Do we need the ISO 55000?

The added value of the ISO 55000 standard series for road infrastructure asset management

MSc Thesis

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SUMMARY

As part of the master programme of Construction Management and Engineering at the University of Twente, this research is executed to find an answer to the following question:
'What is the added value of the ISO 55000 standard for the owners of Dutch road infrastructure Asset Management systems, and how can the ISO 55000 standard contribute to the Dutch road infrastructure sector?'

The research was conducted through interviews, literature review and a case study. First, the subject of Asset Management (AM) and the ISO 55000 standard are examined. AM is the term for the coordinated activities of an organisation to realize value from its assets. This is executed by finding the optimal balance between costs, performance and risks. The ISO 55000 standard describes what elements should be included in an AM system and the standard formulates requirements for such a system. These requirements can be found in ISO 55001.

Following is the analysis of the implementation of two comparable standards, to find the different factors that influence the implementation of a standard. The first examined standard is the predecessor of the ISO 55000, the PAS 55 from the UK. The second examined standard is another management system standard, the ISO 9000. This examination is done through interviews and a literature study. From this examination it became clear that a number of factors influence the implementation of a standard:

- the demand for improvements
- the demand for standardisation
- the degree of regulation
- the motivation of the organisation for implementing a standard
- the involvement of countries and multinational organisations
- sufficient potential benefits

The next part of the research is the examination of different tunnel AM systems through interviews and literature review. The decision to examine tunnels is based on the fact that tunnels are critical elements in a network. Tunnels are seen as separate objects and are managed separately, this makes them interesting for this research. The examined tunnel systems are developed according to certain legislation, regulation and guidance material. The following documents are examined to find out to what extent the existing legislation, regulation and guidance material covers the requirements of the ISO 55001:

- The Dutch 'Tunnelstandaard', which arises from the implementation of the WARVW and RARVW, is developed by Rijkswaterstaat (RWS). Developing a tunnel's AM system according to the Tunnelstandaard will result in an AM system which is for 96% ISO 55001 compliant.
- The 'Leidraad Risicogestuurd Beheer en Onderhoud', which can be used to develop the operational part of an AM system, developed by RWS. Developing a tunnel's AM system according to this document will result in an AM system which is for 63% ISO 55001 compliant. This is achieved by ISO compliant operational elements, but it lacks strategic and tactical elements which meet the ISO 55001 requirements.
- The requirement specification developed by the municipality of Maastricht and ARCADIS for the long term maintenance of the Markt-Maastunnel. Developing a tunnel's AM system according to this specification results in an AM system which is for 81% ISO 55001 compliant. The major deviations can be found in the supporting requirements.
- The ISO 9001 standard for the development of a quality management system. It is not possible to develop a tunnel's AM system according to the ISO 9001 since this standard contains requirements for a quality management system. A quality management system can be used as a basis for the development of an AM system and will be compliant to the ISO 55001 requirements for 57%.

Next, different tunnel AM systems are compared to the requirements of the ISO 55001. The following tunnels are examined:

- A73 tunnels; Roertunnel and Swalmentunnel, state tunnels
- Salland-Twentetunnel, state tunnel
- Waterwolftunnel, provincial tunnel
- Markt-Maastunnel, municipal tunnel
- Tunnels of Amsterdam; IJtunnel, Piet Heintunnel and the Michiel de Ruijtertunnel, municipal tunnels

This research shows that the AM systems of the examined state tunnels meet all the requirements of the ISO 55001. This is the result of the implementation of the different guidance documents they have developed. RWS can be seen as the leading organisation in this area in the Netherlands and has developed a lot of guidance material about tunnel management and AM. Provinces and municipalities do not have all the possibilities an organisation like RWS has. The AM system of the Markt-Maastunnel corresponded to most of the ISO 55001 requirements, the Waterwolftunnel and the tunnels of the municipality of Amsterdam did not meet many ISO 55001 requirements. In practice, this is mostly not seen as a large problem and none of the examined organisations intended to become ISO 55001 certified.

