but ironically enough the objectives were separated from both the policy and strategy

documents on the other hand. Objectives are often considered to be part of the policy document according to some of the above definitions.

The following problems were identified with the asset management policy definition:

- The asset management policy is redundant with respect to the organizational strategic plan (OSP). Typically policy defines stakeholder goals: it answers what a company is striving for. As this is already covered in the OSP the meaning of the asset management policy becomes void.
- What consequently happens is that the PAS55 is very evasive in defining what should be in the asset management policy. It describes various uses (a means of communication, a framework, etc.) of the asset management policy without precisely defining what should be in it.
- At times it encourages to answer the how question. This should be covered in the strategy document.
- It does not explicitly define stakeholder values. This can be come problematic when making strategy.

Because of the overlap that exists with the Organizational Strategic Plan and the asset management policy, the policy document's definition becomes ambiguous and redundant with respect to other documents. PAS55 states that the stakeholder expectations within the policy document should be derived from the Organizational Strategic Plan. The asset management policy then becomes a duplicate of the Organizational Strategic Plan. Moreover, the PAS55 standard does not give further instructions on how to find these expectations.

The strategy document was found to be in line with the definition found in literature. A problem that might be foreseen, however, is the role that is left for the asset management strategy, as the PAS55 encourages answering the 'how' question in the policy document. The strategy document however does not force the policy makers to make an explicit link with the assets or the day-to-day activities surrounding these assets. It states that high level mechanisms by which organisational objectives are attained should be adopted, but does not provide any further clarification on what these mechanisms are and what they should qualify to.

In the LoS framework factors – that become objectives when norms are set for them – are present throughout all layers, not just the definition layers. Definition factors are directly related to the stakeholder interests. In order to attain these objectives that fit within the definition layers, goals need to be set for the other layers as well. Furthermore it is argued that objectives do not contribute to the LoS. Instead, they rather serve as a check to see to what extent the policy and strategy have been achieved.

In Table 15 below a comparison is done between the building blocks of the LoS framework and the PAS55 planning system. The building blocks are the basic elements that essentially make up the LoS framework. In the table we compare the building blocks with the occurrence of these building blocks in the PAS55 planning system.

Table 15: Comparison between the building block of the LoS and the occurrence of these in the PAS55 planning system

Building block LoS framework	Occurrence in PAS55
1. Stakeholder value as starting point	The asset management policy should be based on the OSP which in turn is based amongst others on the stakeholder expectations. The asset management policy should be consistent with the objectives from the OSP, but does specifically state to take the stakeholder expectations as a starting point
2. Definition of stakeholder values	Logically, as there is no strong emphasis on stakeholder expectations, there is no definition of stakeholder expectations.
3. Causal chains through technical aspects	The PAS55 states that the asset management strategy should describe the high level mechanisms by which organizational objectives are attained, it does not encourages to describe the technical aspects that make up these mechanisms.
4. Improvement actions that connect to technical aspects	The strategy should make reference to improvement programmes, but does not further specify what these programmes comprise or what they should qualify to. An important aspect of the improvement of the LoS framework is that they connect with one of the factors in the causal chain of technical aspects. This is not the case with the PAS55 standard.

In Figure 24 an overview is presented of the PAS5 planning system in relation to the LoS framework. We see that the PAS55 elements do not strictly follow a specific order when coupled to the elements in the LoS framework. From this figure however it is not evident that the PAS55 struggles with definition issues.

Because of this definition ambiguity that starts in the policy document and consequently impacts the strategy, the wrong order of elements we raise questions whether following the PAS55 planning system leads to the desired LoS. On the other hand, for the LoS framework clear definitions and requirements can be set. PAS55 does not seem to present an unambiguous and structured manner that leads to a clear connection between the stakeholder interests and the day-to-day activities as the standard intends.

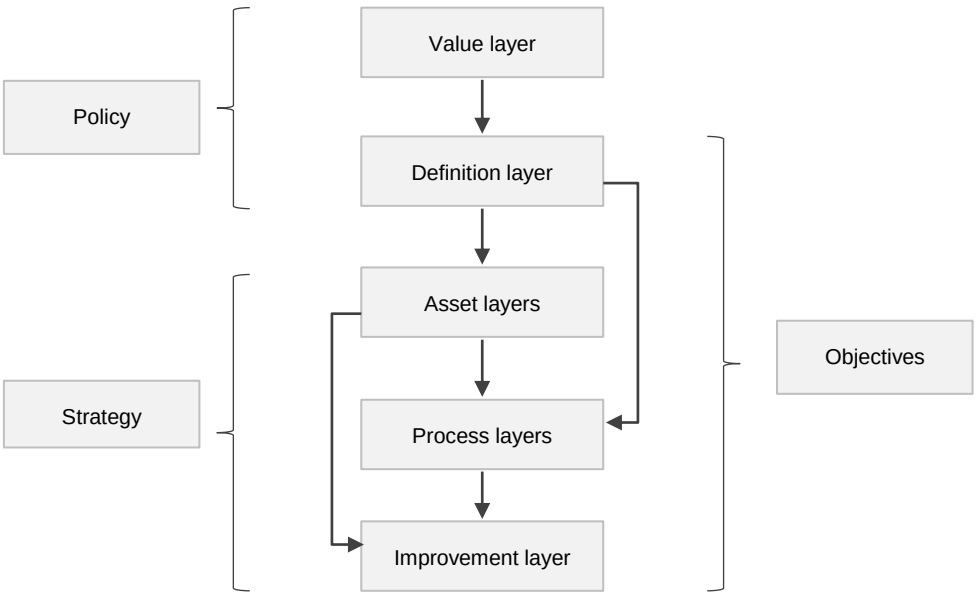


Figure 24: The reconciliation of the PAS55 with the LoS framework

6.3 Metro and Tram policy and strategy

Next to a comparison with the PAS55 planning system, a comparison between the LoS framework and the MaT policy and strategy document is performed as well. Similarly to the previous comparison, the goal is to make a predictive statement about the usefulness of the LoS framework in the formulation of policy and strategy. This comparison is considered to be more naturalistic than the comparison with the PAS55 planning system, as the MaT policy and strategy are documents that relate to real world issues. This presumably leads to different insights than a comparison with a theoretical planning system. Ideally, a verdict needs to be provided about the degree to which MaT adhered itself to the PAS55 planning system format in order to see if the PAS55 planning system leads to a LoS in a worked out example. This is however not a trivial task and lies outside the scope of this research.

Two separate documents exist for the asset management policy and asset management strategy within the MaT organisation. MaT states that their policy and strategy are made in accordance with the PAS55 standard (Verdenius, 2017). In essence the policy and strategy consist of ten spearheads. A brief summary is provided in Table 16 below.

Table 16: Ten spearheads of the MaT policy

Spearhead	Summary
1. Putting the traveller central	The infrastructure serves to transport the traveller from A to B in a fast, reliable, comfortable and safe manner. These values should be pursued in the management of the infrastructure.
2. Striving for transparent relationships with the carrier and the VRA	The VRA wants to have insights into the costs and wants a reliable cost prognosis for the future. The carrier wants to know under what conditions it can exploit the infrastructure.
3. Directing on performance requirements	The performance requirements are derived from the demands of the carrier and those of other stakeholders.
4. Securing safety	The safety of travellers, personnel, residents and other traffic should be safe during exploitation, maintenance and construction where the legal requirements are met.
5. Striving for covering costs during the lifetime of an asset	Changes in the size and function scope of the asset portfolio should be compensated. Also should the continuity of the financing be stable over time.
6. Directing on Life Cycle Costs (LCC) and Total Cost of Ownership (TCO)	Assets costs should be minimized during the life cycle of an asset while attaining the functionality. Next to this, the costs from a system (infrastructure and vehicles) perspective should be minimized.
7. Correct management of new assets to be taken into use and functional scope changes	New built assets or scope changes for the systems need to be managed correctly. The transfer from project organisation to the management organisation is considered to be risky.
8. Striving for innovation and development of system knowledge	The question is raised how the technical innovations for the infrastructure systems need to be managed. In order to manage these innovation correctly MaT needs to developed system knowledge.
9. Introduction of asset management according to PAS55	MaT wants to fulfil the expectations of the carrier and the travellers against the lower possible life cycle costs through asset management according to the PAS55 standard.
10. Striving for a transparent and formal relationship with GVB as service provider	This formal relationship is established by clearly defining the roles as asset owner, asset manager and service provider and the corresponding responsibilities.

The spearheads were made in a workgroup with mainly the management team. The workgroup made explicit what was already in the minds of the personnel. The spearheads are said to stem from the consultations the personnel of MaT had with the various stakeholders. The spearheads are elaborated in the policy document. In turn, the strategy document adopts the ten spearheads as a starting point and consequently presents measures by which these spearheads should be achieved. We will not further elaborate on all of these strategy items as they are numerous, but only highlight those that are exemplary for the problems that were identified.

A downside of scrutinizing the policy and strategy documents was that they originated from 2013. Although they are the most recent documents they are at the same time outdated in some issues.

6.3.1 Peculiarities of the The MaT policy

In the policy document three peculiarities were identified, for each of these one or more examples are provided. In a sense the peculiarities overlap as some of them explain the presence of the other. The ranking of these findings indicates also their relevance.

1. Large focus on organisational aspects
2. Putting means before the ends
3. Absence of stakeholder values and/or definitions thereof
4. Presence of stakeholder values that do not fit within scope LoS

Large focus on organizational aspects

The MaT organisation is a relatively young organisation that still struggles with much organisational inefficiencies. Much of the focus is on improving the organisational efficiencies and the creation of amenities. These organisational amenities can be anything from personnel competencies, to information technology, human resource capacity, finances and subsidies or stakeholder relationships. Spearheads 3, 5, 7, 8, 9 and 10 are labelled to be related to enhancing these organizational aspects. We want to make a clear distinction between the technical activities within asset management that connect to the technical aspects and these amenities that enable them.

This strong emphasis on organizational issues immediately exposed the strength and a pitfall of the LoS framework. The pitfall is that the efforts as to enhance organizational amenities do not fit in well within the framework. The LoS alone should not be considered to be the Holy Grail to asset management success. The LoS framework has strong emphasis on technical aspects, rather than organizational aspects because of the asset and he activity layer.

The strength on the other hand is that it helps management organisations such as MaT keep their efforts focussed towards these technical aspects. The asset manager of tram at MaT stated that many improvement initiatives on process levels fail to be successfully implemented at GVB because these plans have weak ties with the actual maintenance works (De Moor, 2017; De Vrind, 2017). For this reason, the disproportionate attention for organizational aspects in considered to be problematic for the policy.

When talking about securing finances (spearhead 5) one might raise the question in how far this relates to the physical management of assets in the first place; although the resources are meant for the management of the physical infrastructure it does not relate to the technical aspects.

In a later subsection we will discuss how these organizational amenities relate to the LoS framework.

Putting means before ends

Some policy spearheads were identified to be means rather than ends. The cause for the second peculiarity is suspected to be twofold. The first is solution thinking which is a built-in habit of people as described by De Haan and De Heer (2012). A second possible explanation for solution thinking might be because PAS55 encourages answering the 'how' question in the policy document.

An example of means and ends being confused is 'striving for innovation and developing system knowledge'. Innovation itself can never be a goal, but rather it is a means to reach a certain end. There is no picture as to why innovation is needed and how this contributes to any of the stakeholder values. Similarly the spearhead 'directing on performance requirements' is a means to formalise the relationship with the service provider that should therefore be part of the strategy of spearhead 10. Directing on LCC and TCO (spearhead 6) can be a means to reach cost efficiency. Introducing asset management (spearhead 9) is also a way of increasing cost efficiency – cost efficiency being a stakeholder value in this case.

Absence of stakeholder values and/or definitions thereof

In the policy document there was no explicit mentioning of stakeholder values, let alone that they were clearly defined. When talking about safety, is the safety of the travellers of the passengers or the maintenance personnel problematic? A lot of ambiguity is created when talking about terms and concepts such as safety.

In other instances stakeholder values are lacking the first place. From a stakeholder analysis at least sustainability, liveability and traveller's experience are included in the lines of sight. None of these issues were found back in the policy document. In our opinion, the policy document should create a thorough understanding of the stakeholder's interest and how they are defined. This lack of focus on stakeholder values is presumably explained by the excessive emphasis on organizational amenities.

Presence of stakeholder values that do not fit within scope LoS

It was after analysing the strategy document that it became evident that the spearhead about transparent relationships between MaT and VR relate to cost predictability. This strongly coincides with the definition factor 'cost deviations' under the LoS cost efficiency. The Transport Region wants to know in time what expenditures are to be expected as they also have to report to their superiors, that is the Ministry of Infrastructure and Environment. The policy document makes no mention of this and instead immediately directs the focus to collaboration.

Transparency in this sense also means clear agreements about the performances the infrastructure systems should deliver in the form of the Integral Standard of Requirements (IPvE) and the Net Agreement (netverklaring), that specifies that conditions by which the carrier can use the infrastructure.

Transparency is thus defined cost predictability and agreements. The former can be fit within the LoS framework, but the latter falls outside the scope of the LoS. Although the agreements directly relate to the asset conditions and to the exploitation that affect them, the process of creating these agreements is considered to be too far disassociated with the daily activities of managing the infrastructure system.

6.3.2 Peculiarities within the MaT strategy

In the MaT strategy the following peculiarities came to the front. Here again it applies that there may be an overlap in these peculiarities as they may reinforce each other.

1. No connection to the eventual stakeholder goals
2. No causality through asset and maintenance aspects

No causalities in relation to the eventual stakeholder goals
The strategy document is made around the same ten spearheads as the policy document. Consequently the strategy document continues with these spearheads. In the policy document we already found that several issues came to the front.

In the strategy document various measures are listed in order to accomplish the ten spearheads. Generally speaking it is not clear how these measures are related to the stakeholder values. The reasons for this might be because of the issues identified in the policy document, namely that the stakeholder values were not explicitly mentioned and defined.

The first reason is that there is no definition of stakeholder values. In the case of the first spearhead 'the traveller central' there is no mentioning what traveller's value and how their expectations are going to be attained. We argue that the definitions of values provide useful levers by which the stakeholder value can be achieved. Instead, the strategy document states that all of the following nine spearheads will achieve this spearhead. Moreover, the document says that MaT will appoint an account manager exploitation, but does not further specify what he or she is going to do. No concrete measures are proposed and this seems more like delaying choices in making strategy.

A second reason for the lacking connection to stakeholder values is due to the internal focus of MaT on organisational aspects. From the policy document it already became apparent that many of the efforts of MaT are focussed on improving their organizational processes and amenities. In the policy document stakeholder values such as sustainability, liveability and (system) attractiveness were absent, but these were recognized to be of importance as was the result of the stakeholder analysis.

The last reason was because already in the policy document means and ends are already mixed up. Some policy spearheads are identified to be specific means to certain ends. Ends in this case are stakeholder values. When answering how these spearheads will be attained, that are in fact already means, the relation with stakeholder values become even vaguer.

No causality through asset and maintenance aspects
This peculiarity is strongly connected with the previous one, as the technical aspects are closely connected to the stakeholder values. It is in the LoS framework that, after the definition of the stakeholder values, directly the asset and activity properties follow.

Questioning how improvement efforts will contribute to enhancing asset or maintenance properties is a good test for MaT to check whether there is good connection with the technical aspects. In the past several improvements from MaT towards GVB Rail Services have been suggested that contribute little or nothing to the actual maintenance process (De Vrind, 2017). On paper the improvements seem promising, but as these suggested improvements are said to have too little connection with the actual maintenance processes they did not result in savings (De Vrind, 2017). In the interviews with both the asset manager tram and the asset manager at GVB it became apparent that MaT lacks technical knowledge, especially in the field of maintenance works.

In the words of PAS55 the strategy should describe the high level mechanisms for achieving the requirements of PAS55 (The Institute of Asset Management, 2008b). These high level mechanisms

are the causalities that are established by the asset and the activity layer and consequently affect the stakeholder values.

As it is now, it is not known how the various improvement measures contribute to enhancing the asset or maintenance and eventually the stakeholder values. Now some examples will follow of improvement measures that are adopted in the strategy document but that do not display a clear causality through the technical aspects.

Safety, for instance, is said to be guaranteed through the safety management system (Veiligheidsmanagementsysteem, VMS). Although this system consists of hundreds (or perhaps thousands) of measures, the high level mechanisms by which this is done are not described. None of the strategy measures makes a reference to availability.

Another example is provided by business intelligence that is intended to be utilized without an idea of how this will lead to improvement, as it is not clear how it will affect the technical aspects. No clear LoS is present in how these methods will lead to the fulfilment stakeholder values. Business intelligence is said to eliminate performance killers and cost drivers and there it stops. Many questions remain unanswered. What data will be analysed? What kind of efficiencies do we aim to improve? How will this lead to better asset conditions or maintenance performance?

Spearhead 9 was about the introduction of asset management according to the PAS55 asset management standard. Perhaps the most important measure of introducing asset management is the MaT personnel developing asset management competencies and knowledge. It is again not clear what these competencies and knowledge are about. Asset management is toolbox that comprises various methods such as (amongst others) life cycle cost analyses, FMEA, Risk-Based Maintenance, Root Cause Analysis, Reliability-Based Maintenance, Level of Repair Analysis, Systems Engineering, etc. Which of these techniques must the personnel learn? And how will this influence the assets or maintenance performance?

When these asset management competencies are complemented with better information provision this should result into insights in asset degradation. Again, it is only when the information about asset deterioration is combined with these aforementioned tools that a useful improvement can be made. It is not clear from the strategy document what tools are going to be used, which inefficiencies are going to be tackled and how eliminating these inefficiencies contribute to stakeholder values.

In sum, we conclude that a lot of these strategy measures actually postpone actual strategy. There is no insight in where efficiency improvement might be within the actual infrastructure or the maintenance process. From the strategy document an image arises that MaT does not yet have a clear idea where to start when it comes making strategy as they do not have the right information nor the technical knowledge. No connection is made with the technical aspects and the eventual stakeholder goals.

6.3.3 Line of sight in MaT policy and strategy

The question remains whether a LoS is visible in the MaT policy and strategy. Similarly to the comparison between the PAS55 planning system and the LoS framework, we will use the building blocks of the LoS framework and see to what the degree these are represented in the MaT policy and strategy. Several problems are made with respect to the policy and strategy of MaT. These observations are summarized below.

- Policy document does not take stakeholder values as a starting point. It takes the spearheads as a starting point which are said to be an indirect translation of stakeholder concerns;
- Where stakeholder values are mentioned, however, there is hardly any definition;
- Some spearheads are found to be means as to serve to fulfil other spearheads, therefore the policy document contains means and not always ends (stakeholder values);
- The descriptions of the spearheads were not complete in the policy document at times. It was only with further interview the rationale for some of the spearheads became apparent;
- The strategy document answered the how questions only to a certain extent: the causality through technical aspects to the stakeholder values was not visible;
- The impression is created that MaT still had to create a strategy at time of policy and strategy formulation but needed more knowledge, competencies and information in order to do so;
- Although the organizational aspects are important for good organisation management they do not directly enhance performance. They rather serve as a prerequisite as to enable performance. How such organisational amenities fit within the LoS framework is elaborated in the next subsection.