Concluding, the added value, the downsides, and the possible contributions of the ISO 55000 for the Dutch road infrastructure sector are explained.
The added value of the ISO 55000 consists of:

- The ISO 55000 offers a structure for the development of an AM system;
- The ISO 55000 can be used for the development of an AM system for the management of specific objects, or an entire (infrastructure) AM system;
- The standardisation of processes of an organisation delivers added value.

The downsides of the ISO 55000 for the Dutch road infrastructure sector are:

- The ISO 55000 standard is developed for AM system owners who also own the (major part of) the asset portfolio;
- The ISO 55000 is too general;
- More specific documents are available for the development of the AM system of a tunnel.

The contribution of the ISO 55000 for the Dutch road infrastructure sector is different for every asset owner and asset manager. Some of the factors that influence the implementation of a standard are beneficial for the implementation of the ISO 55000. The Dutch road infrastructure sector demands improvement and standardisation. The standard can provide benefits for many organisations, and the governmental asset owners have the right motivation. The less stimulating factors are that RWS has decided not to implement the ISO 55000, and the general road infrastructure sector's regulation does not demand standardisation.
The national road tunnels manager (RWS) has guidance material for the implementation of an AM system that is beyond the ISO 55000. Provincial and municipal road tunnel managers do not use this so far. These organisations have to decide if they want to follow on to the procedures of RWS, or if they want to develop their own tunnel AM systems according to the ISO 55000.

Resulting from this research are recommendations specifically for the AM of tunnels, AM in the general road infrastructure sector, and how ARCADIS should deal with accreditation. Dutch tunnels AM systems should be developed according to the Tunnelstandaard.
Opportunities appear for ARCADIS in the area of the Dutch provincial and municipal infrastructure asset owners. At state infrastructure, there are not much opportunities for ARCADIS because RWS is one of the pioneers in Dutch AM. At a tactical level, ARCADIS can offer its services to RWS. However, the bulk of the work has to come from the municipal and provincial assets. Working as a managing agent or consulting these asset owners with or without the ISO 55000 can be beneficial for ARCADIS. ARCADIS can assist service providers in becoming a trustworthy partner in an AM system.

SAMENVATTING

Als onderdeel van de masteropleiding Construction Management and Engineering aan de Universiteit Twente is dit onderzoek uitgevoerd om de volgende onderzoeksvraag te beantwoorden:
'Wat is de toegevoegde waarde van de ISO 55000 voor de eigenaren en beheerders van Nederlandse droge infrastructuur assets, en wat kan de ISO 55000 bijdragen aan deze sector?'

Het onderzoek is uitgevoerd door middel van interviews, literatuuronderzoek en een case studie. Eerst wordt uitgelegd wat Asset Management (AM) is, en wordt de ISO 55000 norm nader bekeken. AM is de naam voor de gecoördineerde activiteiten van een organisatie om waarde te genereren uit haar assets. Dit wordt gedaan door de optimale balans te zoeken tussen kosten, prestaties en risico's. De ISO 55000 norm beschrijft de elementen die aanwezig moeten zijn in een AM systeem, en aan deze elementen worden eisen gesteld. Deze eisen zijn te vinden in de ISO 55001.

De volgende stap is het analyseren van de implementatie van twee andere standaarden. Hierbij wordt gezocht naar de factoren die dit proces beïnvloeden. De eerste norm is de PAS 55 uit Engeland, dit is de voorloper van de ISO 55000. De andere onderzochte norm is de ISO 9000, dit is een norm die ook eisen beschrijft voor een management systeem. Deze analyse is gedaan door middel van interviews en een literatuur studie. Er is gebleken dat een aantal factoren de implementatie van een norm beïnvloeden:

- de vraag naar verbetering
- de vraag naar standaardisatie
- de mate van regulering
- de motivatie van een organisatie om een norm in te voeren
- de mate waarin regeringen en multinationals zich met de norm bezig houden
- er moeten genoeg potentiele voordelen zijn.

Het volgende onderdeel van het onderzoek bestaat uit het bekijken van verschillende tunnel management systemen. Er is gekozen om tunnels te onderzoeken omdat dit kritieke elementen in een wegennet zijn, en dat ze vaak als gescheiden objecten worden behandeld, onder andere het beheer en onderhoud worden gescheiden behandeld. De management systemen van deze tunnels zijn ontwikkeld aan de hand van bepaalde wetten, leidraden of andere documenten. Deze documenten zijn onderzocht om te kijken in welke mate ze de eisen bevatten die gesteld worden in de ISO 55001:

- De Tunnelstandaard, welke door RWS is ontwikkeld na het uitkomen van de WARVW en de RARVW. Het ontwikkelen van een tunnel AM systeem aan de hand van dit document resulteert in een systeem die voor 96% overeenkomt met de eisen gesteld in de ISO 55001.
- De Leidraad Risicogestuurd Beheer en Onderhoud, welke ook door RWS is ontwikkeld en gebruikt kan worden voor het operationele deel van het AM systeem. Het ontwikkelen van een tunnel AM systeem aan de hand van dit document resulteert in een systeem dat voor 63% overeenkomt met de eisen van de ISO 55001. De eisen voor operationele elementen komen voor het grootste deel overeen.
- De vraagspecificatie ontwikkeld door de gemeente Maastricht en ARCADIS voor het langjarig onderhoud van de Markt-Maastunnel. Het ontwikkelen van een tunnel AM systeem aan de hand van dit document resulteert in een systeem dat voor 81% overeenkomt met de eisen van de ISO 55001. De eisen voor de ondersteunende elementen ontbreken voor een groot deel.
- De ISO 9001 norm voor het ontwikkelen van een kwaliteitsmanagementsysteem. Het is niet mogelijk om een AM systeem te ontwikkelen aan de hand van dit document, maar het ontwikkelen van een kwaliteitsmanagementsysteem levert al wel een goede basis voor een AM systeem. Deze zal hierdoor voor 57% overeenkomen met de eisen uit de ISO 55001.

Vervolgens worden bestaande AM systemen van tunnels vergeleken met de eisen uit de ISO 55001. De volgende tunnels zijn onderzocht:

- A73 tunnels; Roertunnel en Swalmentunnel, Rijksoverheid
- Salland-Twentetunnel, Rijksoverheid
- Waterwolftunnel, provincie Noord-Holland
- Markt-Maastunnel, gemeente Maastricht
- IJtunnel, Piet Heintunnel en Michiel de Ruijtertunnel, gemeente Amsterdam

Dit onderzoek laat zien dat de AM systemen van de onderzochte rijkstunnels voldoen aan alle eisen uit de ISO 55001. Dit is te verklaren door te kijken naar de documenten die gebruikt zijn bij het ontwikkelen van deze systemen. RWS kan gezien worden als een van de meest vooruitstrevende partijen in Nederland op het gebied van AM. RWS heeft al menig begeleidend document geschreven over AM en tunnelbeheer. Provincies en gemeenten hebben meestal niet de middelen om een dergelijke ontwikkeling in gang te zetten. Het AM systeem van de Markt-Maastunnel voldeed aan een groot deel van de ISO 55001 eisen, de Waterwolftunnel en de tunnels van de gemeente Amsterdam voldeden aan vele eisen niet. Vaak wordt dit niet gezien als een groot probleem en geen van de onderzochte partijen had de intentie om daadwerkelijk de volledige ISO 55000 te implementeren.
De resultaten uit dit onderzoek geven inzicht in de toegevoegde waarde, de mindere kanten, en de mogelijke bijdrage van de ISO 55000 voor de Nederlandse weg infrastructuur.
De toegevoegde waarde van de ISO 55000 bestaat uit:

- De ISO 55000 biedt een kapstok voor de ontwikkeling van een AM systeem;
- De ISO 55000 kan gebruikt worden voor de ontwikkeling van een AM systeem voor een specifiek object, een compleet systeem of alles daartussenin;
- Het standaardiseren van processen in een organisatie kan al meerwaarde opleveren.