The fact that most of the efforts are put in organizational aspects is not considered wrong per se. This is simply what MaT needed at the time of policy formulation. It is argued however that the organizational (i.e. non-technical) LoS is more complex if it is to be seen in relation with the eventual stakeholder goals. The conclusion from this is that the LoS framework built from literature is not yet eligible to deal with these kinds of aspects.

Table 17 provides an overview of the building blocks of the LoS in relation to the MaT policy and strategy. The first two building block primarily relate to the policy document, the latter two relate to the strategy document.

Table 17: Comparison between the building blocks of the LoS framework and the occurance of these within the MaT policy and strategy

Building block LoS framework	Occurrence in MaT policy and strategy documents
1. Stakeholder value as starting point	The MaT policy takes the ten spearheads as starting point. These spearheads are found to be measures rather than values in many instances.
2. Definition of stakeholder values	There was no definition of the stakeholder values that were mentioned. Several stakeholder values that were mentioned related to safety, comfort, availability (although this one requires no definition),
3. Causal chains through technical aspects	The technical aspects (asset and activity properties) were absolutely lacking in the MaT strategy.
4. Improvement actions that connect to technical aspects	Many of the measures proposed (asset management competencies, business intelligence, system innovation, amongst others) had no connection with the technical aspects. There was no idea exactly how these measures could improve the technical aspects nor contribute to particular stakeholder values.

In conclusion, we argue that the LoS in the MaT policy and strategy is weak. Especially the technical aspects were completely absent. These aspects connect the stakeholder values with the improvement measures. Both personnel from MaT and GVB stated that the improvement plans in the past made by MaT had little to no connection with the technical aspects and therefore failed.

A clear separation between means and ends through policy and strategy was not present at times. We argued that some of the spearheads functioned as means to consequently fulfil other spearheads.

What was also found to be problematic was thinking from the perspective of stakeholders. MaT reasonably chose to combine the OSP and the asset management policy into a single document, but lost track of clearly formulating and defining stakeholder expectations. A major emphasis of the policy document was on establishing organizational efficiency through some of these spearheads. In the cases where the policy spearheads were related to stakeholder values, clear definitions lacked that otherwise would have helped in identifying the technical aspects.

These above findings can be partly blamed due to the PAS55 guideline we believe. The PAS55 standard (i) did not encourage to clearly define stakeholder values, (ii) encouraged to answer the how question in the policy document and (iii) only mentions that the strategy needs to describe the high level mechanisms, but does not prescribe a clear connection with the technical aspects. Nevertheless it was not examined in this research in how far MaT followed the PAS55 planning system.

6.4 The role of the line of sight in policy and strategy formulation

6.4.1 Technical policy and strategy formulation

The LoS framework provides structure and guidance in establishing the link between stakeholder values and the assets and the activities surrounding these assets. The building blocks that comprise the LoS framework are deemed essential to establish this aforementioned link. The framework can provide a useful contribution as it forces policy developers (or management) to collaborate with experts within and outside the organisation and make explicit the stakeholder values and technical aspects.

In this research there was no room to actually examine the development of policy and strategy on the basis of the developed lines of sight. What we can conclude from the comparison of the LoS framework with PAS55 planning system and the MaT policy and strategy is that the LoS framework provides a useful tool that encourages policy makers to recover stakeholder values, define them and connect them to actual asset and maintenance properties. From interviews with asset managers it became apparent that improvement plans in the past failed because of the weak connection with the technical aspects. Surely, this can be the result of the policy and strategy document that have weak ties with the technical aspects, as policy and strategy set the foundation for many of the plans developed.

Can the LoS provide in the entire policy and strategy? We think not. Several times stakeholder interests and organizational activities (factors) were encountered that did not fit within the scope of the LoS. When looking at the definition of the LoS it was about the connection between the stakeholder values and the technical aspects. Some organizational activities cannot be influenced by these technical aspects. Asset properties cannot, for instance, influence collaboration and negotiation processes and vice versa. The demarcation of the scope of the LoS lies thus within the technical aspects. If there is no causal connection with these aspects it does not belong in the LoS. Even asset intensive organisations are much more than just technical aspects. Therefore the policy and strategy are not solely based on developed lines of sight.

Then how should an organisation use the LoS? We argue that the LoS provides an – albeit limited – overview of real world processes of causes and effect. When developing the lines of sight not always causal chains come to the front that provide useful levers for influence. Sometimes, the causal chains

are found to be significant but cannot be influenced. It is thus up to the policy developers to strategically select the causal chains that influence a stakeholder value and in turn can also be influenced by improvement measures. In other words, not the entire LoS should end up in the policy and strategy document; policy and strategy consists of more than just technical aspects, as is demonstrated in Figure 25. The stakeholder analysis, identification of stakeholder values and the definition thereof are considered to be part of the policy document as this relates to the 'what do stakeholders want' question. The causal chain of technical aspects including the improvement measures are considered to be part of the strategy document as this pertains to the 'how do we achieve this' question.

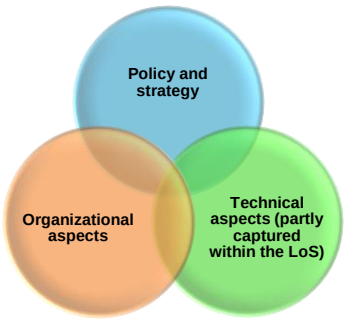


Figure 25: the relation between organizational and technical aspects

As the LoS can assist in policy and strategy formulation it sounds logical that the creation of the lines of sight precedes the formulation of policy and strategy. In the MaT context however distinction needs to be made between the analysing the need for new infrastructure and the management of existing infrastructure. MaT focusses on the latter, the former is done by VO&R. The responsibility of V&OR, and hence the policy, is directed towards designing a transit system that can transport passengers between two geographical locations. The focus of MaT, on the other hand, is on managing this built (rail) transit system. Although asset management also concerns life cycle considerations through investment decisions, the focus of the LoS remains on the management of an existing asset stock because of the continuous character of asset improvement and maintenance. The LoS is hence always created for an organisation with an established asset portfolio.

The improvement measures (or improvement factors) have not been fully explored in the case study of MaT. Incidentally some already existing improvement measures could be connected to the technical aspects. This last step is connected with the strategy formulation as an organisation then chooses what causal paths are strategically selected from the LoS into the strategy document that are influenced through improvement measures. As actual strategy development on the basis of the LoS has not been covered in this research, there was no point in seeking for improvement measures.

6.4.2 Organizational aspects

From scrutinizing the MaT policy document it became apparent that the LoS framework primarily focusses on technical aspects while neglecting the organisational aspects that are also part of asset management, albeit they do not fit within the LoS framework because of its explicit emphasis on technical aspects. Technical aspects were those aspects that related to either the asset properties or the properties of activities surrounding these assets.

Organizational aspects have a wide variety effects within an organisation and only have their effects on the maintenance or the assets through another chain of cause and effect than the asset and

activity layers. This is especially why these aspects fit poorly within the framework. Sometimes organizational amenities do not directly influence the factors in the LoS framework at all, but simply enable them such as many of the back office processes. In this case the amenities are a prerequisite for creating performance. Another example is the policy spearhead about directing on performance requirements. When the policy document was created back in 2013 there was no PMS available at MaT. The PMS is an amenity that does not lead to improvement in performances, it rather makes them transparent. Consequently the discrepancies between the desired (or expected) and the actual performances provide information to undertake action. The amenities make possible the various tasks within the asset management system and therefore intervene on several levels of the asset management responsibilities. Other examples of organisational aspects might be information technology systems, culture and leadership, and personnel competencies.

To better understand how these amenities relate to various tasks within asset management the various technical layers of activities of asset management are portrayed in Figure 26 . The circles are the various technical elements that exist within asset management. Policy & Strategy and Programming & Investment in this sense have a strong orientation towards the technical aspects of asset management, as there is also financial planning and policy strategy on non-technical matters. Policy & Strategy formulation is considered to be the strategical level of asset management. Programming & Investment is considered to be the tactical level of asset management that relates to maintenance programming and to asset investment decisions. Maintenance can also directly influence performances, in the case of safety for example. The amenities hover over all these technical tasks as they can intervene on any level and can vary from IT technologies to competencies of personnel.

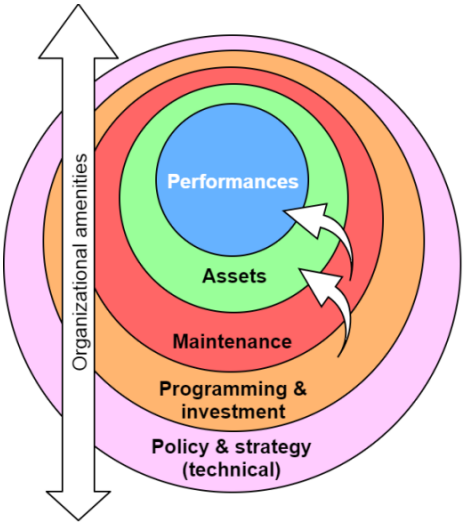


Figure 26: The technical elements within asset management juxtaposed to the organizational amenities that can intervene on all of these elements

Although the LoS framework contains activity layers, there are just two. Mapping the chain of cause and effects when it comes to these organisational amenities is therefore difficult to be captured within just two activity layers, next to the maintenance processes to which they can intervene. This model presented above slightly hints how the LoS framework can be further expanded as to include at least the amenities that eventually will improve or enable asset or maintenance performance. Asset management competencies might be an example of which. What further complicates things is that these amenities are generic and therefore their effects often contribute to a variety of stakeholder

values. The biggest problem is that some of these amenities intervene in a way that does not always follow the causal logic as suggested in the LoS framework.

The organizational amenities are all part of the asset management system. In order to better grasp how the asset management system relates to the goal efficiency – which essentially is what the LoS is all about – the following metaphor is presented in Figure 27. The asset management system is best thought of as a car that should be properly maintained and have the right specifications. Without a navigation system however, which is represented by the LoS, the car will not reach the right destination. Both the navigation system and the car are necessary in order to reach the destination.

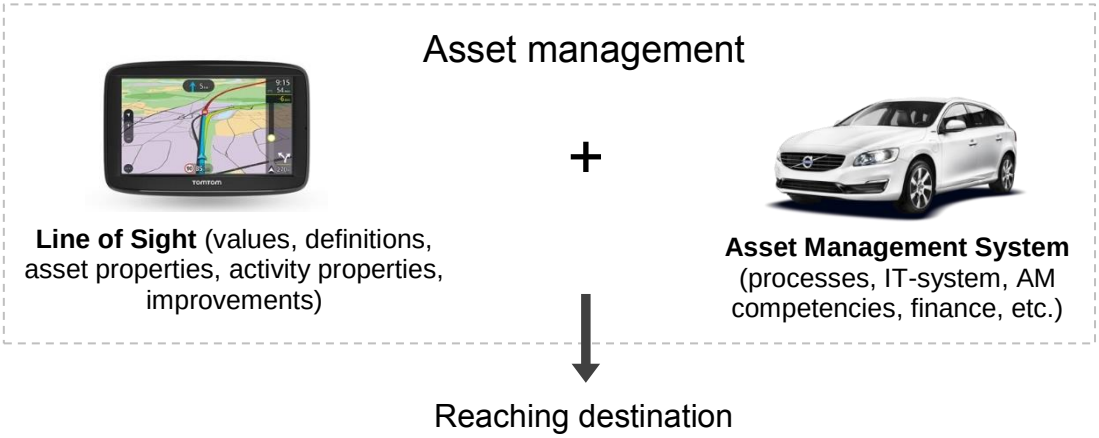


Figure 27: A metaphor to express the relationship between the asset management system and the LoS

In chapter 8 we will discuss how the LoS can be further expanded so that it can be made fit for more than just the technical aspects.

From this chapter we can answer the following two sub research questions:

Sub research question 4: How does the LoS framework compare to professional literature?

- A connection that should resemble a LoS is somewhat visible in the PAS55 standard although it is weak.
- The PAS55 does not clearly specify what exactly needs to be in the policy and strategy documents, let alone how to include this.
- The LoS framework has clear definitions of the various elements of which it is comprised that are connected in a logical manner.
- The PAS55 on the other hand does not explicitly force policy makers to map and define stakeholder values and connect these to the technical aspects of the asset stock.

Sub research question 5: What is the role of a LoS with respect to policy and strategy formulation?

The LoS is foreseen to help in policy and strategy formulation in the following areas:

- All relevant stakeholder values are identified and clearly defined.
- It forces policy makers to be explicit how their strategies are established through technical aspects.

- Describe what stakeholder want and how this is defined in the policy document and describe how these is achieved in the strategy document.
- This aforementioned effect brings policy makers/management in dialogue with experts on a particular stakeholder value: experts provide context and policy makers provide purpose.
- Policy maker should be picky in the causal chains they want to adopt in their policy and strategy: not every causal chain influences the stakeholder value significantly.

Policy and strategy are not entirely based on the LoS. Even asset intensive organisations have non-technical aspects; these sometimes cannot be fit into the LoS framework as it was developed now.

7 Performance measurement

As part of the evaluation of the LoS framework a comparison is done between the framework and the MaT performance measurement system (PMS). This evaluation, similarly to the previous chapter, serves as a predictive evaluation as was discussed in chapter 2. The goal of this evaluation is to predict the usefulness of the LoS framework in relation to performance measurement. In this chapter we start by elaborating on the relationship between the policy and strategy and the PMS, and what the role of the LoS is between these two. Consequently the PMS of MaT will be analysed and it will be compared against the building blocks that were also used in the comparisons done in the previous chapter. The chapter ends with a statement about the usefulness of the LoS framework in relation to performance measurement.

7.1 Policy, strategy and performance measurement

Ideally policy and strategy documents should have a clear link with the PMS of an organisation. The PAS55 standard states for example that:

> *The process(es) and/or procedure(s) [of performance measurement] shall provide for the consideration of proactive monitoring to seek assurance that the asset management system and assets and/or asset systems are operating as intended. This shall include monitoring to ascertain that the asset management policy, strategy and objectives are met […] (The Institute of Asset Management, 2008b, p. 42)*

The PMS thus works as a check to examine the degree to which organizational objectives are attained. In the past chapters we have seen that for at least a public organization the organisational objectives are majorly defined through the stakeholder values. Although consensus lacks on the definitions of the policy and strategy document, we defined that the policy document relates to 'what do our stakeholders want' and the strategy document to 'how do we achieve this'. For both of these objectives can be set, objectives that check whether the stakeholder values – that are made specific through definition factors – are attained and objectives that check whether strategy is implemented correctly, or whether the strategy contributes to stakeholder expectations in the first place: after all, strategy is a set of hypotheses about cause and effect. Performance measurement thus checks the attainment of objectives set in policy and strategy. If the policy and strategy are based upon a LoS, the PMS should thus also reflect the LoS. This principle is illustrated in Figure 28.

Moreover, an important distinction can be made between diagnostic measures and strategic measures (Kaplan & Norton, 1996b). Diagnostic measures are measures that relate to factors that always need to be in check regardless of what the strategy is. An example can be the absenteeism of personnel. Strategic measures on the other hand are those that specifically relate to check the implementation of strategy. In the previous chapter the use of the LoS in relation to policy and strategy formulation was discussed. From this it was concluded that the policy and strategy developers should explicitly focus

on those causal chains that can are influential and can be influenced. There is thus a strategic selection of factors that are deployed to achieve stakeholder expectations.

The LoS framework is strongly inspired by the strategy map of Kaplan and Norton (2000) and the adaptation of this strategy map of Arthur et al. (2016). In chapter 5 several guidelines were conceived that helped steering the design of the lines of sight for MaT. One of these guideline states that all selected factors had to be measurable. Not only did this help make factors be unambiguous but this also proves to be a useful rule when translating the LoS into a PMS. The factors are in many instances well suited as performance indicators.

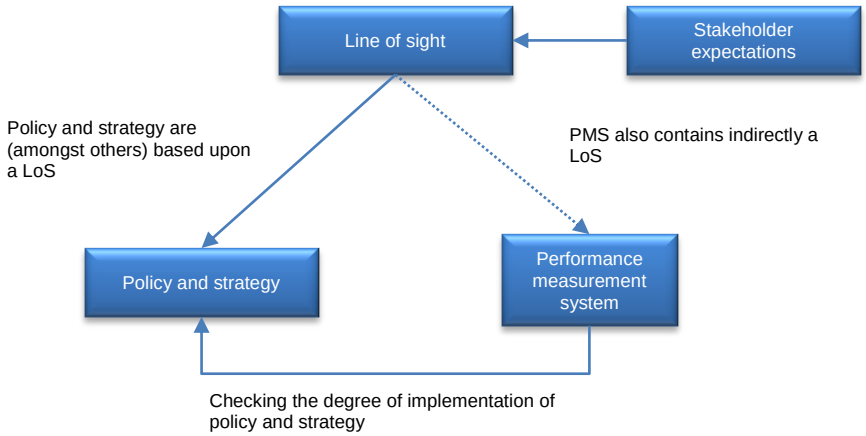


Figure 28: The relationship between the LoS, policy and strategy, and the PMS

As these causal chains used by policy and strategy are already made explicit in the developed lines of sight for an organisation and the factors by which they are comprised are already quantifiable in many instances, developing a PMS checks on the implementation of policy and strategy and verifies the assumptions of strategy is expected to be not too difficult.

7.2 Metro and Tram performance measurement system

7.2.1 Description of the current performance measurement system

The current line of sight of MaT is based upon the 2015-2024 BORI agreement between MaT and GVB Rail Services. Three major Key Performance Indicators (KPI) exists on the fields of safety, quality and value for money. The KPI's can take on three modes from best to worse: green, orange and red, respectively. These three KPI's are constituted by underling (normal) performance indicators (PI). These PI's can in turn also take on three colours depending on the state by which the PI performs. The PI's are in turn defined by intrinsic factors (IF). It are these IF's that have a direct relationship with the contractual agreements as made between MaT and GVB Rail Services. In the remainder of this section it will be further elaborated what the relationship between the KPI's, PI's and IF's is. A breakdown structure of the PMS for the KPI 'quality' is presented in Table 18. The entire PMS of MaT is adopted in Appendix B.

Table 18: The PMS of MaT with its KPI's, PI's and IF's

KPI	Performance Indicator	Intrinsic Factor
Quality	Availability route	Availability standards set for multiple traces or individually
	Compliance with Output Specifications	A certain number of the assets is allowed to deviate from the standard with a certain percentage
	Accessibility (metro only)	The number of reported incidents of missing, defect or incorrect: tactile pavement, double banisters on staircases and the gap between platform and vehicle or the sagging of platform height with respect to the vehicle
		Availability of elevators
		Number of stations unreachable from street to platforms longer than 15 minutes due to broken elevators more than 10 times per years
	Availability escalators	Number of stations unreachable from street to platforms longer than 15 minutes due to broken escalators more than 10 times per years
		Total availability of the escalators
	Availability security gates (metro only)	Total availability
		Availability per station

Relationships and norms

The KPI's and PI's themselves have no intrinsic value. The scores of the KPI's (green, orange, red) are determined by the scores of the underlying PI's. In Table 19 an overview is presented of how the KPI's are built up in relation to the PI's. Some PI's have more weight in determining the KPI's than others. In the case of safety, the weakest PI determines the score of the KPI.