De mindere kanten van de ISO 55000 voor de Nederlandse weg infrastructuur zijn:

- De ISO 55000 is ontwikkeld voor AM systemen waarvan de eigenaar dezelfde is als de eigenaar van (het grootste gedeelde van) de assets;
- De ISO 55000 is heel algemeen geschreven;
- Er zijn al veel specifiekere documenten beschikbaar voor het ontwikkelen van een AM systeem

De bijdrage van de ISO 55000 voor Nederlandse weg infrastructuur verschilt per organisatie. Er zijn factoren die de uitwerking van de ISO 55000 positief beïnvloeden. Er is een vraag voor verbetering en standaardisatie in de sector. De ISO 55000 beloofd, en kan ook daadwerkelijk voordelen opleveren voor organisaties, dit komt mede doordat publieke asset eigenaren voor een groot deel intern gemotiveerd zijn. Een van de factoren die niet helpen om de ISO 55000 te verspreiden is dat regulering momenteel niet stuurt richting het gebruik van de ISO 55000. Ook heeft de grootste speler in de sector, RWS, al heeft aangegeven de ISO 55000 niet te zullen gebruiken. RWS heeft zelf al documenten ontwikkeld aan de hand waarvan ze haar AM systemen voor tunnels ontwikkelt. Deze systemen zijn al verder ontwikkeld en voldoen aan de eisen uit de ISO 55001. Provinciale en gemeentelijke tunnel managers gebruiken dit vooralsnog niet. Zij zullen moeten kiezen tussen het aansluiten bij RWS, of toch een AM systeem ontwikkelen aan de hand van de ISO 55000.

Afsluitend worden er aanbevelingen gegeven specifiek voor het AM van tunnels, AM in de Nederlandse droge infrastructuur in het algemeen, en over hoe ARCADIS om moet gaan met accrediteren. Nederlandse tunnel AM systemen moeten worden ontwikkeld aan de hand van de Tunnelstandaard. Er liggen kansen voor ARCADIS bij de Nederlandse provinciale en gemeentelijke eigenaren van infrastructuur. Bij de assets van de rijksoverheid zijn minder kansen. Dit komt vooral omdat RWS al heel vooruitstrevend is, zonder gebruik te maken van de ISO 55000. Op het tactische niveau kan ARCADIS mogelijk opdrachten krijgen van RWS. Het grootste deel van de opdrachten zal echter moeten komen vanuit provincies en gemeenten. ARCADIS kan deze partijen adviseren, of de plaats innemen van managing agent. Het is echter maar de vraag of de ISO 55000 hier een onderdeel van uit zal maken. Het laatste niveau is het operationele niveau, ARCADIS kan hier mogelijk service providers ondersteunen om gewaardeerde spelers te worden binnen AM systemen.

PREFACE

This master thesis is the outcome of the research which I have executed at ARCADIS Nederland. It is the last hurdle before I can round up the master programme Construction Management and Engineering.
I have always had, and still have, a very broad interest. The decision to study the bachelor programme of Civil Engineering (and Management), and subsequently the master programme of Construction Management and Engineering was motivated by this interest. I think the subject of this research, Asset Management, is very appropriate for someone who wants to integrate all disciplines of civil engineering into one profession. During this research I have learned a lot about Asset management, the Dutch road infrastructure sector and about the execution of a research.

ARCADIS has supported me throughout the research. I have worked on average 2 or 3 days a week at the office of ARCADIS in Amersfoort. ARCADIS Nederland is a large organisation with ca. 2000 employees working in many different areas. For this research, people from all over the organisation have helped me. Many help came from employees of the advisory group Asset Management of the Roads, Traffic and Information management department, including my daily supervisor who has introduced me to many people from all over the organisation, national and international and outside ARCADIS.
I have also obtained information from many other departments of ARCADIS, including the asset managers of the Rail department, experts of tunnel development and maintenance, other people working with road assets and many others. I even talked to employees of EC Harris, the UK subsidiary of ARCADIS.

For the examination of the tunnel cases, I was dependent on the cooperation of employees of external organisations. Employees of RWS, the Highways Agency and municipal officials and some others have cooperated to this research.

Finally, I want to thank everybody who have supported me during this research. Among others the supervisors from the university Andreas and Irina, Jos from ARCADIS, and my family and friends.

Hellendoorn, April 2015
Robert Ruiter

GLOSSARY AND ABREVIATIONS

Glossary

Asset: item, thing or entity that has potential or actual value to an organisation. (ISO, 2014)
Asset management: coordinated activity of an organisation to realize value from assets. (ISO, 2014)
Management system: set of interrelated or interacting elements of an organisation to establish policies and objectives and processes to achieve those objectives. (ISO, 2014)
Asset management system: management system for asset management whose function is to establish the asset management policy and asset management objectives. (ISO, 2014)
Infrastructure: Infrastructure is any long-life physical asset that consists of an entire system or network (including components), not otherwise defined, which provides the foundation to support public services and enhance the capacity of the economy. (LGAM, 2014)
Road infrastructure: On-land infrastructure for transportation of goods and people, that is part of or related to a road. This includes the roadway, pathway, shoulder, the structures forming part of the roadway, pathway or shoulder, the materials from which a roadway, pathway or shoulder is made and the road-related infrastructure. (LGAM, 2014)

List of abbreviations

AM	: Asset Management
BMS	: Management System (Beheers Management Systeem)
DIVV	: Dienst Infrastructuur Verkeer en Vervoer
I&M	: Infrastructure and the environment, Ministry (Infrastructuur en Milieu, Ministerie)
IAM	: Institute of Asset Management
ISO	: International Standardisation Organisation
LCC	: Life Cycle Costs
OMS	: Maintenance Management System (Onderhouds Management Systeem)
ProBO	: Probabilistic Management and Maintenance
RARVW	: Arrangement additional rules safety of road tunnels (Wet aanvullende regels veiligheid wegtunnels)
RWS	: Rijkswaterstaat
WARVW	: Law additional rules safety of road tunnels (Wet aanvullende regels veiligheid wegtunnels)

CONTENT

1. INTRODUCTION

This chapter has been written to introduce the area of research. First, the context of the research subject is examined. Second, the problem is explained. Subsequently, the research objective is described, followed by the research questions and the used methodology. The last paragraph contains a reading guide for the following chapters of this thesis.

1.1 Context

The subjects of Asset Management, the Dutch road infrastructure sector, the maintenance of the different objects in the infrastructure sector and the different involved parties are a difficult matter. This paragraph is written to make these subjects more clear.

1.1.1 Road infrastructure in the Netherlands

Road infrastructure has always been a vital part of society. In the past, most cities developed at a crossroad of different modes of transportation, as this was a great opportunity for trade. The Romans were the first infrastructure planners. They have built extensive road and water infrastructure networks. The gas, rail, telecommunication, electricity and airline infrastructure are more recent infrastructure networks. (Wijnia & Herder, 2009).

From the 19th century, many large infrastructure projects were executed in the Netherlands, resulting in a country with one of the highest infrastructure densities in the world (Lintsen, 2005). The focus in these projects was mostly on new design and construction. It took years until the life-cycle stages after construction; utilization, maintenance and the final disposal and replacement (theIAM, 2012), were taken into account. The last decades there has come a change in thinking about infrastructure and its maintenance, starting with ideas coming up from the environmental ideology such as life cycle costing (Bekker, 1982). The infrastructure sector searched for methods to implement these new ideas and found their solution in asset management (AM), which was already being used for decades by other industries.