Table 19: Weighting of the various PI's in relation to the KPI's for the metro

KPI	Relative weight	Commentary
Safety	Worst PI determines KPI safety	All underlying PI's are considered to be so important that the colour of the KPI is defined by the worst scoring PI
Quality	Availability: 30% Compliance with OPS: 30% Accessibility: 15% Availability escalator: 15% Availability security gates: 10%	The availability of the route and the compliance with OPS are considered to be direct output
Value for money	Lifecycle costs: 50% Condition of the assets: 50%	Life cycle costs and the asset condition are considered to have a strong relationship with one another.

In turn, the performance indicators neither have an intrinsic value. They are composed of various intrinsic factors. The intrinsic factors are however measurable. Each of the intrinsic factors has norms set for them, but what these norms exactly are is not relevant for this research. The focus of this research is on *what should be measured* rather than *what is allowed*. We will take one example however to demonstrate how intrinsic factors can determine the score of a performance indicator. For this purpose the intrinsic factor of availability of metro escalators is selected. In Table 20 the norms for this performance indicator is shown. Two intrinsic factors lay at this basis of this performance indicator. The first intrinsic factor was (i) the number of stations unreachable from street to platforms longer than 15 minutes due to broken escalators more than 10 times per years and (ii) the total availability of

escalators. For each intrinsic factor three ranges are defined with a corresponding score of green, orange and red. The intrinsic factor with the worst score will determine the score of the performance indicator.

Table 20: The norms set for the IF's of metro escalator availability and the corresponding score (green, orange, red).

IF 1 IF 2	≤ 10 ≥ 95,00%
IF 1 IF 2	10 < x ≤ 20 92,50% < x < 95,00%
IF 1 IF 2	> 20 ≤ 92,50%

7.2.2 The LoS in the MaT PMS

Similarly to the evaluation of the LoS framework with the PAS55 planning system and the MaT policy and strategy we will analyse the MaT PMS through the same building blocks that were used in the previous chapter.

Although the PMS explicitly measures the values of availability, safety and cost efficiency to a certain degree, there are still many stakeholder values lacking within the PMS. From the stakeholder analysis of chapter 4 it became apparent that there were more stakeholder values than the ones comprised within the MaT PMS.

Not all values are properly defined in the current PMS. The values availability and safety have both been sufficiently defined through performance indicators. Although availability is not hard to define, safety nevertheless has been defined through seven intrinsic factors. The 'value for money' key performance indicator proved to be rather problematic with its current definition. The name does not cover the actual content through performance indicators according to personnel (De Moor, 2017). The term 'value' now relates to the economic value, but it can also relate to availability. The asset manager tram of MaT wants a performance indicator that juxtaposes the costs with all kinds of other performances. Cost savings can result in sub optimizations of other performances. When combined however with other performances into a single indicator, this will prevent sub optimization. This exposes a pitfall of the current LoS on cost efficiency. This LoS compares in no way the performances of other stakeholder values in relation to the costs, but the condition of the assets. Because of the separation of lines of sight per value a risk of sub optimization exists if the PMS is designed in a similar way.

Although there is coherence through the categorisation in the PMS, there is hardly any explicit causal relationship between the various performance indicators. There is a strong tendency for lagging indicators, while the leading indicators that are included are also considered to be lagging indicators. For example, the performance indicator 'compliance with OPS' (output specifications) is considered to be a lagging indicator while it is a predictor for other lagging indicators such as safety or the condition of the assets. There are hardly any drivers of performance. If the management wants to increase availability, cut down on costs or enhance safety, what levers are there to be pulled? And how do these drivers of performance themselves perform? This is the causality that is

Although MaT has adopted several improvement measures in their strategy, none of these improvement measures are being monitored in their PMS. Like stated before, the PMS contains many

lagging indicators but no drivers of performance. Improvement measures can be considered the most essential drivers of performance.

In Table 21 an overview is presented of the comparison between the LoS framework and the MaT PMS.

Table 21: Comparison between the building blocks of the LoS framework and the occurance of these within the MaT PMS

Building block LoS framework	Occurrence in MaT PMS
1. Stakeholder value as starting point	Although the PMS is strongly oriented surrounding stakeholder values, some important stakeholder values are still lacking.
2. Definition of stakeholder values	Availability and safety were sufficiently defined through performance indicators. In interviews with the asset manager tram of MaT it became apparent that the 'value for money' key performance indicator lacked the comparison with other performances than just the asset condition. This also exposed a pitfall of the LoS of 'cost efficiency' as this LoS also solely includes the asset condition and not any other performances.
3. Causal chains through technical aspects	There was no relationship between the performance indicators except categorisation. Some performance indicators do relate to the technical aspects such as the Output Specifications (OPS), asset condition, .
4. Improvement actions that connect to technical aspects	The PMS contained no improvement measures at all. No drivers of performance are identified. The PMS consists primarily of lagging indicators.

7.2.3 Issues in relation to policy and strategy

Besides comparing the MaT PMS with the building blocks of the LoS framework, a comparison between with the policy and strategy also proves useful, as the PMS can be considered a check upon the attainment of the objectives set in the policy and strategy document.

It is noteworthy that the MaT policy and strategy, and the PMS differ much in scope. The policy and strategy document have a strong inward orientation, focussing primarily on organizational amenities such as information technology and competencies that can be regarded as the improvement measures. The PMS on the other hand focusses primarily on external stakeholder values such as availability, safety and cost efficiency – focussing on solely outcomes. The policy and strategy nor the PMS contain the cascade of definitions, asset and activity properties and improvement measures.

The improvement measures that were covered in strategy document were not reflected in the PMS. Kaplan and Norton (1996b) argue that a PMS should contain outcomes and drivers of performance. Improvement measures, which they refer to as the learning and growth perspective, intervene on the drivers of performance, which we recognized as the asset and activity factors. Logically, also the roll out or implementation of improvement measures should be measured in order to see whether the improvements are successfully deployed in the first place. Consequently the performance indicators belonging to the activity factors, the asset factors and eventually the definition factors should change in numbers over time. This principle was demonstrated in Figure 29.

7.3 The role of the line of sight framework in performance measurement

7.3.1 Bringing coherence in a PMS

From analysing the MaT PMS from the perspective of the building blocks it was found that stakeholder values were prioritised, although the selection of stakeholder values was not complete and not all stakeholder values were properly defined. The PMS displayed no causality between performance indicators other than categorisation. Finally, the MaT PMS did not monitor improvement measures that were adopted in the MaT strategy document. Rather than being internally focussed like the policy and strategy documents, the PMS was however externally focussed as its emphasis was on the stakeholder values of availability, safety and cost efficiency.

The question remains how the LoS can help building a PMS. We foresee that following the LoS framework in the development of a PMS also leads to the fulfilment of the building blocks, although this has not been actually tested. We argue that developing a PMS can never be done separately from the organizational policy and strategy that are also based on the developed lines of sight. In the case of MaT there was no synchronisation between the MaT policy and strategy documents and the PMS of MaT. It is predicted that developing policy, strategy and the PMS on the basis of developed lines of sight ensures coherence between these three. As was argued at the beginning of this chapter, the PMS operates as a check for the implementation of the strategy and the attainment of stakeholder objectives from the policy document. In the previous chapter it was discussed that the strategy can be built on the basis of the causal chains from the lines of sight that are ought to influence the stakeholder values and are able to be influenced through improvement measures.

For developing a PMS this means that the causality that is comprised of factors are operationalized through performance indicators that monitor performances over time. In chapter 5 the criterion was set for factors to be measurable. This not only leads to specific, non-ambiguous factors that need little explanation, but this criterion also contributes greatly to the capability for measuring the performance of the chosen strategy.

In Figure 29 a causal chain with the associated performances over time is displayed. The various performance indicators can display whether a hypothesized causality holds true. In this example an increase in Type-A maintenance backlog leads to, with a certain time delay, to worsened longevity of the assets, which in turn drives up the average fixed costs and in turn leads to less cost efficiency. From this example it becomes apparent that when a strategy is evaluated on its effectiveness then obviously the aspects on which it intervenes need to be mapped and measured. These are the technical aspects of asset and activity properties which are now lacking in the strategy document.

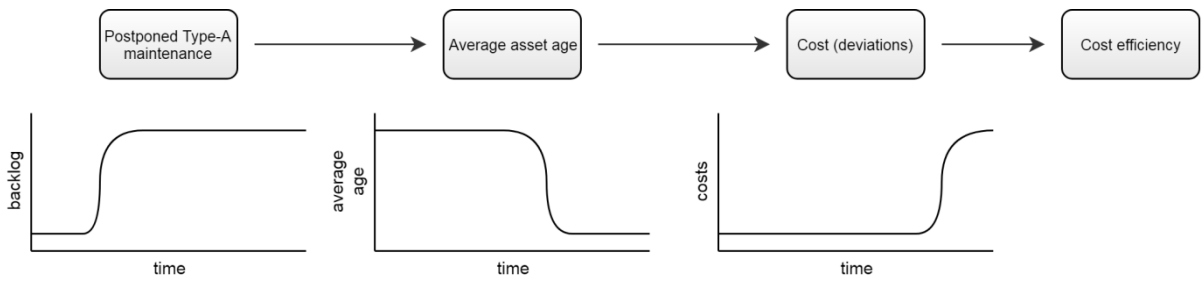


Figure 29: Relationship between a causality and potential measured performance over time

If the added value of the LoS with respect to performance measurement should be summarized in one word it would be ‘synchronization’. Following the LoS framework ensures the incorporation of the building blocks on the basis of which the policy and strategy, and the PMS were evaluated. Developing both the strategy and consequently the PMS on the basis of the lines of sight leads to synchronization between the two. The PMS then serves as a check for the implementation and validation of the chosen strategy.

7.3.2 The risk of sub optimization

From comparing the LoS with the MaT PMS not only generic insights with respect to the applicability of the LoS framework became apparent, but also a downside came to the surface. The LoS framework primarily vertical connections: all factors within a LoS framework contribute to that particular value. However, in reality many cross connections exits. Some factors influence multiple stakeholder values at the same time. In other instance the enhancement in terms of performance of one factors comes at the expense of other factors. This particularly becomes evident when measuring performances. Kaplan and Norton (1996b) already warned against the risk of sub optimization and argue that there balanced scorecard provides in a one-sided selection of performance indicators in order to counter this. In this research it was chosen to split the lines of sight per value and the problem of sub optimization could be reintroduced again.

The sixth research question is answered as follows:

> *Sub research question 6: What is the role of a LoS with respect to performance measurement?*
>
> We foresee a role for the LoS framework in performance measurement
>
> - When policy and strategy are based on a LoS this make it much more convenient to design a PMS on the basis of a LoS as well. This way, there is a synchronization in policy, strategy and performance measurement.
> - The LoS ensures there is coherence between the various performance indicators: it becomes much more sensible to monitor various performance indicators next to each other over time in order to see whether a strategy works.
>
> There is however a risk of sub optimization as the developed lines of sight are separated per value. If the PMS is consequently also split per value there might be a danger of sub optimization.

8 Discussion

The evaluations with respect to policy, strategy and performance measurement made a predictive statement about the potential of the LoS framework in the creation of these. The comparisons also made apparent the strengths, weaknesses and the potential future development of the framework. In this chapter we especially elaborate on the strengths and weaknesses of the LoS framework and how the weaknesses could be tackled. Moreover, we discuss the limitations of this research. This chapter starts off with a reflection on the research and on the model. Subsequently remarks are made how the LoS can be put to practice in a non-research context. The chapter is concluded by examining the LoS framework from various perspectives in order to enhance the theoretical understanding of the framework.

8.1 Reflection on research

8.1.1. Generic applicability

The lines of sight were developed for one particular case study. The general applicability of this LoS is not yet tested. Although the LoS framework might seem generic its usefulness in other contexts has not yet been effectively demonstrated.

A logical next question would be: can this framework also be used by the carrier of the infrastructure system? The asset layer might seem as a first logical step for the carrier, as the rolling stock makes it asset intensive in a sense, but the assets might support particular services that stand more closely to the fulfilment of stakeholder values than the assets themselves. The order of perspectives thus might depend on the distance the organisation has to the eventual users of the systems.

Another issue in generic applicability lies within the values that can differ per organisation. Of course, each organisation has different values that call for different factors, but some values display certain peculiarities. In chapter 5 for instance, the amount of asset and activity layers was limited to two, but for particular values there might be a need for additional activity layers to describe the causality of the maintenance process in more detail. This is thus case dependent, and therewith organisation dependent. The LoS framework might be in need for organisation specific modifications.

8.1.2 Little naturalistic evaluation

In chapter 2 the evaluation methods were discussed. The first evaluation was done through building the lines of sight for the MaT organisation. This form of evaluation was somewhat naturalistic as this involved the personnel that could display particular behaviour during the design process. The second evaluation on the other hand was purely artificial through informed argument. It was a predictive evaluation about the potential use of the LoS framework in the formulation of policy and strategy and the creation of a PMS.

Although a role for the LoS is predicted it has not been actually tested in practice: no policy and strategy documents nor a PMS was created on the basis of LoS. The evaluation thus remains speculative.

Despite the lacking naturalistic evaluation a potential role for the LoS has been discovered. Several building blocks have been discovered that essentially comprise the LoS. These building blocks proved to be a useful instrument for the comparison with the PAS55 planning system, the MaT policy and strategy, and the MaT PMS. It was from these two comparisons that pitfalls of the LoS framework became apparent namely. Generally speaking, the more naturalistic evaluations have led the most useful insights, or shortcomings, concerning the LoS framework.

8.1.3 Little investigation of maintenance works

Filling the lines of sight was done with the help of experts at MaT. There was no possibility to develop the lines of sight in collaboration with the help of experts of GVB. In the previous subsection we already wrote about that the more naturalistic the research becomes, the better the insights into the applicability or downfalls of the design product become. It would have been beneficial to gain additional insights through developing the lines of sight with experts of GVB.

Particularly the lines of sight on availability and safety would have strongly benefitted from consultations with GVB experts. The lines of sight on these two values are considered to be not complete because of the lacking input of GVB. In chapter 5 it was not sure how many activity layers were necessary for mapping the causal chain through maintenance aspects. Developing the lines of sight in consultation with GVB would point out in a process of trial and error how many layers would be optimal.

8.2 Reflection on the model

8.2.1 Cross connections

By choosing for the LoS framework over a network causality (see Figure 30) the emphasis is placed on vertical alignment so much that the cross connections start playing a subordinate role. The significance of cross connections cannot be proved other than quantitative data analysis. The added value of including these cross connections thus remains speculative.

The issue of cross connections can also be portrayed as one that relates to the sub optimization. It was through analysing the MaT PMS it became apparent that this also is a downfall of the LoS because a separate LoS is created for each value. Particularly the LoS surrounding cost efficiency needs to include the performances of other values. When cutting on costs, this comes at the expense of performances in many instances. This issue has already been made evident by Kaplan and Norton (1992) a few decades ago.

Although a PMS therefore needs to monitor costs and performances simultaneously to prevent sub optimization, we argue that it would be beneficial to map these cross connections already in the LoS in a visual matter that is comprehensible. Not only a PMS needs to account for cross connections, but also policy and strategy documents that are formulated on the basis of the lines of sight.

Sometimes cross connections also lead to ambiguity in the LoS framework. In the sustainability LoS, for example, it was found that a definition factor contributes to attaining another definition factor. Energy consumption in this LoS, leads to the production of CO_2, both of which are defined as definitions. A solution to this could be to add more than one definition layer in the framework. In order to keep the LoS as simple as possible it was chosen not to do so. Instead a reference factor (see section 5.2) was used for this purpose. In the sustainability LoS the definition factor ‘utilization’ of the transit network was reliant on the traveller’s experience. In this case a factor is influenced by an entire LoS. For this reason, the reference factor also proved to be valuable.

More generally speaking, all sorts of cross connections exists within the LoS and between lines of sight. These cross connection are not to be thought of too lightly as they can influence factors in another LoS more serious than the factors in the same LoS. It is often in the very operational layers where these cross connections become visible. For instance, maintenance and in particular the quality thereof seems to play a central role in this horizontal linkage of factors.

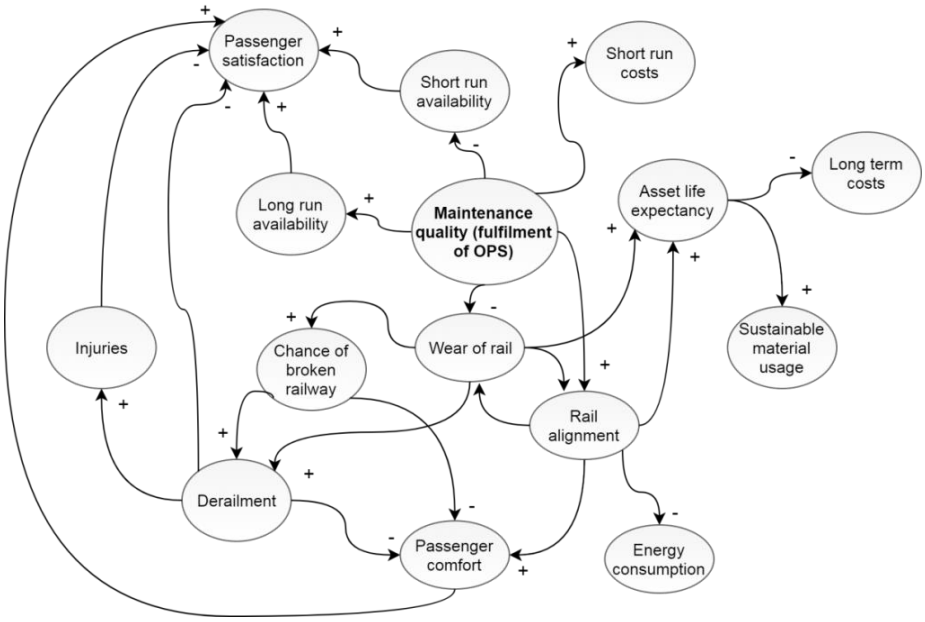


Figure 30: The causality the factor 'maintenance quality' has with other factors

In Figure 30 a suggestion is made of how a causal map for the factor maintenance quality could look like; maintenance quality is measured through the fulfilment of Output Specifications. Maintenance quality was found to be an influential factor; not surprisingly as maintenance is one of the primary tasks within asset managing organisations. The quality of maintenance was found to have an effect on the values of availability, costs, safety and sustainability at least. The figure above is nowhere claimed to be exhaustive and in reality many more links between factors might exist.

Drawing these cross connections within the lines of sight, similarly as the vertical connections, would harm the comprehensibility and it is therefore not recommended. The reference factor could be one possible solution as to map the cross connections.

Regardless of the eventual outcome of the efforts to visualize these cross connection we suspect that the vertical connections of the LoS framework prevail over these cross connections. Main effects of changes, in most cases, outweigh the negative side effects. The cross connections were not actively sought in this research because of limitations of time.

8.2.2. Inability to deal with organizational aspects

From analysing the MaT policy and strategy the scope of the LoS became apparent. The most important scope delineation lies within the relation that values and factors need to have with assets and the activities surrounding these assets that directly influence the assets. Many organizational processes and amenities do not influence asset properties directly but rather enable or influence them through another chain of cause and effect. Three types of of organizational aspects were at least identified that MaT tried to steer in their policy and strategy that could not be properly fit within the developed LoS framework, namely information capabilities, asset management competencies and

collaboration efforts. Of course, many more organizational aspects exist that might not fit within the LoS framework as it is designed now.

Programming and investment

From analysing the current MaT policy and strategy documents it became apparent that a majority of their efforts was on improving the information infrastructure and acquisition. The LoS is presumably in need of an additional layer that relates to maintenance programming and the acquisition of new assets.