1.1.2 Increasing need for maintenance

Historically, AM focused primarily on the reliability and maintainability of assets and their functions; organisations have since then accepted the notion that a much larger array of processes govern the life and use of an asset. In the future there will be an increased emphasis on infrastructure maintenance, and the construction of new roads will only decrease. Due to this, AM will become more important. It encompasses elements of: strategy; economic accountability; risk management; safety and compliance; environment and human resource management; and stakeholder and service level requirements. These elements have previously existed as separate departments (or silos) within an organisation and in many cases continue to do so (Frolov et al, 2009). An infrastructure asset is owned, maintained and operated by one or different organisations. There is in many cases a subdivision between the management and the practical work, these different tasks can be incorporated in one, or multiple organisations. This research will use the three AM roles differentiated by Van der Velde et al (2013); the asset owner, the asset manager and the service provider.

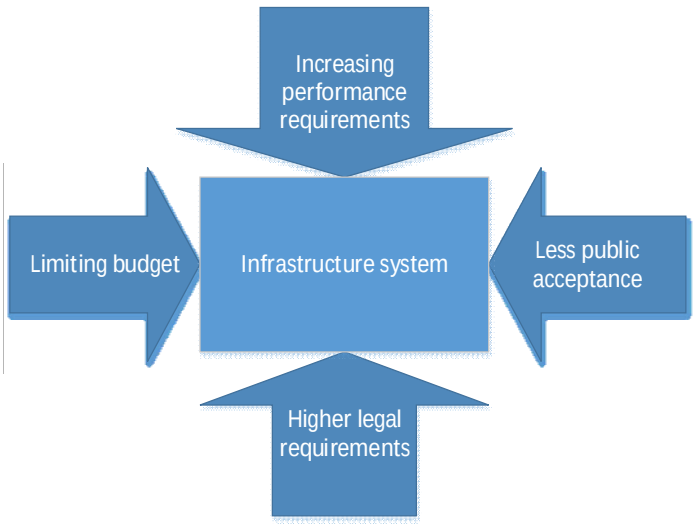


Figure 1.1 The pressures on infrastructure systems (Wijnia & Herder, 2009)

1.1.3 The need for Asset Management

The circumstances for infrastructure networks have changed during the last decades. Wijnia & Herder (2009) state that infrastructure systems have to deal with increased pressures such as increasing performance requirements, less public acceptance, higher legal requirements and a limited budget (Figure 1.1). It is up to the infrastructure owners, or their designated contractor, to resolve these issues. AM helps to obtain maximal value of the assets involved. In this light, it is no surprise that AM has gained the attention of many infrastructure operators.

Wijnia & Herder (2009) state that the total operation of an infrastructure system not only depends on its physical assets, but also on other elements, like information systems, data, standards and procedures, employees, capabilities and culture. These elements are only to a certain extent independent of each other and are most likely to influence each other (over time). Therefore Wijnia & Herder (2009) talk about loosely coupled elements, this is shown in Figure 1.2, were the black box infrastructure system of Figure 1 is replaced by the elements mentioned before which are coupled with mass springs.