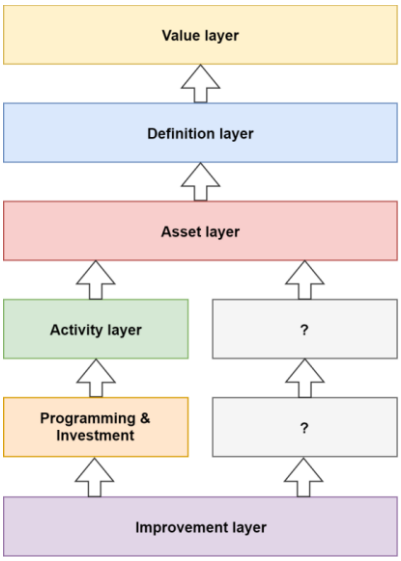


Figure 31: Expansion of the LoS framework with at least the programming and investment layer and potentially other (parallel) layers that relate to collaboration efforts, currently denoted with a question mark

To this layer improvement measures that, amongst others, enhance information capabilities. This way risks become more transparent. Better transparency in risks leads to better programming and investment choices. For instance, in many cases preventive maintenance is performed with a certain redundancy because of the philosophy “better safe than sorry”. In these scenarios there is no real insight in what the actual risks are and a slight redundancy in preventive maintenance is applied in order to ensure that undesired events do not occur. The investment part of this layer also greatly benefits from improvement measures that aim to enhance information capabilities. Better information leads to better investment choices made as more information is available on the current condition of an asset and its future performances. In Figure 31 the suggested layer is placed in between the activity and the improvement layer.

Nowadays the added value of asset management becomes especially apparent in the design phase where the maintainability of the to be acquired assets is already considered in a life cycle analysis. Therefore it could be wise to combine programming and investment factors into one single layer. A problem however is that investment factors, we suspect, primarily affect asset factors and not activity factors. This means that the investment factors would actually have to skip the activity layers. It is predicted that this would harm the comprehensibility of the LoS framework to a certain extent.

Although this new layer would allow for some organizational amenities and processes to be adopted within the LoS, not all of these organizational aspects can be included in this layer. The criteria for the factors in this potential new layer thus have to somehow influence the activities that in turn influence the assets or relate to investment decisions that influence the assets. Back office amenities and

processes that relate to salary administration are not likely to directly influence the maintenance activities, for instance.

Collaboration

Another category of organizational aspects that MaT prioritised in their strategy are collaboration efforts and the formalisations thereof through agreements. Although the effect of collaboration on assets, and perhaps also the way maintenance is performed, has is much more indirect, negotiations outcomes can certainly influence assets and the activities surrounding them. What makes incorporating collaboration efforts difficult into the LoS is that its throughput, advances and outcomes are hardly measurable. In chapter 5 we briefly discussed the issues of defining collaboration in the first place.

In Figure 31 a suggestion is done how the LoS framework can be expanded with additional types of layers that allow for the incorporation of collaboration aspects. In a sense, collaboration can also be seen as an activity that can influence the assets, or the activities that influence assets. In the figure a suggestion is done to place the collaboration layers in parallel with the activity and the programming and investment layer. Of course, many more possibilities are possible and this is just an initial suggestion. Like stated before, collaboration can also influence activities. An example of which can be the net agreement between MaT and GVB Exploitation that specifies under what conditions GVB is allowed to exploit the infrastructure. The exploitation activities influence the assets. From this example it immediately becomes apparent that the suggestion made in Figure 31 is perhaps too simplistic.

All in all, the programming and investment layer is predicted to be a useful addition to the LoS framework, but the expansion of additional layers that allow for collaboration still needs much more thought.

8.2.3 Comprehensibility versus accuracy

The reality is always more complex than models want us to make believe. In this respect a model is always a trade-off between accurately describing the world and the comprehensibility to understand it. Figure 32 depicts this trade-off.

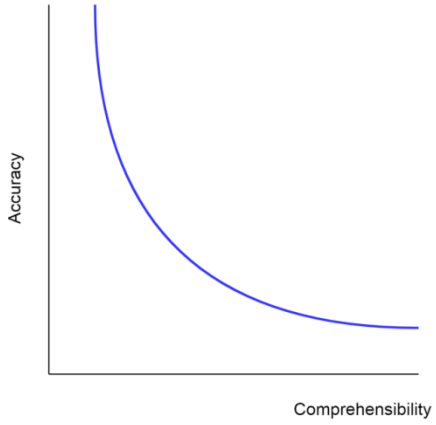


Figure 32: The trade-off between accuracy and comprehensibility in modelling represented in a curve

By omitting the cross connections some accuracy is lost but it greatly benefits the comprehensibility of the framework. We argue however that the cross connections should be sufficiently considered. The current LoS framework makes use reference factors. Illustrating the real life complexity by including the many cross connection can make a LoS unclear. The strength of the current framework is the simplicity by which outsiders can understand the causality. Nevertheless we do not claim that the

current framework cannot be improved in anyway. The only danger is maintaining the comprehensibility while increasing the accuracy – and thus the complexity.

Another problem with the LoS is that it is an instrument of aggregation. On the one hand, this provides overview, but simultaneously crucial details can get lost. The MaT asset manager tram stated that MaT is working towards performance measures that are displayed through Geographic Information Systems in order to visualize geographical discrepancies in performances. This is also recognized as a challenge for the LoS: the current framework does not allow for the differentiation of performances in a geographical area.

In the previous subsection the addition of new layers was discussed. Their added value remains speculative and potential pitfalls need be considered. Here too the trade-off between comprehensibility and accuracy is relevant.

Finally, we emphasize the importance of naturalistic evaluation of the LoS framework. As can be seen from the previous subsections there are many considerations to be made in terms of accuracy and comprehensibility. Applying the LoS framework in practice will best show where the LoS framework lacks either accuracy or comprehensibility, or how the optimum between the two can be sought.

8.2.4 Towards an asset management utopia

In a future situation a municipal executive board is interested in making their light rail infrastructure system more sustainable: the current CO_2 footprint is considered to be too large. They ask their asset manager what can be done to make this infrastructure more sustainable – and more importantly: what does it cost? The asset manager has a piece of software in which there is a slide that says ‘desired system CO_2 output’. He drags the slides to the desired level, all other performance remaining equal, and presses the ‘compute’ button. The software will tell him exactly how much the novel ambition of the municipal executive board will cost. The asset manager reports back the results and the responsible alderman turns pale upon seeing the costs of realising his intended ambition. ‘Is there no other way we can realise this ambition? I want my city to be in the top 5 ranking cities when it comes to sustainability!’ he says. The asset manager immediately points him to the fact that the availability of their infrastructure system performs above average when compared to cities of similar size and that there is the possibility to downgrade in order to enhance the sustainability without any further cost increase. The alderman agrees on handing in on availability. Again, the asset manager returns to the software, but this time he also drags a slide that says ‘desired cost level’ to what the alderman had in mind, but the availability is set to be a free variable. After some processing time, the second computation has the desired level of sustainability and remains within the budgetary targets; the availability has dropped, but is still considered to be competitive relative to other respectable metropolises.

What has been described above is seen by many asset management practitioners as the ‘asset management utopia’. This research has so far limited the application of the LoS framework to policy and strategy formulation and performance measurement. Potential use of the LoS framework within the field of IT applications, such as decision support tools, has not yet been considered in this research.

Within a few decades perhaps everything can be measured against low costs. Data on itself however is just a mean to certain ends. The question then becomes how to bring structure in these enormous datasets. Intelligent software can detect correlations amongst various variables (what we refer to as factors) in a data set, but is not yet able to build a model that maps the entire causal network. And

even when software will be able to autonomously build these models it will not tell you where to look for new variables that may correlate with existing variables that are already adopted in the model.

For this purpose, the LoS framework can give clues on where to start looking for new variables. Even when such sophisticated software in place, we thus still need to input the variables. Many techniques exist that capture the interaction of various factors in a quantitative matter. Public asset systems are typically large systems where many stakeholder values need to be fulfilled that are sometimes contradictory. Another complicating aspect could be the dynamics of asset management system that create particular behaviour that cannot be explained by looking at the system structure alone. For this reason, we recommend further research on the combination of modelling techniques like System Dynamics and the LoS framework for the creation of decision support tools in the field of asset management.

8.3 The line of sight in practice

8.3.1 The involved parties

In chapters 4 and 5 the actual development of the lines of sight for MaT were described. Although developing the lines of sight was considered to be explorative, no thoughts were given on how a LoS can be best developed within a non-research context where various parties are active. In this research the lines of sight were developed by the author of this document with the help of experts within the asset management organisation. Depending on whether the roles of asset owner, asset manager and service provider are divided among three separate organisations, developing a LoS can involve several parties.

We argue that the development of the LoS primarily should take place between the asset manager and the service provider. These two parties have the most knowledge on the actual assets. The LoS developer can best be selected to be someone from the asset managing organisation as the asset management policy and strategy are typically formulated by this organisation. Moreover, an asset owner lacks the technical knowledge, whereas the service provider is too far removed from the stakeholders. The developer of a LoS needs to have support from the management teams of both the asset managing organisation and the service provider. Figure 33 provides an overview of stakeholders that can be involved in the development of a LoS.

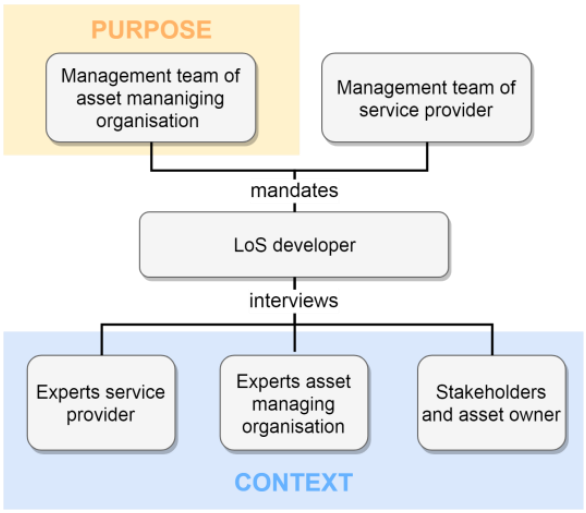


Figure 33: Involved stakeholders (internal/external) in the development of LoS and the relationships between them

The LoS developer interviews the experts from the service provider, the experts from the asset managing organisations and the stakeholders. These three actors give context to the LoS, this implies that they hold the tacit knowledge that needs to be translated into factors that are linked with each other. Stakeholder typically emphasize what they think of as important, these can be then translated into the definition factors that better specify the values. Simultaneously the stakeholder can indicate a target value for the definition factor. For instance, when it comes to the noise production in the Amsterdam light rail context, inhabitants can state they tolerate a certain level of decibels.

The management team of the asset managing organisation on the other hand gives purpose to the use of the LoS: they select what stakeholders are considered to be important for the management of the asset stock and what stakeholders are dependent on the asset stock. Besides, they decide how the lines of sight will be used in the formulation of policy and strategy. They know in what areas the organisation is underperforming and needs attention. They could for instance state that they want to have good insights in a particular stakeholder value to see what levers they can pull to enhance this stakeholder value that is underperforming.

Of course, the proposed working scheme in this subsection might be different per organisation. The MaT context knows a single service provider that is contracted for a longer period of time. In different asset management contexts there may be a multitude of service providers that alternate each other in a high pace. We do not know what the consequences of such scenarios might be on the development of a LoS in collaboration with the multiple service providers.

8.3.2 Route map to a LoS

In a summarizing effort we present a route map in Table 22 to developing a LoS. Most of these steps have been described in more detail in the chapter 4 and 5. In this research no validation was sought through workshops and validation, but these have been added to the table however as it presents the route map to a validated LoS. In relation to the previous subsection we have also added the relevant interviewee for each of these steps.

Table 22: The route map to developing a LoS

Step	What	Who	How
1. Identification of stakeholders	Fulfilling stakeholder values is considered to be the primary objective of a public organisation. Typically the palette of stakeholder values is much wider for a public organisation than for a commercial organisation.	Management Team asset management organisation	Interview
2. Transform stakeholder interests to generic values	Various stakeholder interests have a common factor many times: this is the high level interest we refer to as a value. In order to keep the number of lines of sight limited, as many as possible interests are converted to the same value. For each value a LoS is created.	Stakeholders	Interview
3. Define stakeholder values	Many of the stakeholder interests are then used again as a definition for that particular value. Sometimes new definitions were found other than the identified stakeholder interests.	Stakeholders	Interview
4. Finding asset and activity factors	Asset factors are properties of assets. Activity factors are the properties of activities that directly influence an asset property (asset factor). Together these factors make up the causal chains.	Experts from both asset management organisation and service provider	Interview
5. Validation	Two ways of validation have been identified in this research. The first was data analysis and the second is a workshop with experts from both the asset	Experts from both asset	Workshop

	managing organisation and the service provider. Optionally an external expert can also be included if some parts of a LoS remain disputed.	management organisation and service provider	
6. Connect improvements to the asset and activity factors	Strategy development is about the strategic selection of causal chains that organisations want to improve through improvement measures. These improvement measures connect to the technical aspects.	Experts and management team asset management organisation	Workshop

Two remarks can be made at step 4. One might ask why this step is not done through workshops. We argue that the finding asset and activity factors is best done through individual interviews with the experts as the LoS developer can quickly progress through the development of a LoS. Logically, the particular stakeholder value, for instance safety, can best be covered by the expert on that particular field; it is pointless to organise a workshop for the LoS of safety with personnel that hold no knowledge on this field. Besides, it was already found to be time consuming to set up a LoS with a single expert.

The second remark relates to the fact that only experts from a single organisation were interviewed. The lines of sight were developed in collaboration with the experts of MaT. Typically the service provider also has its own expert on a particular stakeholder value. In this research the experts of the service provider could not be included in the development of a LoS. If this would be the case, we would have developed two separate lines of sight for the same value and later try to unify them into a single LoS through a workshop validation. The primary rationale to do is to get a fresh perspective on particular value, rather than that one expert easily agrees with the LoS that was built from the expert from the other organisation.

8.3.3 The social dimension of a LoS

This research has not covered the social dimension of developing a LoS framework. The social dimension is defined as the way the actors inside the organisations, which are involved in the development of the LoS, behave during this development. Although this research has been considered only from a technical point of view, the LoS surely is a social product as well. This is evident from the fact that the development of the LoS strongly relies on the tacit knowledge of personnel. One could argue that personnel could consciously manipulate or frustrate the development of a LoS. We are aware that this can play an important role in the development of a LoS.

De Bruijn (2007) discusses the behavioural aspects of performance measurement. Personnel using a PMS can display behaviour that works in their advantage but at the expense of the organisation. De Bruijn (2007) also argues that in the development phase of a PMS personnel can opt for strategical behaviour; measuring performance can make bad performances evident after all. Bourne, Mills, Wilcox, Neely, and Platts (2000) state that resistance in performance measurement is often difficult to observe as the acts of resistance are concealed. They too noted that resistance can manifest in the design phase. The question remains what to do about this.

Personnel can also choose to manipulate the creation of the LoS, which eventually results in a PMS. Of course, policy and strategy can also be manipulated this way in order to press their agenda. Other reasons for strategic behaviour can be the repulsion against a different way of working or the fear of additional bureaucracy.

The evaluation in this research has been primarily artificial rather than naturalistic, meaning that the evaluation was performed rather from a theoretical perspective and has not been applied thoroughly in a real world setting with actors. Although the lines of sight were built in collaboration with the experts from MaT, it was not verified to what level opportunistic behaviour might have occurred. Logically, examining the social dimension is best done through naturalistic evaluation.

We reason that developing the lines of sight in collaboration with experts from the various organisations and external consultants – through individual interviews and workshops – could prevent strategic behaviour as this acts as a double check on the knowledge provided by the various personnel.

Another risk can be the unwillingness to cooperate as personnel might not be convinced of the added value of a LoS. Alongside with deliberate manipulation, unwillingness to cooperate is, we suspect, strongly influenced by the way the LoS development process is communicated. Communicating that 'the management team wants you [the personnel] to think along in the formulation of policy and strategy' is much less likely to result feelings of resistance than when it is communicated that 'the management team wants to enhance organizational efficiency'. The first message might evoke feelings of enthusiasm whereas the second might evoke fears of increased performance demands. It is noteworthy that the author of this document was introduced as an intern to the personnel of MaT that is diagnosing the current situation through the development of a LoS. Perhaps, when stated that the author was an external consultant that was mandated by the management team to enhance organisational efficiency this might have changed perspective on the collaboration in the development of the LoS. In sum, we argue that personnel will always reason what eventual changes that are brought about by the LoS will have for impact on their jobs; this should deserve considerate thought as the LoS is in part a social product.

8.3.4 The use of a LoS

Building the LoS is actually already formulating policy and strategy. We already argued that not all causal chains need to be selected to be influenced through improvement measures. Only the causal chains that are deemed fit to be influenced will have improvement measures connected to them. This selection process, devising the improvement measures and connecting these measures to the causal chains is, we argue, essentially an important part of strategy building. In Figure 34 a cycle of policy and strategy formulation is illustrated. We already saw that steps 1 and 3 of the cycle reoccur in Table 22.

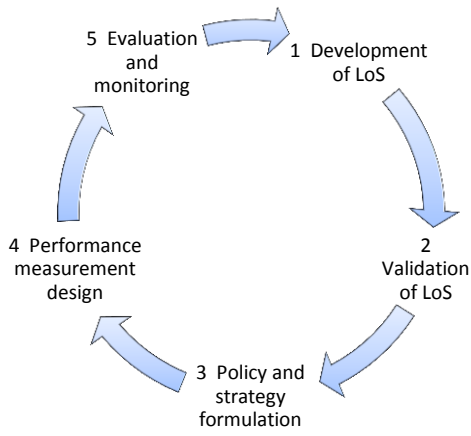


Figure 34: The LoS in the process of policy and strategy formulation and implementation

If the causal chains are mapped and have improvement measures connected to them, formulating policy and strategy is considered to be merely describing these chains with associated improvements in textual form.

What has not been done in this research is that targets (or norms) were set for each of the factors; this is also an important part of policy and strategy formulation. Especially the definition factors lend themselves as output measures that are the most important check to see to what degree stakeholder values are attained.

Consequently a PMS can be designed that uses these same causal chains, as each factor in these chains is measurable. Not always do organisations have quantitative information available to measure the hypothesized causal chains. Regardless whether this information is readily available or not, at some stage performance measurement needs to take place to check whether the strategy is successfully rolled out or if the assumed causalities might be flawed in the first place. Efforts thus have to be made to start collecting data for the PMS and this is where the LoS can make a useful contribution as it structures this process of data collection.

When the PMS is in place the targets for each of the factors can be monitored and evaluated. This is where at least a quantitative validation of the assumed causalities takes place, if this was not performed in step 2 already. On the basis of the evaluation it might prove that either the strategy is not successfully implemented or the assumed causalities do not hold true. In the latter case, the LoS might be readjusted and the circle of Figure 34 starts over again. Of course, only adjustments are made to the LoS, the policy and strategy wherever necessary according to the evaluation results. Although in this research the circle of Figure 34 has not been fully completed, we foresee that in practice typically several iterations are necessary to come to satisfactory policy and strategy documents in a process of learning from the evaluations.

8.4 The line of sight in perspective

The cross connections proved to be one of the biggest challenges for the framework. In chapter 5 an analysis with a classification of types of cross connection was provided. To further the understanding in the actual causal complexity that underlies the LoS with its cross connections we discuss two perspectives that shed new light on viewing these cross connecting that we believe help further research.

8.4.1 A hierarchical view on causality

Kaplan and Norton (1996a) argued that the strategy can be thought of as a hypothesized set of causes and effects. The LoS framework finds its roots primarily in the strategy map. Kaplan and Norton (2000) made these causalities in the strategy map explicit, but simultaneously provided structure through the perspectives of learning and innovation, (organizational) processes, customer valuation and finance. This causality of perspectives proved useful for developing a framework that brings structure for analysing how the fulfilment of stakeholder is done through assets.

In Figure 35 two perspectives on causality between factors are presented. In the left part of the figure a classical causal map is displayed in which many cross connections exist, the readability is however poor and finding factors that are linked to each other can be even more daunting. The right part of the figure presents a set of causalities according to the LoS framework. The emphasis is on vertical alignment, thus what contributes to the eventual stakeholder value. This comes however at the expense of the cross connections as can be seen in the left part of the figure.

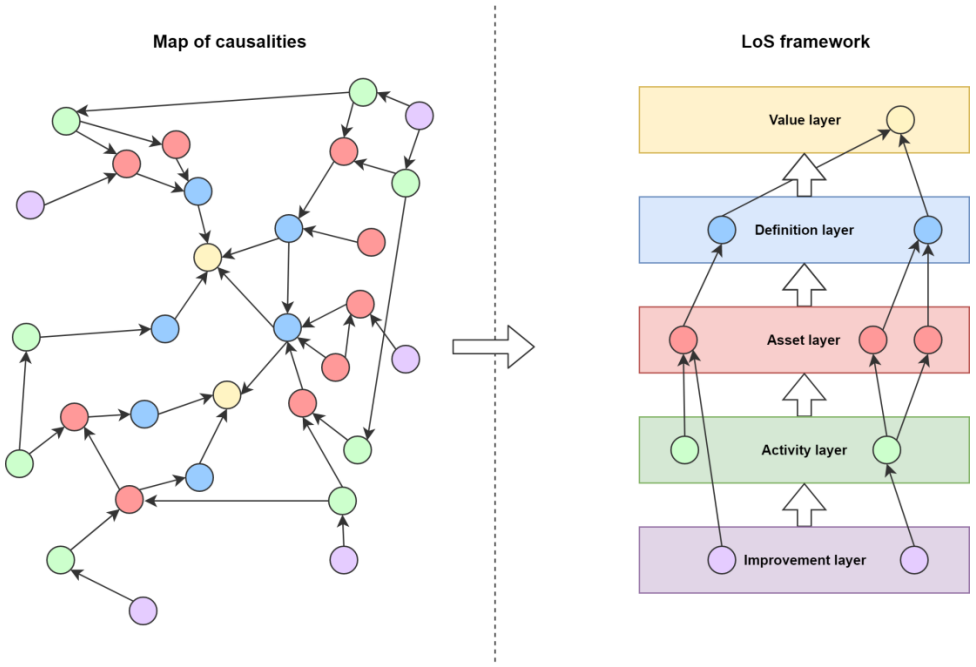


Figure 35: On the left a network of causalities is displayed that is unstructured; in the right part the LoS framework is displayed that brings structure to this causality.

It is not so much for the readability that the top down working method of the LoS was applied – although this surely helps – but rather for the identification of factors in a structured manner. Just as unstructured the left part of Figure 35 looks, just as unstructured is it to identify factors in a balanced matter without an explicit emphasis on factors from a particular layer. The LoS framework however categorises the factors according to the layers which helps finding factors in a balanced matter. Above all, one is not likely to create a causal reasoning of values, definitions, technical aspects and improvements through the spaghetti causality. This logical reasoning helps in creating a well-structured strategy that allows itself to be monitored trough performance measurement.

8.4.2 The bigger picture

The lines of sight that were created in this research are in reality part of larger system than just the metro and infrastructure system. We identify three domains in this system, namely infrastructure exploitation, infrastructure management (which has been the focus of this research), and infrastructure governance. This system is portrayed in Figure 36.

These domains belong to the responsibility of various actors. Between each of these domains there is an interface that can result in various kinds of problems. The infrastructure management domain is largely represented by the LoS. Within this domain there primarily are two actors at play, namely the asset manager and the service provider. In the Amsterdam light rail context there is already a problematic interface as it there is no consensus of who should take up the task of asset manager (De Moor, 2017; De Vrind, 2017). Although this assignment of task responsibility is not part of the research scope, we would like to emphasize that the real world is more complex than just the causal connection of factors.

Wat further complicates this is, is that the Figure 36 looks different for various values. The image of Figure 36 best suits a value like availability. For sustainability it becomes completely different as some sustainability efforts stop at the infrastructure management domain, whereas others are done in collaboration with the infrastructure manager (MaT) and the carrier (GVB Exploitation). The value of

availability is in the direct interest of the carrier whereas the value cost efficiency has little relation with the carrier since they do not experience consequences of the MaT expenditures; as long as the infrastructure is available and in good condition.

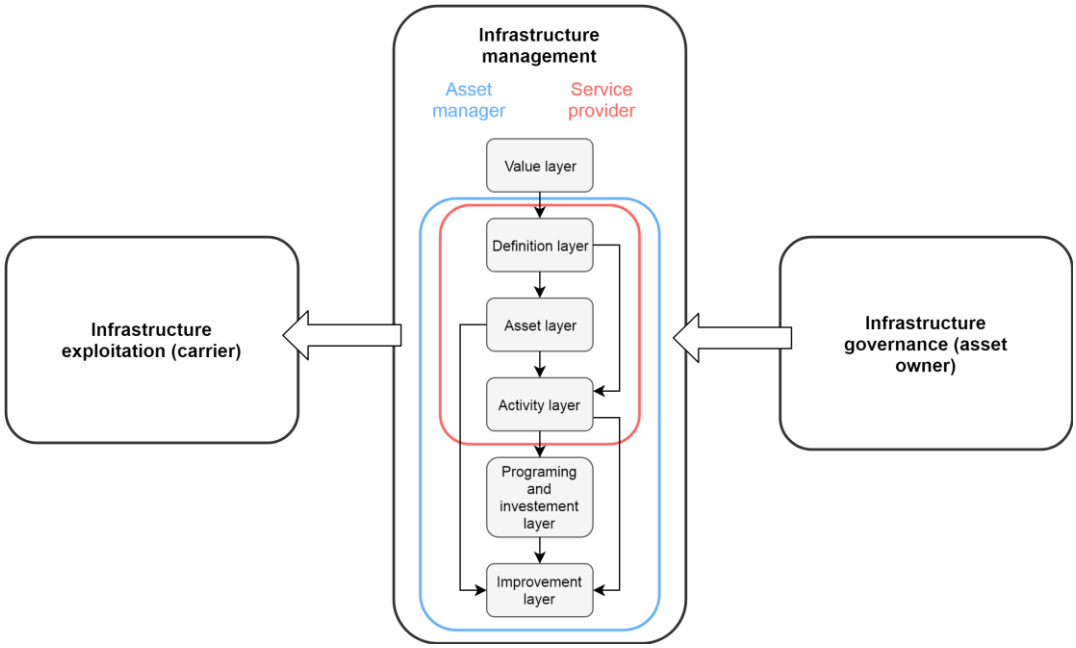


Figure 36: The created LoS as part of larger system. Three domains can be distinguished.

What also poses to be problematic with the figure above is that, in the case of safety, some actions by the carrier can lead to incidents or dangerous situations that fall under the responsibility of the infrastructure manager. These actions of the carrier are now put in the activity layer in the LoS on safety, although they should belong to a LoS that belongs the exploitation domain. What becomes apparent from this is that a distinction between the three domains as portrayed in Figure 36 does not always work out. This example illustrates that the whole system of infrastructure and exploitation with the three domains can have cross connections between them. Drawing a picture that accurately describes all these links would perhaps become so complex that it will deter any future use.

It is expected that the party that exploits the infrastructure has its own LoS somewhat similar to that of the domain of infrastructure management. Although it seems reasonable to place the LoS of the carrier above that of the infrastructure management domain, it is probably more complex than a continuation. If, for instance, the infrastructure manager achieves to attain high availability for the infrastructure, but the operator (carrier) fails to achieve a similar availability for his vehicles, then the travellers will experience poor availability. In this case, the availability of the infrastructure and the vehicles are completely independent from each other. This thus does not follow a serial cascade but both parties need to have their availability in place in order to deliver performance to the traveller. Moreover, the carrier can also damage the infrastructure of the asset managing organisation, this would then require an arrow in a backward direction. From these examples it becomes evident that connecting the lines of sight of the carrier and the asset managing organisation does not guarantee a fluent integration of frameworks.

9 Conclusion

The objective of this research was to generate more knowledge in the concept of the LoS within asset management. As the LoS is relatively new concept this research is considered to be explorative and serves as a stepping stone for future research. The evaluation performed had a strong artificial emphasis meaning that the LoS framework developed in this research has not actually been applied in the environment of MaT for the creation of policy, strategy or a PMS. The use of the LoS framework was instead evaluated on a predictive basis. The first section of this chapter covers the six sub research questions. The main research question will be answered in the second section and the chapter ends with recommendations for future research.

9.1 Sub research questions

Sub research question 1: What requirements can be identified for a LoS framework that is to be applied for a public asset intensive organisation?

Existing attempts on designing a LoS through performance measurement made it a logical step to use performance measurement literature as a starting point. From both the MaT environment and the literature on performance measurement several requirements were distilled to which a LoS framework should qualify. The requirements that applied for MaT overlapped with those found in literature at times. When combined this resulted in the following requirements:

1. The framework should be able to address various stakeholder values. This makes it eligible for a public organisation
2. The framework should include causality
3. The framework should be able to include the properties of physical assets
4. The framework should be able to include the properties of activities surrounding assets

Existing performance measurement frameworks were compared on the basis of these requirements. None of the existing performance measurement frameworks qualified to all the requirements simultaneously. Because of this, it was decided to build an own framework. The framework consists of a cascade of layers that contain factors that are connected with each other. It starts off with a value layer that captures the stakeholder interest in a most abstract way. This value is then defined through definition factors in the definition layer. These definition factors are primarily influenced by asset factors; these are typically asset properties such as the condition of an asset. In turn, the asset factors are influenced by activities factors. The activity factors are properties of these activities such as the frequency of maintenance. The last layer in the framework is the improvement layer. From this layer improvement measures can be connected to either the asset or activity factors. This LoS framework, as we call it, establishes the connection of stakeholder values to the technical aspects.

Sub research question 2: How to identify relevant stakeholder values for developing a LoS?

The LoS framework takes the stakeholder values as a starting point. In public organisations the stakeholder values are considered to be highest organizational objectives. The identification of stakeholders was done through a mixture of several techniques. Using several stakeholder identification techniques ensures that no important stakeholders are omitted. A stakeholder is

considered important or relevant when either the public organisation is dependent on that stakeholder or vice versa, or when there is reciprocal dependency.

Consequently not all stakeholder interests fit within the scope of the LoS. To this end two additional criteria have been formulated. The first is that stakeholder interests must be able to be influenced by the organisation directly. The second criterion states that the interest should be influenced through technical aspects: those are the asset and activity factors. These four criteria determine what stakeholder interest is adopted within the LoS and what interest is not.

Interests are often specific objectives a stakeholder has. Therefore the interests are clustered in so called values. These are general descriptions under which the interests can be placed in the form of definition factors. It is considered to be beneficial to group as many interests under the same value.

Sub research question 3: How to fill a LoS framework?

This research question might seem trivial, but the LoS framework on itself does not always guarantee a logical order of factors, or causality as we call it. The filling of the LoS framework was done for the MaT organisation for which six stakeholder values were identified. For each separate stakeholder value a LoS was created. This building exercise was considered to be a naturalistic evaluation of the LoS framework.

It was during the building of the lines of sight for MaT several problems came to the front for which guidelines had to be developed that ensured that the lines of sight were filled in a consistent matter. A reoccurring problem when filling the LoS was in what layer a particular factor should be placed, as some factors could be interpreted as both an asset or activity factor. Furthermore, a guideline was developed for selecting what factors are sensible to include with regards to performances that can vary over time, amongst others. Because of the limited time scope of this research we believe the topic of guidelines has not yet been fully explored. We suspect that there are much more guidelines to be generated from applying the LoS framework within the environment where the maintenance activities take place.

Moreover, criteria for factors were found. For instance, all factors, from definition factors to the improvements factors, should be measurable as this helps to clearly define them and this proves to be useful later when developing a PMS. Another criterion is that, similarly to values, all factors in the asset and activity layer need to be related to assets and the activities surrounding these assets. Although this sounds obvious it can be tempting to include factors in the asset and activity layers that do not belong there such as collaboration efforts in the activity layer.

The first step after the identification of stakeholder values is defining them through definition factors. Several methods were proposed for doing so, but in this research there was a particular lack of external resources, as many definition factors were found through consulting internal documents and experts.

The lines of sight were primarily built in consultation with the experts of that particular stakeholder value. Filling the lines of sight was an iterative process that required some preparatory work and approximately two to three interviews of an hour. Although some methods have been provided for the identification of asset and activity factors this was still found to be an iterative and unstructured process.

The built lines of sight can be validated either through workshops or data analysis. Workshops can be done with experts from various organisations. The workshop validation is considered to be more subjective and is primarily related to the scope of the LoS. The data analysis is more objective and primarily pertains to the correctness of the assumed causalities.

Sub research question 4: How does the LoS framework compare to professional literature?
As the PAS55 coined the term and concept of a LoS within asset management, the developed framework was compared with the PAS55 planning system. PAS55 states that its planning system guarantees a LoS through the policy, strategy, objectives and plans. PAS55 did make a separation between organizational objectives, that are contained within the Organizational Strategic Plan, and the asset management objectives. We argue that both these objectives are comprised within the policy and strategy documents respectively. Therefore we only examined the PAS55 policy and strategy definitions. These definitions are compared with the four essential elements of the LoS framework that we refer to as the building blocks. This comparison was considered to be an artificial (non-naturalistic) evaluation. The building blocks are:

1. Stakeholder value as starting point
2. Definition of stakeholder values
3. Causal chains through technical aspects
4. Improvement actions that connect to technical aspects

The PAS55 was found to be a cumbersome document that does not clearly state what should be contained within the policy and strategy documents, let alone that it provides a clear step-by-step plan to establish a LoS. Although some of the elements of the building blocks appeared within the PAS55 standard, it did not explicitly define these concepts.

The LoS framework is argued to be a more concrete document than the PAS55 planning system that unambiguously specifies what elements are to be comprised in a LoS and, above all, shows what the connection between these various elements is.

Sub research question 5: What is the role of a LoS with respect to policy and strategy formulation?
The LoS framework was consequently compared with the MaT policy and strategy document to make a predictive statement about its usability in relation to policy and strategy formulation. The same building blocks as in the previous sub research question were used. This form of evaluation was considered to be an artificial evaluation as the LoS has not been actually applied in policy and strategy formulation.

Roughly speaking did the MaT policy and strategy showed a poor LoS: stakeholder values were not put first and clearly defined, and there was no description of the technical aspects. Improvement measures were described but did not connect to technical aspects. As a consequence, the emphasis of the policy and strategy document was on improvement measures that had no clear connection with the stakeholder values.

The comparison also revealed a downfall of the LoS framework on the other hand. As MaT is an organization that is strongly developing by enhancing asset management competencies of the personnel and the information infrastructure, this exposed the inability of the LoS framework to include such organizational aspects. Especially enhanced asset management competencies cannot directly

connect to technical aspects; the need for an additional layer that relates to maintenance programming and asset investment became apparent.

Although no policy and strategy document have been formulated on the basis of developed lines of sight, some deficiencies in the MaT policy and strategy could be demonstrated by comparing them with the building blocks. Simultaneously the comparison showed the inability of the LoS framework to cope with organizational aspects.

We foresee a role for the LoS framework in the formulation of policy and strategy. The LoS framework establishes this connection between stakeholder values and improvement measures through the technical aspects. As we envision it, the strategy document can, on basis of the LoS, selectively pick the causal chains that are consequently affected by the improvement measures. The policy document then is primarily focussed on what the stakeholder values are and how these are defined.

Sub research question 6: What is the role of a LoS with respect to performance measurement?
Performance measurement is closely related to policy and strategy formulation as both the policy and strategy documents contain objectives. The state of affairs regarding these objectives can be measured through performance measurement. For this reason, the role of the LoS in performance measurement was also examined. Similarly to the previous two sub research questions, this comparison also made use of the building blocks.

The MaT PMS was found to be externally oriented, meaning stakeholder values were used as a starting point, and contained some technical aspects. Nevertheless, it lacked a clear causality through these technical aspects and did not monitor improvement measures. The LoS can help bring a logical order in the various performance measures so that the connection from stakeholder values to improvement measures through technical aspects is attained.

As the PMS monitors the objectives from policy and strategy there should be a significant overlap between the two. For MaT this was however not the case as the policy and strategy document were internally oriented by focussing on the organizational aspects, whereas the PMS was solely externally oriented.

Especially in the harmonization of the policy and strategy documents and the PMS we see a role for the LoS framework. Policy and strategy selectively pick causal chains from the LoS, where each factor of this chain can consequently be monitored through performance measurement. One of the guidelines for the LoS stated that all factors had to be measurable: this not only helped to clearly define factors but also proves to be useful in performance measurement.

9.2 Main research question

The PAS55 standard defines the LoS as the connection between the organizational strategic direction and the day-to-day activities of manging assets. The definition of this concept has gradually transformed to the connection of stakeholder values to the assets and the activities surrounding these assets. Two alterations have been made to the PAS55 definition for this research, namely that (i) public organisations have to fulfil a wide variety of stakeholder values and this is their primary objective and that (ii) assets also play a major role in fulfilling these stakeholder values. This is also echoed by the main research question as this relates to the public and asset intensive character respectively. The main research question of this document stated:

How to design a line of sight for a public asset intensive organisation?

It was rather broadly set up and is therefore answered by the preceding six sub research questions. This research roughly consisted of a design research phase and two evaluation phases. This research resulted in a line of sight framework, a method for finding the relevant stakeholder values, design guidelines for a line of sight and an evaluation for the potential future use of the framework. Alongside these products, accountability for all of the made design choices has been provided.

Designing a LoS is done on the basis of a self-developed LoS framework. The LoS framework consists of five separate layers. Each layer contains factors that pertain to a real world attribute of the asset system or the actions that can be undertaken within this asset system. The factors are connected with each other in a vertical matter and together form a causal chain. This way, stakeholder values are connected to improvement measures through the technical aspects; those are asset factors and activity factors. The general roadmap of step to designing a LoS was provided in subsection 8.3.2.

From developing the lines of sight for the MaT organisation it seemed that the line of sight framework proved to be an intuitive instrument for outsiders that generally was filled without too much difficulty. In many instances a connection could be made with the stakeholder values, the assets and the day-to-day activities. At times, design guidelines were necessary to streamline the development process.

The comparison of the line of sight framework with the MaT policy and strategy document and PMS resulted in reciprocal insights. The MaT policy and strategy documents were found to have little to no LoS embedded within. Reversely did the policy and strategy documents highlight the inability of the LoS framework to cope with organizational amenities such as information technologies and asset management competencies. These amenities do not directly affects the assets, but certainly do on a longer time span. A new layer for the LoS framework was proposed in order to include these organizational aspects, but the expanded framework could not be put to practice.

The comparison between the LoS framework and the MaT PMS showed that this system did not show much LoS either. The LoS not only proves to be useful for ensuring a logical causality of performance indicators, but also for harmonizing the policy and strategy documents and the performance measurement system. On the other hand, the comparison with the performance measurement system made apparent the poor ability of the line of sight framework to cope with cross connections that run horizontally across the line of sight or between two or more separate lines of sight.

On the basis of the above, we foresee that the LoS framework can make a useful contribution to the formulation of policy and strategy, and the creation of a PMS. From the developed lines of sight the causal chains can strategically be selected in which an organisation sees room for improvement. These causal chains can be further elaborated in policy and strategy document and targets can be set for them. Consequently the PMS which is designed around these same selected causal chains monitors the attainment of these targets for each of the factors in the causal chains. Especially synchronizing policy, strategy and the PMS is predicted to be the strength of the LoS, as all off these three are based upon the same selected causal chains. This creates a shared basis.

The biggest weakness of the framework is its poor capability to cope with cross connections. Those are connection between factors that run horizontally across the framework or in between two or more separate lines of sight. Especially the cross connections that run between two separate lines of sight create the risk of sub optimization. Another weakness is that the framework can hardly incorporate

organizational aspects such as collaboration that do not directly affect the assets, but do in a longer time span.

Kaplan and Norton stated that the formulation of strategies is an art and it would, in their eyes, remain so. Nevertheless, they claim that the description of strategy should not be an art. We would like to conclude with a citation from their work that, we believe, summarizes the essence of the strategy map that forms the basis of the developed LoS framework:

> *If people can describe strategy in a more disciplined way, they will increase the likelihood of it successful implementation. […] Strategy implies the movement of an organization from its present position to a desirable but uncertain future position. Because of the organization has never been to this future place, the pathway to it consists of a series of linked hypotheses. A strategy map specifies these cause-and-effect relationships, which makes them explicit and testable. The key, then, to implementing strategy is to have everyone in the organization clearly understand the underlying hypotheses, to align all organizational units and resources with those hypotheses, to test the hypotheses continually, and to use those results to adapt as required. (Kaplan & Norton, 2000, p. 176)*

9.3 Recommendations for future research

9.3.1 More naturalistic evaluation

It was found that the closer the evaluation is to the actual environment where the LoS is applied, the better insights generated. Predictive evaluation proved to be a useful tool for quickly evaluating the potential applications of the LoS framework, but when the lines of sight were built for the MaT organisation practical application problems became apparent for which consequently guidelines were developed.

Operational levels

A limitation in this research was that the service provider of the rail infrastructure system could not be interviewed. We feel that many practical insights are to be gained in the area of the activity layers. Especially the lines of sight on availability and safety were not fully explored as they had a large share of factors that related to the maintenance process. Developing the same LoS with an expert from another organisation is considered to be a good way of collecting the most reliable information.

In this research individual interviews were performed, but no workshop sessions with multiple stakeholders simultaneously were carried out. In the previous chapter we also argued that through building the lines of sight personnel could chose for strategic behaviour as to push their own agendas. Building a LoS in collaboration with multiple stakeholders is considered to be an effective way to counter potential strategic behaviour. We recommend developing two lines of sight separately on the same topic with experts from two organisations, and later unify these lines of sight in a workshop.

Different context

This case study research has been performed in a light rail context for an organisation that calls itself asset owner and asset manager. The environment in which any organisation operates is unique in composition of stakeholders. This consequently leads to different sets of values that each organisation has to fulfil. Although some values are generic, like cost efficiency, the way these values are interpreted might be different. Of course, there is also differentiation in the scope of values. We encourage the appliance of the LoS framework in different organisations that operate in different

sectors, public or commercial, in order to generate insight to the generic applicability of the LoS framework.

Application of the framework
The developed lines of sight have not been applied for actual policy and strategy formulation nor the creation of a PMS. The evaluation in relation the policy, strategy and the PMS was of a predictive nature. We recommend that actual policy and strategy formulation is done on the basis of developed lines of sight, eventually followed by the creation of a PMS.

9.3.2 Expansion of the framework

Programming and investment layer
In the discussion chapter the new programming and investment layer was proposed. The programming relates to maintenance programming and the investment to the acquirement of new assets from a life cycle perspective. This allows for the inclusion of improvements in the field risk based maintenance and life cycle costs analyses respectively. Many improvements in the form of information technology and asset management competencies can connect to the factors in the programming and investment layer we suspect, as this especially relates to asset management on a tactical level. The inclusion of this layer enhances the capability of the LoS framework to include some organizational aspects that do not directly influence to the technical aspects.

Additional layers to capture collaboration
Besides these aforementioned improvement measures that were frequently presented in the MaT policy and strategy, collaboration was also a reoccurring organizational aspect that did not fit well into the LoS framework. Collaboration is difficult to measure: when can collaboration be said to be effective? Can particular breakthroughs be accounted for by successful collaboration? That collaboration is of great influence for many of the technical aspects is indisputable. Perhaps collaboration will never fit into the LoS framework as one of the guidelines stated that factors needed to be measurable. We recommend great caution trying to implement such a hardly quantifiable, let alone definable, concept as collaboration.

Line of sight framework for other domains
We already argued in the previous subsection that future research should at least expand itself to operational field of the service provider in order to better grasp the activity layers and seek for new guidelines that can be distilled. Next to that, the LoS framework can also be expanded over the various domains. As it is now, the actions of the carrier are included in the activity layer. The carrier may have an entire LoS on its own that is much more focussed on activities that have a direct influence on stakeholder values. The LoS framework can perhaps not be copied one-on-one and be used by the carrier. This might require a change of order in the perspectives. Mapping the interface between the various domains is expected to be a complex task. We foresee a challenge in visually presenting these overlapping domains in a comprehensible matter. It is recommended to first develop a separate LoS for the carrier and later try to integrate it with the LoS of the infrastructure manager.

9.3.3 Weaknesses of the framework

Cross connections
In this research some cross connections are included in the lines of sight that were displayed with reference factors. We do not claim this is the best way to present these cross connections in the LoS framework, but it surely keeps the LoS comprehensible.

Because of the strong emphasis of the vertical alignment of the LoS framework, the cross connections between the various factors were not actively sought. It is not known what the relative weight of the cross connections is with respect to the vertical alignment. Many questions still remain for the cross connections. Are they worthwhile to include in the LoS in the first place? And if so, what would be a structured approach to identify these cross connections without overseeing some? This latter question is perhaps the one that deserves the most attention when scrutinizing these cross connections.

Sub optimization

Performance measurement literature spoke about the necessity of performance measurement frameworks to pay attention to multiple areas within an organisation, not just the financial perspective. In this research for each value a separate LoS was developed. A possible risk is that of sub optimization as the various LoS are created separately. This issue is closely related to that of the cross connections. If the LoS does not sufficiently emphasizes the side effects of factors on other values then the issue of sub optimization may become prominent, especially if the PMS is designed in a similar fashion, namely if the performance indicators are split from one another per value.

References

Alsyouf, I. (2006). Measuring maintenance performance using a balanced scorecard approach. *Journal of Quality in Maintenance Engineering, 12*(2), 133-149.

Andrews, K. R. (1971). The concept of corporate strategy. *New York*.

Arthur, D., Schoenmaker, R., Hodkiewicz, M., & Muruvan, S. (2016). *Asset Planning Performance Measurement.* Paper presented at the Proceedings of the 10th World Congress on Engineering Asset Management (WCEAM 2015).

Atkinson, A. A., Waterhouse, J. H., & Wells, R. B. (1997). A stakeholder approach to strategic performance measurement. *Sloan management review, 38*(3), 25.

Attwater, A., Wang, J., Parlikad, A., & Russell, P. (2014). Measuring the performance of asset management systems.

Birkland, T. A. (2014). *An introduction to the policy process: Theories, concepts and models of public policy making*: Routledge.

Bourne, M., Mills, J., Wilcox, M., Neely, A., & Platts, K. (2000). Designing, implementing and updating performance measurement systems. *International journal of operations & production management, 20*(7), 754-771.

Brown, M. G. (1996). *Keeping score: Using the right metrics to drive world-class performance*: AMACOM Div American Mgmt Assn.

Bruns, W. J., Jr. (1998). *Profit as a performance measure: powerful concept, insufficient measure.* Paper presented at the First International Conference on Performance Measurement, Cambridge.

Cochran, C. E., Mayer, L. C., Carr, T., Cayer, N. J., & McKenzie, M. (2015). *American public policy: An introduction*: Nelson Education.

De Bruijn, H. (2007). *Managing performance in the public sector*: Routledge.

De Haan, A. R. C., & De Heer, P. (2012). *Solving Complex Problems: Profressional Group Decision-Making Support in Highly Complex Situations*. The Hague: Eleven International Publishing.

De Moor, A. (2017) *Interview sessions with Andre de Moor (asset manager tram at MaT) on performance measurement, sactioning and the collaboration with GVB/Interviewer: B. Vogelaar*.

De Vrind, M. (2017) *Interview with asset manager at GVB on performance measurement and the collaboration with MaT/Interviewer: B. Vogelaar*.

Dye, T. R. (1995). *Understanding public policy [by] Thomas R. Dye*.

Enserink, B., Kwakkel, J., Bots, P., Hermans, L., Thissen, W., & Koppenjan, J. (2010). *Policy analysis of multi-actor systems*: Eleven International Publ.

Fernández-Muñiz, B., Montes-Peón, J. M., & Vázquez-Ordás, C. J. (2007). Safety culture: Analysis of the causal relationships between its key dimensions. *Journal of safety research, 38*(6), 627-641.

Fitzgerald, L., Johnston, R., Brignall, T. J., Silvestro, R., & Voss, C. (1991). *Performance Measurement in Service Businesses*. London: Chartered Institute of Management Accountants.

Hartmann, A., & Dewulf, G. (2015). Effectiveness of infrastructure asset management at public agencies.

Hatcher, W., Whittlestone, A., Sivorn, J., & Arrowsmith, R. (2012). A service framework for highway asset management.

Hestermann, L. (2012). Line of Sight in Asset Management. *The Property Professional, 24*.

Hevner, A. (2007). A three cycle view of design science research. *Scandinavian journal of information systems, 19*(2), 4.

Hevner, A., March, S. T., Park, J., & Ram, S. (2004). Design science in information systems research. *MIS Quarterly: Management Information Systems, 28*(1), 75-105.

Houlihan, E. (2017). Nearly 56,000 American Bridges on Structurally Deficient List, New Analysis of Federal Data Shows [Press release]

Huff, A. S. (2000). 1999 Presidential address: Changes in organizational knowledge production. *Academy of management Review, 25*(2), 288-293.

IAMPro. (2017). Line of sight. Retrieved from http://iampro-e.crow.nl/what-asset-management/line-sight

Kaplan, R. S., & Norton, D. P. (1992). The Balanced Scorecard - Measures that Drive Performance. *Harvard Business Review, 70*(January-February 1992).

Kaplan, R. S., & Norton, D. P. (1996a). *The balanced scorecard: translating strategy into action*: Harvard Business Press.

Kaplan, R. S., & Norton, D. P. (1996b). Linking the balanced scorecard to strategy. *California management review, 39*(1), 53-79.

Kaplan, R. S., & Norton, D. P. (2000). Having trouble with your strategy? Then map it. *Focusing Your Organization on Strategy—with the Balanced Scorecard, 49*.

Kaplan, R. S., & Norton, D. P. (2004). The strategy map: guide to aligning intangible assets. *Strategy & leadership, 32*(5), 10-17.

Keegan, D., Eiler, R., & Jones, C. (1989). Are Your Performance Measures Obsolete. *Management Accounting, 70*(12), 45-50.

Markides, C. (2004). What is strategy and how do you know if you have one? *Business Strategy Review, 15*(2), 5-12.

Milczarek, M., & Najmiec, A. (2004). The relationship between workers' safety culture and accidents, near accidents and health problems. *International Journal of Occupational Safety and Ergonomics, 10*(1), 25-33.

Neely, A. (2005). The evolution of performance measurement research: developments in the last decade and a research agenda for the next. *International journal of operations & production management, 25*(12), 1264-1277.

Neely, A., Gregory, M., & Platts, K. (1995). Performance measurement system design: a literature review and research agenda. *International journal of operations & production management, 15*(4), 80-116.

Neely, A., Kennerly, M., & Adams, C. (2007). Performance measurement fameworks: a review. In *Business Performance Measurement*: Cambridge University Press.

Nicholas, J. M., & Steyn, H. (2017). *Project management for engineering, business and technology*: Taylor & Francis.

Nickols, F. (2012). Strategy: Definitions and Meanings. Retrieved from http://www.nickols.us/strategy_definition.htm

NRC. (2016). Merwedebrug in reparatie. *NRC.* Retrieved from https://www.nrc.nl/nieuws/2016/10/18/haarscheurtjes-merwedebrug-in-reparatie-4877768-a1527251

Parida, A. (2012). Asset performance assessment. In *Asset management* (pp. 101-113): Springer.

Parida, A., & Chattopadhyay, G. (2007). Development of a multi-criteria hierarchical framework for maintenance performance measurement (MPM). *Journal of Quality in Maintenance Engineering, 13*(3), 241-258.

Parida, A., Kumar, U., Galar, D., & Stenström, C. (2015). Performance measurement and management for maintenance: a literature review. *Journal of Quality in Maintenance Engineering, 21*(1), 2-33.

Parlikad, A., & Jafari, M. (2016). Challenges in infrastructure asset management.

Pintelon, L., & Parodi-Herz, A. (2008). Maintenance: An Evolutionary Perspective. In *Complex System Maintenance Handbook* (pp. 21-48). London: Springer London.

Prenger, F. (2017). Forse toename storingen bruggen en tunnels. *EenVandaag.* Retrieved from http://binnenland.eenvandaag.nl/tv-items/71343/forse_toename_storingen_bruggen_en_tunnels

Sandford, S. (1985). Better livestock policies for Africa.

Soetenhorst, B. (2011). Gemeente Amsterdam introduceert Dienst Metro. *Het Parool*. Retrieved from https://www.parool.nl/amsterdam/gemeente-amsterdam-introduceert-dienst-metro~a1874159/

SRA. (2013). *Convenant Beheer en Onderhoud railinfrastructuur Amsterdam 2013 tot en met 2024*.

SRA. (2015). *Visie lokaal spoor Stadsregio Amsterdam 1 december 2015 - 30 november 2019*. Retrieved from https://zoek.officielebekendmakingen.nl/bgr-2015-397.pdf.

Stefanou, C. J. (2001). A framework for the ex-ante evaluation of ERP software. *European Journal of Information Systems, 10*(4), 204-215.

The Institute of Asset Management, I. (2008a). PAS 55 Part 1: Specification for the optimised management of physical assets. In. UK: British Standards Institution.

The Institute of Asset Management, I. (2008b). PAS 55 Part 2: Guidelines for the application of PAS55-1. In. UK: British Standards Institution.

Thomson, A. M., Perry, J. L., & Miller, T. K. (2007). Conceptualizing and measuring collaboration. *Journal of Public Administration Research and Theory, 19*(1), 23-56.

Too, E. G., & Tay, L. (2008). *Infrastructure Asset Management (IAM): Evolution and evaluation*. Paper presented at the CIB International Conference on Building Education and Research, Heritance Kandalama, Sri Lanka.

Torjman, S. (2005). *What is policy?* : Caledon Institute of Social Policy Ottawa, Canada.

Van Aken, J. E. (2005). Management research as a design science: Articulating the research products of mode 2 knowledge production in management. *British journal of management, 16*(1), 19-36.

Van der Lei, T., Herder, P., & Wijnia, Y. (2012). *Asset management*: Springer.

Venable, J., Pries-Heje, J., & Baskerville, R. (2016). FEDS: a framework for evaluation in design science research. *European Journal of Information Systems, 25*(1), 77-89.

Verdenius, R. (2017) *Interview sessions with Rik Verdenius on the MaT policy and strategy/Interviewer: B. Vogelaar*.

Wijnia, Y., & De Croon, J. (2015). The asset management process reference model for infrastructures. In *9th WCEAM Research Papers* (pp. 447-457): Springer.

Wijnia, Y., & Herder, P. (2010). The state of asset management in The Netherlands. In *Engineering Asset Lifecycle Management* (pp. 164-172): Springer.

Zuashkiani, A., Rahmandad, H., & Jardine, A. K. (2011). Mapping the dynamics of overall equipment effectiveness to enhance asset management practices. *Journal of Quality in Maintenance Engineering, 17*(1), 74-92.

Appendix A: PAS55 planning system

A.1 The planning system: an overview

The PAS55 standard prescribes a planning system that is composed of an asset management policy, an asset management strategy, asset management objectives and asset management plans. The policy, in turn, is based on the organizational strategic plan. The organizational strategic plan is defined as (The Institute of Asset Management, 2008a):

> *"Overall long-term plan for the organization that is derived from, and embodies, its vision, mission, values, business policies, stakeholder requirements, objectives and the management of its risks."*

Simply put, it are the requirements and expectations from the stakeholders and the legal requirements that provide the legitimacy of an organizations existence. Legal requirements can be laws and rules imposed by regulators in the case of a utility, infrastructure operator or other network operators.

Figure 37 presents an overview of the PAS55 planning system.

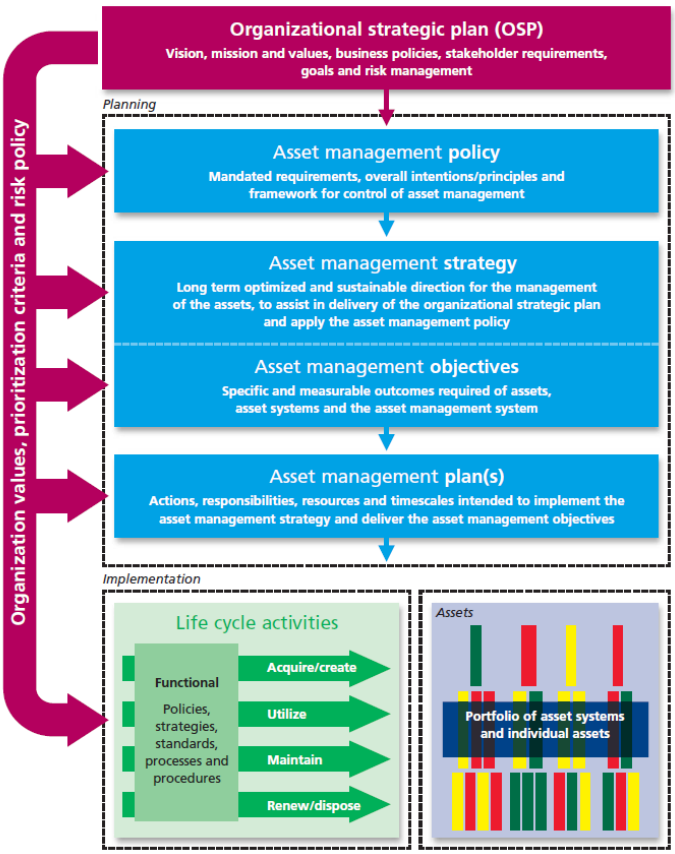


Figure 37: The PAS55 planning system (The Institute of Asset Management, 2008a)

Many of the PAS55 planning system elements have a list of various requirements set to them in the PAS55-1 standard. The PAS55-2 provides additional explanation to each of these requirements. It is

from this more elaborate explanation provided definitions, of what comprises policy or strategy for instance, come to the front. The PAS55 sets all kinds of requirements to these documents, but only those that are related to creating a LoS are elaborated in more detail in the following sections.

A.2 PAS55 policy

What distinguishes the PAS55 policy from typical policies, first of all, is that it should be derived and consistent with the organizational strategic plan (The Institute of Asset Management, 2008a). The PAS55 standard considerers the OSP not be part of the PAS55 management system. The organizational strategic plan consists of the vision, missions and values, general company policy, goals and organizational strategies (The Institute of Asset Management, 2008b). These are in part based on the stakeholder expectations. The PAS55 standard does not specify however how this translation of stakeholder expectations from goals takes place. In this research the stakeholder values were identified through a stakeholder analysis, which were consequently defined through specific factors.

The asset management policy is the first document to be created and part of the asset management system. In the words of the PAS55 standard it 'provides the framework around which the asset management strategy, objectives and plans' are to be developed. It is also said to be a high level statement of the organizational principles, approach and expectations relating to asset management. Moreover, it is stated to be a means for top management to communicate its position and intentions regarding asset management towards the stakeholders and employees. So far, the PAS55 is very evasive on what exactly defines policy. We found in the previous subsection that policy is at least about stakeholder interests and the respective goals that follow from these. Perhaps the most specific hint that is provided in relation to stakeholder requirements is provided in one of the steps to be taken in setting up asset management policy:

> *Identify the requirements of the organizational strategic plan in terms of how it will be achieved through the management of physical assets, and the principles that should be applied. These should reflect the requirements and potentially conflicting expectations of the organization's stakeholders. (p. 4)*

This is the only time a connection is made with the stakeholder's requirements and the principles[5] *to be used in doing so. Simultaneously it states how these stakeholder requirements should be achieved through the management of physical assets. One might argue that these are the high level mechanisms by which these requirements are met, but this is exactly what the PAS55 standard says about the strategy.* A similar point is brought forward when the PAS55 standard states:

> *"The asset management policy should clearly define how it […] enables achievement of the organization vision, mission and business objectives." (p. 4)*

Again the PAS55 policy encourages to answer the how question. All in all, the PAS55 is not explicit what exactly comprises a definition of policy. It gives various requirements about what should be in the policy, while some of these in fact rather belong to the strategy. The standard provides an exemplary text by which a policy document can be started. It contains many ideograms and ambiguous language. The PAS55 provides an example statement:

[5] *Principles are norms, rules or values that represent what is desirable and positive for a person, group, organization, or community.*

"We are committed to maximizing the return on our shareholder's investments through providing high value services to our customers in a legally and environmentally compliant and sustainable manner, without compromising the health and safety of our employees, customers or the public. We shall achieve this by..." (p. 4)

Policy statements like these often leave us with more questions than answers. For instance, what do customers consider to be of value, and when is this value then said to be high? Or, when are the organizational activities healthy and safe? How is safety defined in the first place? Defining these high level and abstract stakeholder requirements is what we think should be done in the asset management policy document.

A noteworthy requirement is that the PAS55 states that the policy should consider risks, objectives, strategy, constraints, boundaries, timescales and responsibilities. This is rather remarkable as the policy document is the first in line when making the planning system, while these considerations typically follow after the policy.

A.3 PAS55 strategy

The asset management strategy should, according to the PAS55 standard, 'set out how the asset management policy will be achieved'. It describes at high level the mechanisms used to achieve the requirements of PAS55 throughout the activities of the organisation such as prioritization, optimization and sustainability (The Institute of Asset Management, 2008a). What the requirements of PAS55 are is not specified however, but we assume these are the objectives from the organizational strategic plan. The standard also states that the strategy "should make reference to improvement programmes and provide long-term guidance on continuous improvement" (The Institute of Asset Management, 2008b, p. 6). It does not state that these improvements should connect to the high level mechanisms that aim to achieve the OSP.

The PAS55 definition of strategy seems reasonably line with the one found from literature, as it tries to make a bridge between policy goals on the one hand and improvement programmes on the other. These improvement programmes in turn are comprised of plans. These plans are recognized as a separate element in the PAS55 planning system.

Ironically enough the asset management strategy should identify and consider the requirements of relevant stakeholders. It is also said that it should be derived from, and be consistent with, the asset management policy and the OSP. Here we see a clear overlap or even a confusion in definitions. In the beginning of this chapter we stated that the policy should answer the 'what to achieve' question and the strategy about 'how to achieve' question.

An immediate problem arises to the front when formulating the asset management strategy according to the PAS55 standard. If safety is one of the values identified in the asset management policy to be of great importance, then the asset management strategy deals with the question how this is safety is going to be attainted. However, in between these documents it is not specified how safety is defined. In the case of rail infrastructure safety can be derailments but can also be employee accidents. Of course, high level management have explicit definitions of what safety is according to them in many instances, but the lower layers of the organizational hierarchy may have vastly differing definitions of what safety should be.

Answering the 'how' question is not a trivial one. Here is where the LoS is suspected to be a valuable instrument as it maps the causality between all the factors that are into play in an asset intensive

environment. It provides support for thinking of new ways of working or introducing technologies that contribute to the stakeholder values.

A.4 PAS55 objectives

The PAS55 standard states that measurable objectives should be set that

> *"[…] enable the asset management policy to be implemented and the asset management to be achieved."*

From scrutinising the policy definition it became apparent that policy documents typically contain stakeholder values that are translated into concrete goals or objectives. PAS55 takes a, rather remarkable, approach and puts the goals (or objectives) outside the policy document and places it right after the strategy. This unusual positioning of objectives within the planning system was also noted by MaT when setting up their asset management policy and strategy (Verdenius, 2017). The PAS55 standard further states that potential conflicts between objectives should be identified.

Furthermore it prescribes that the objectives should be derived and consistent with the asset management strategy. These objectives should be measurable in a sense of being quantifiable or else capable of being demonstrated as achieved through objective assessment. Here again the problem of definition plays a role. Values such as safety are still abstract concepts and need to be specified before objectives can be set.

Another noteworthy requirement is that the objectives should be consistent with the organization's commitment to continual improvement, next to the fact that they should be consistent with the asset management strategy. For Kaplan and Norton (1996a) strategy and continual improvement are narrowly connected as they state that strategy is a set of hypotheses about cause and effect. The lowest layer of their strategy map is concerned with learning and innovation. Therefore continual improvement is the starting point in their strategy building.

In the PAS55-2 standard a split is made between organizational objectives and asset management objectives, but no further explanation is provided about what distinguishes organizational objectives from asset management objectives.

A.5 PAS55 plans

The plans are the last element in line in the planning system. The asset management plan specifies the responsibilities, timescales and the allocation of resources. The asset management plans are in accordance with the asset management policy and strategy and its primary goal is to fulfil the asset management objectives. The mechanisms that describe how the plans eventually will fulfil the objectives is captured in the strategy. It is at the level of the plans where risk and life cycle considerations can be implemented. Plans can therefore be considered to be at the tactical level of asset management. The plans perhaps form the majority of the effort as they are numerous while there is only a single policy and strategy document, yet the causality in cause and effect is primarily captured in the strategy and the plans are the mere operationalisation of the causal connections.

Appendix B: Metro and Tram Performance measurement system

KPI	Performance Indicator	Intrinsic Factor
Safety	Safety infrastructure system	Number of derailments and collisions resulting from poor infrastructure condition
		Other safety incidents than derailments and collisions
	Safe working	Frequency of incidents
		Improper use of tools
		Number of reports of incorrect execution of work or the unjustified absence of safety supervisor
	Safety organisation	The number of observations of the noncompliance with safety precautions from the safety programme originating from audits
		The average grade for the experienced safety as evidenced by an annual survey among employees
Quality	Availability route	Availability standards set for multiple traces or individually
	Compliance with OPS	A certain number of the assets is allowed to deviate from the standard with a certain percentage
	Accessibility (metro only)	The number of reported incidents of missing, defect or incorrect: tactile pavement, double banisters on staircases and the gap between platform and vehicle or the sagging of platform height with respect to the vehicle
		Availability of elevators
		Number of stations unreachable from street to platforms longer than 15 minutes due to broken elevators more than 10 times per years
	Availability escalators	Number of stations unreachable from street to platforms longer than 15 minutes due to broken escalators more than 10 times per years
		Total availability of the escalators
	Availability security gates (metro only)	Total availability
		Availability per station
Value for money	Average age (tram only)	Subsystems should be within the bandwidth of the expected longevity
	Life cycle costs	Cost deviations type A maintenance with respect to budget
		Cost deviations type B maintenance with respect to budget
	Condition of the assets	Difference between the actual condition score and the predicted condition score

Appendix C: Lines of sight

See next pages.

Line of sight Metro & Tram Amsterdam: Beschikbaarheid (deel 1 van 2)

Legenda:

Metro specifiek | Tram specifiek | Proxy factor | Verwijzing naar ander element | Verbetering

Waarden

Definitielaag

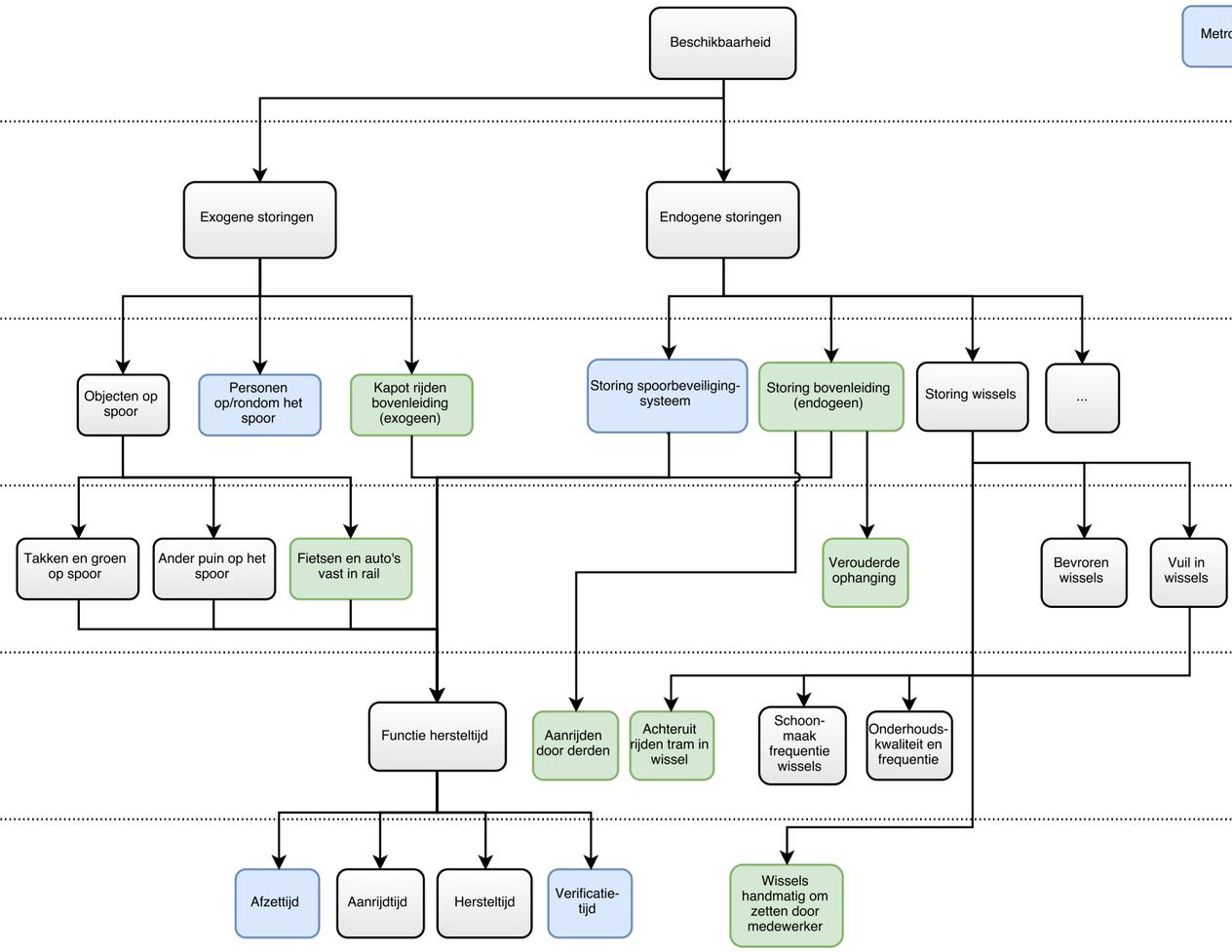
Assetlaag 1

Assetlaag 2

Activiteitlaag 1

Activiteitlaag 2

Verbeterlaag



Line of sight Metro & Tram Amsterdam: Beschikbaarheid (deel 2 van 2)

Legenda:

Metro specifiek | Tram specifiek | Proxy factor | Verwijzing naar ander element | Verbetering

Waarden

Definitielaag

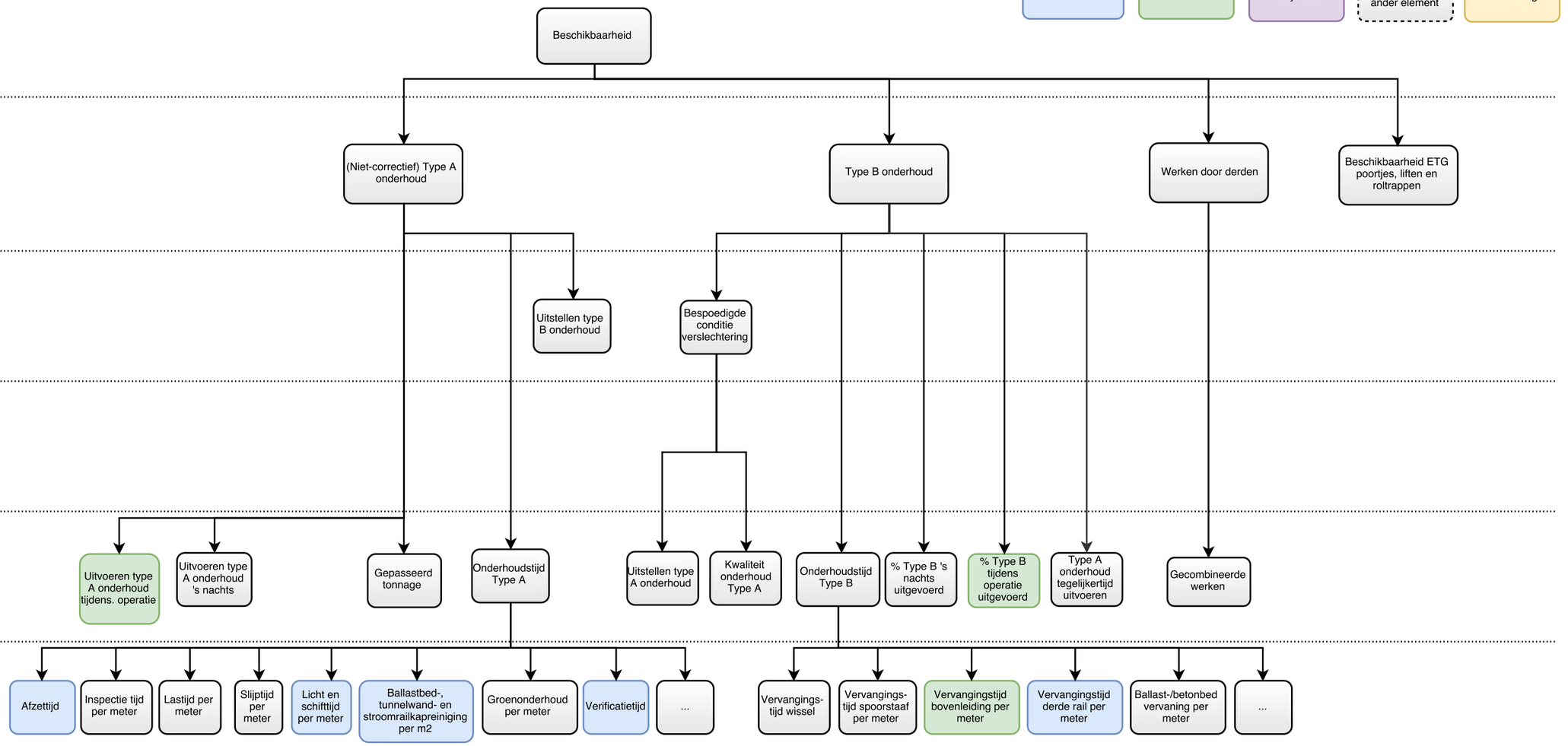
Assetlaag 1

Assetlaag 2

Activiteitlaag 1

Activiteitlaag 2

Verbeterlaag



Line of sight Metro & Tram Amsterdam: Duurzaamheid (deel 1 van 2)

Legenda:

Metro specifiek | Tram specifiek | Proxy factor | Verwijzing naar ander element | Verbetering

Waarden

Definitielaag

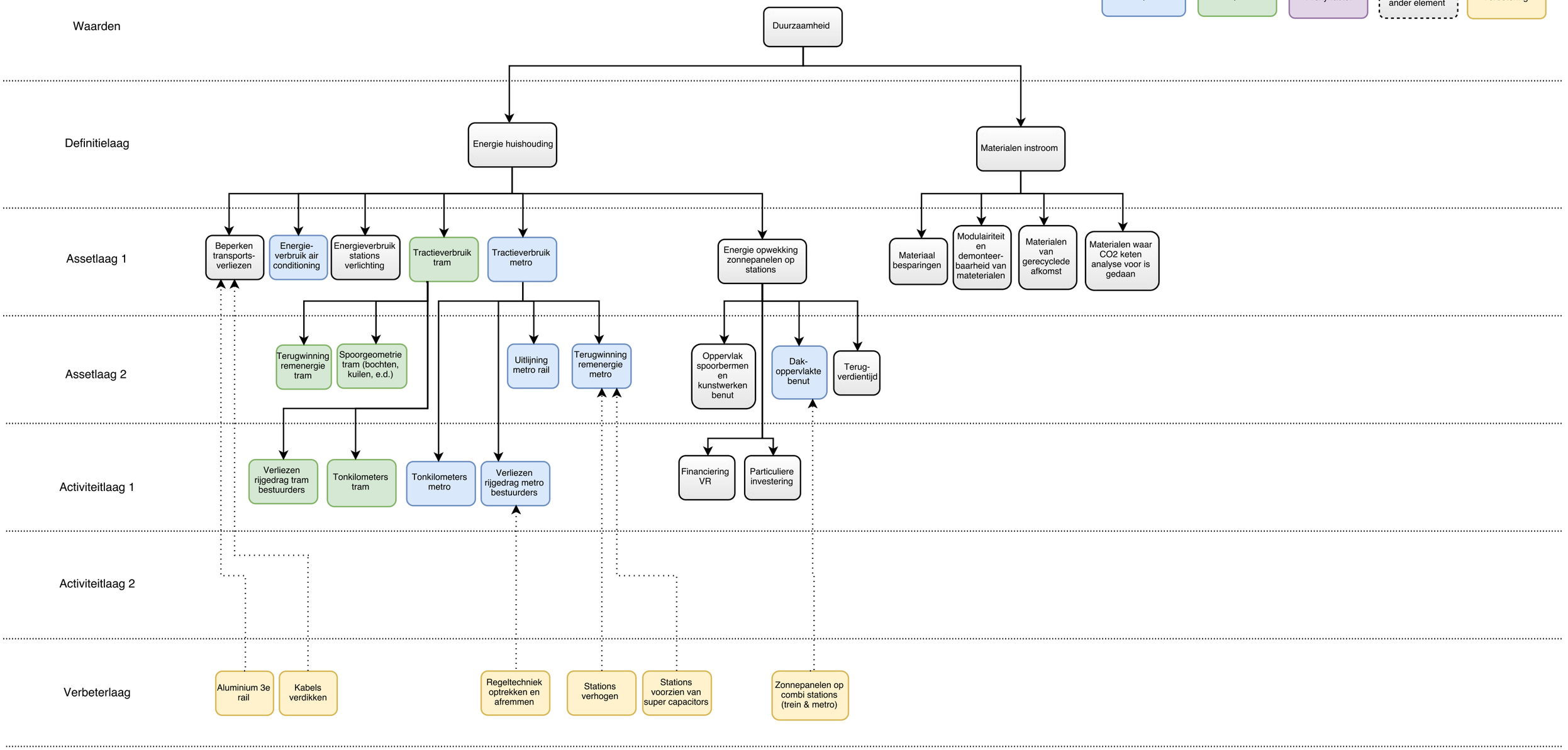
Assetlaag 1

Assetlaag 2

Activiteitlaag 1

Activiteitlaag 2

Verbeterlaag



Line of sight Metro & Tram Amsterdam: Duurzaamheid (deel 2 van 2)

Legenda:

Metro specifiek | Tram specifiek | Proxy factor | Verwijzing naar ander element | Verbetering

Waarden

Definitielaag

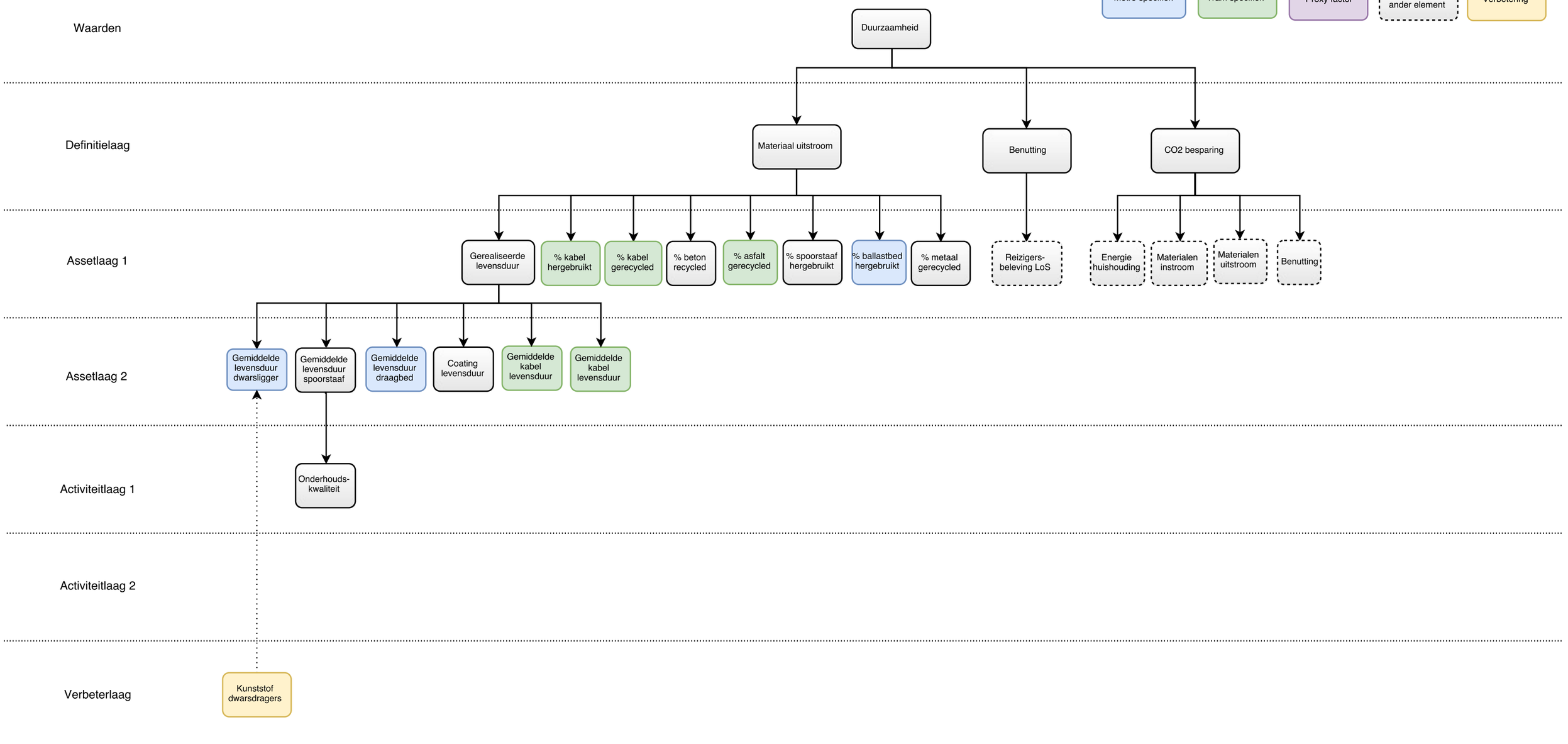
Assetlaag 1

Assetlaag 2

Activiteitlaag 1

Activiteitlaag 2

Verbeterlaag



Line of sight Metro & Tram Amsterdam: Kostenefficiëntie

Legenda:

Metro specifiek | Tram specifiek | Proxy factor | Verwijzing naar ander element | Verbetering

Waarden

Definitielaag

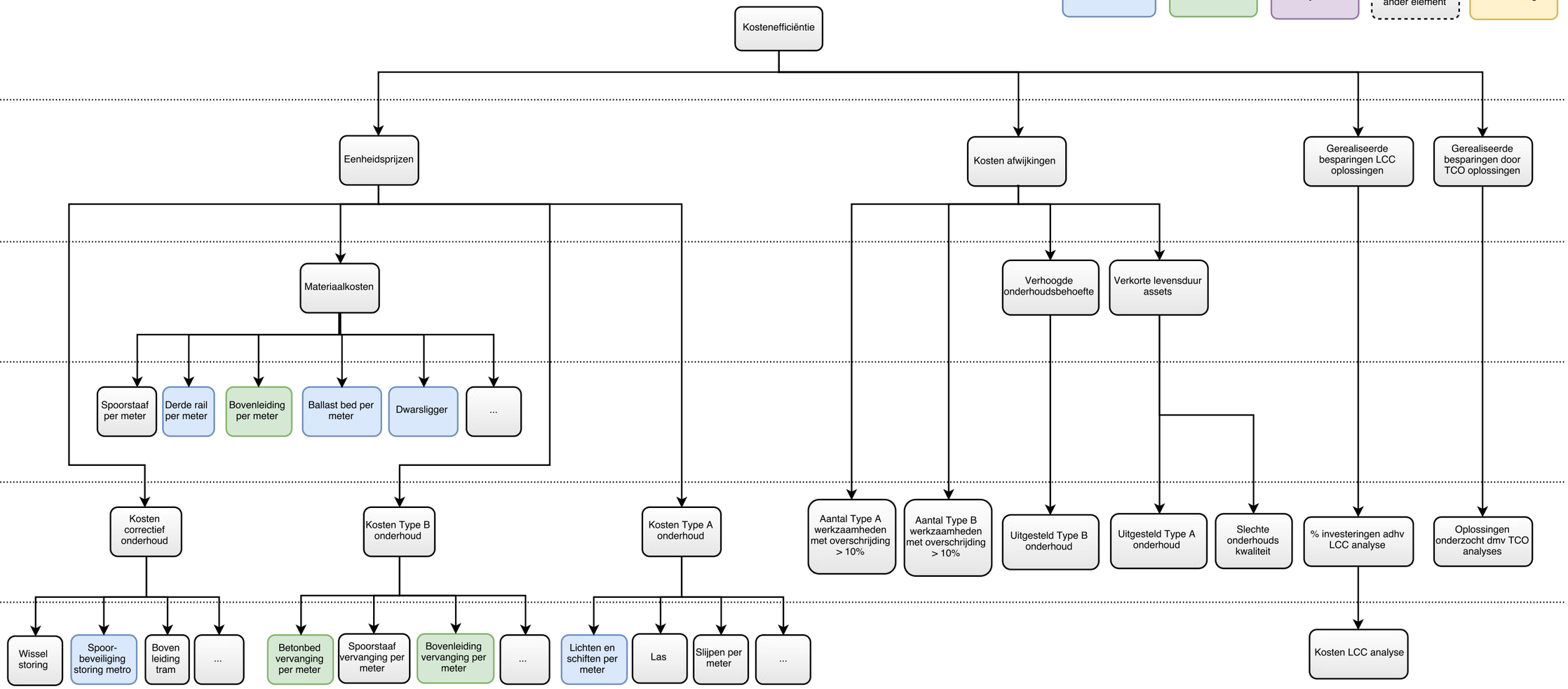
Assetlaag 1

Assetlaag 2

Activiteitlaag 1

Activiteitlaag 2

Verbeterlaag



Line of sight Metro & Tram Amsterdam: Leefbaarheid

Legenda:

Metro specifiek | Tram specifiek | Proxy indicator | Verwijzing naar ander element | Verbetering

Waarden

Leefbaarheid

Definitielaag

Geluidsoverlast

Emissie van stoffen

Verkeershinder medeweggebruiker

Assetlaag 1

Aanwezigheid geluidsschermen

Fijnstof deeltjes tbv tractie elders uitgestoten

Emissie deeltjes van derde rail

Emissie deeltjes van bovenleiding

Geen verkeers-doorstroming mogelijk

Bewegwijzering omleiding

Assetlaag 2

Activiteitlaag 1

Onderhoud uitvoeren in de nacht

Tijdelijke geluids-reducerende maatregelen

Informatie voorziening akoestische bureau's

Exploitatie intensiteit

Duur van verkeershinder

Activiteitlaag 2

Onderhoud tijdens exploitatie

Verbeterlaag

Line of sight Metro & Tram Amsterdam: Reizigersbeleving (deel 1 van 2)

Legenda:

Metro specifiek | Tram specifiek | Proxy factor | Verwijzing naar ander element | Verbetering

Waarden

Definitielaag

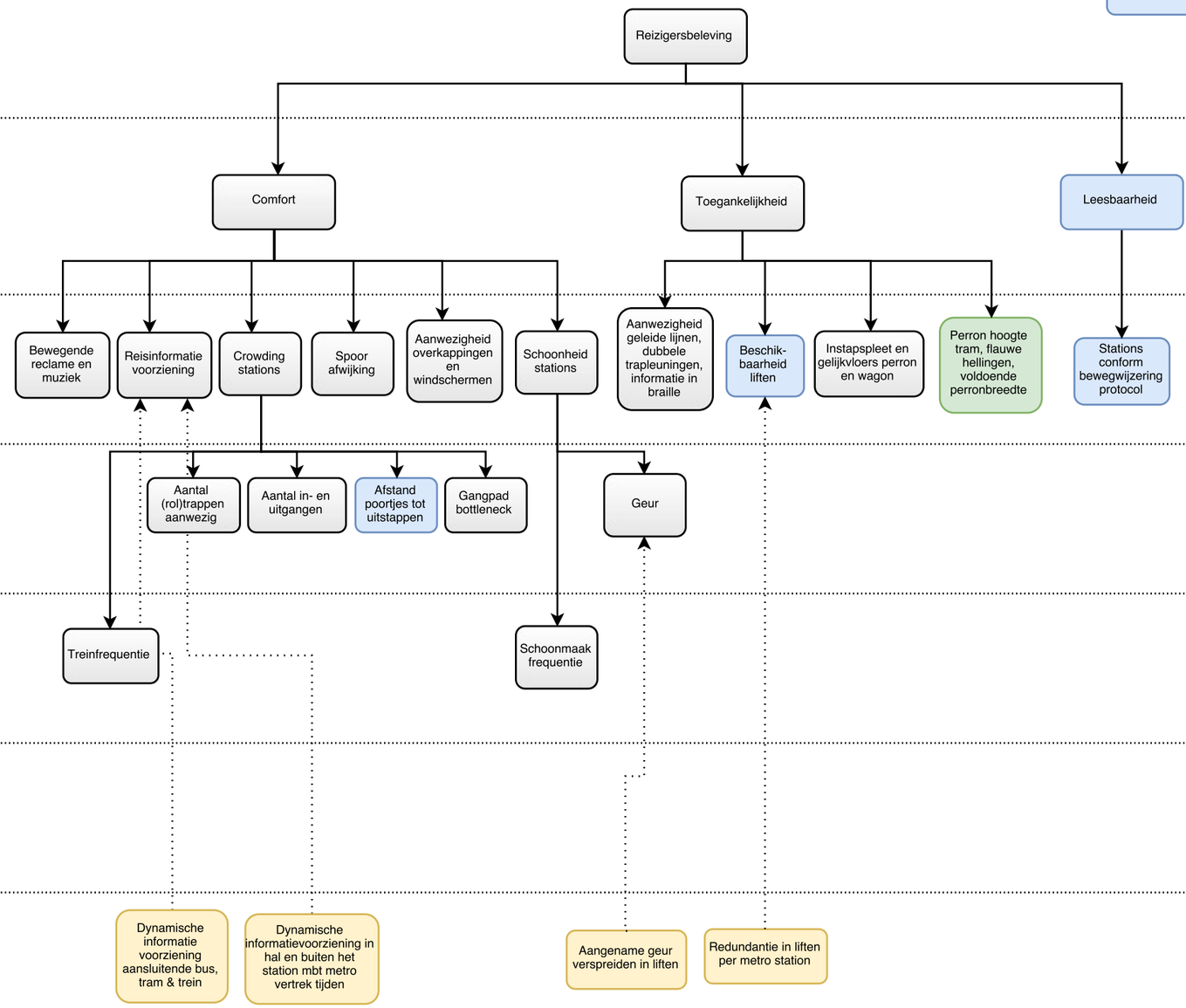
Assetlaag 1

Assetlaag 2

Activiteitlaag 1

Activiteitlaag 2

Verbeterlaag



Line of sight Metro & Tram Amsterdam: Reizigersbeleving (deel 2 van 2)

Legenda:

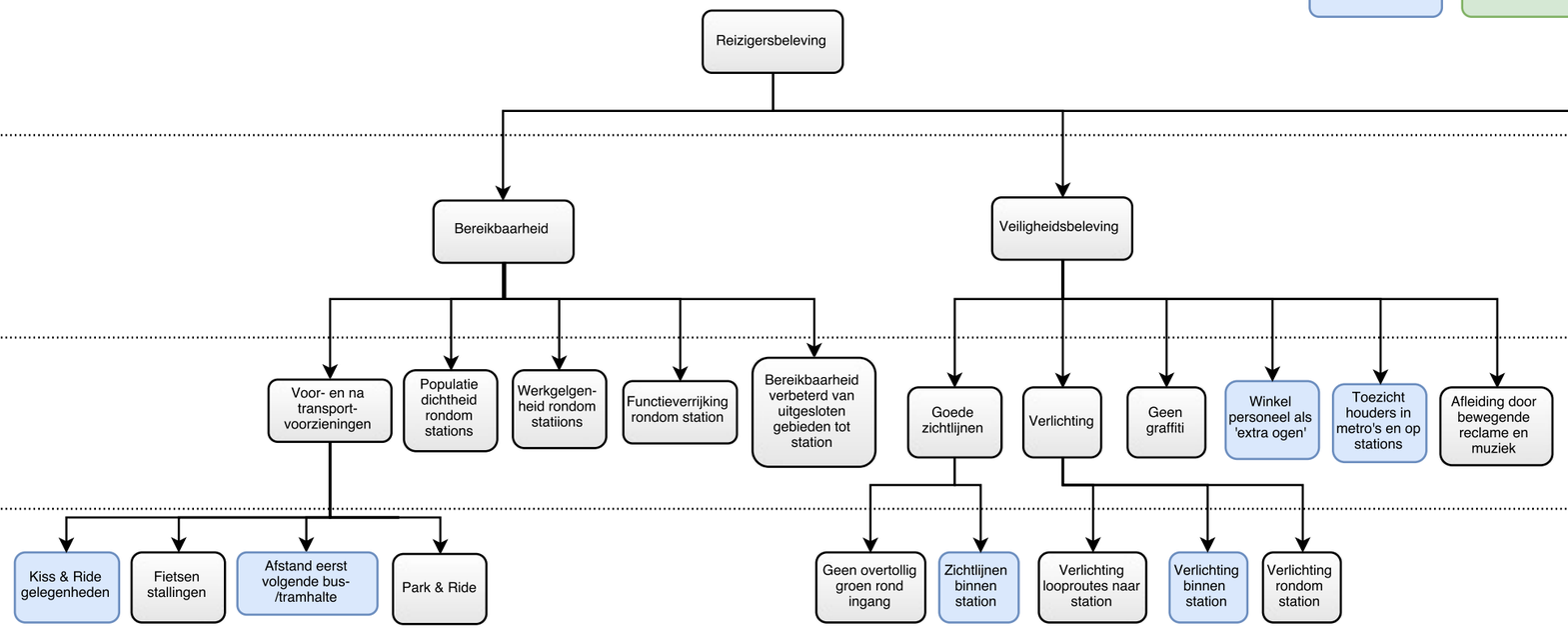
Metro specifiek | Tram specifiek | Proxy factor | Verwijzing naar ander element | Verbetering

Waarden

Definitielaag

Assetlaag 1

Assetlaag 2



Activiteitlaag 1

Activiteitlaag 2

Verbeterlaag

Line of sight Metro & Tram Amsterdam: Veiligheid

Legenda:

Metro specifiek | Tram specifiek | Proxy factor | Verwijzing naar ander element | Verbetering

Waarden

Veiligheid

Definitielaag

Ontsporingen / botsingen verwijtbaar aan gebrekkige infrastructuur

Andere incidenten dan botsingen en ontsporingen

Ongevallen

Cijfer veiligheidscultuur

Assetlaag 1

Slijtage spoorkop

Spoorstaafbreuk

Wisseltong ligt niet goed aan

Bevroren wissels

Bovenleiding onjuiste hoogte

Uitglijden perron

Assetlaag 2

Voldoen aan OPS spoorstaaf

Voldoen aan OPS wissels

Vuil in wissels

Conditie verwarmingselementen

Ophanging breekt door te hoge leeftijd

Activiteitlaag 1

Gepasseerd tonnage

Achteruit rijden tram in wissel

Schoonmaakfrequentie wissels

Onderhoudsfrequentie verwarmingselementen

Aanrijding door derden

Strooizout bij vorst

Foutieve uitvoering

Foutief gebruik van middelen

Aantal meldingen niet naleving

Gemaakte onderhoudsuren

Activiteitlaag 2

Onderhouds-frequentie geleidingsysteem

Onderhouds-kwaliteit

Verbeterlaag