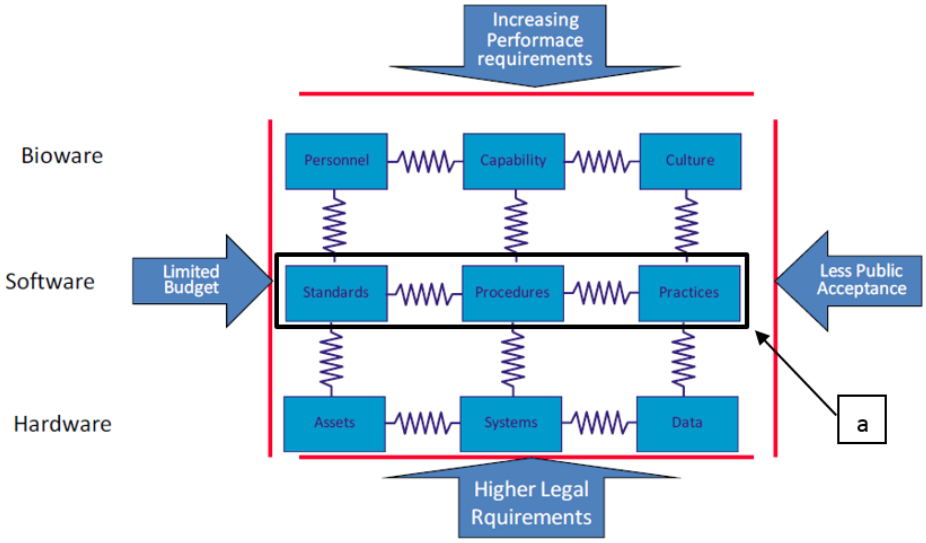


Figure 1.2 The mass-spring metaphor of asset management, with (a) the subjects directly affected by the ISO 55000 (Wijnia & Herder, 2009)

1.1.4 Asset Management roles

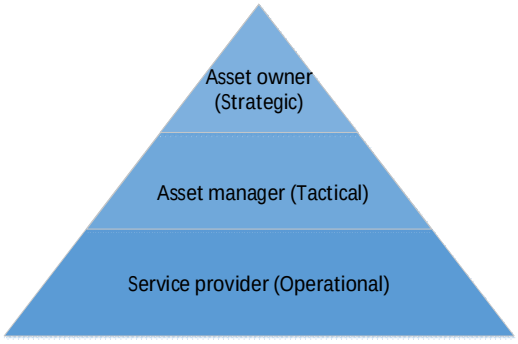


Figure 1.3 Relation between AM roles

Van der Velde et al (2013) distinguish three different roles within an AM system: the asset owner, the asset manager and the service provider (Figure 1.3). Rijkswaterstaat also uses these roles.

The asset owner can be either a governmental department or a private party. The asset owner is dealing with the why question.

Its responsibilities are; to come up with the overall network policy, set targets for performance and condition on a network level, and set targets for an acceptable risk profile. The role of asset manager is to provide a link between the asset owner and the service provider, the asset manager translates the targets and strategies of the asset owner into what, where and when to do. The asset manager is responsible for; investment strategies, maintenance concepts, technological standards, risk management and network management. The role of service provider is outsourced to private companies or can be fulfilled within the organisation itself. The service provider is responsible for; project delivery, maintenance, execution and services, the delivery of asset

information and project management. These AM roles are useful when talking about the distribution of responsibilities within an AM system. Table 1.1 summarises the roles and their responsibilities.

Table 1.1 Roles and responsibilities according to Rijkswaterstaat (FHWA, 2014)

Asset owner	Asset manager	Service provider
Future of the network: (strategic)	Tactical plans: - Investment strategy - Maintenance concept - Technology standard	Operations: - Renewal - Expansion - Maintenance
Framework: **- Target** **- Risk** **- Cost**	Program management: - Risk management - Network management - Performance management	- Project management - Process - Asset data management

1.1.5 Changing infrastructure market

Virtually all infrastructures started as a private, commercial enterprise (Wijnia & Herder, 2009). When these infrastructures had proven what they are worth, governments have stepped in and put these infrastructures under governmental control, either by institutionalizing them, acquiring shares or strict regulation. The last decades, this movement has been reversed. In the nineties many infrastructure sectors have been liberalized, deregulated and privatized. This is the so-called receding government. Rijkswaterstaat now applies the rule; 'the market unless' for outsourcing their activities. Governmental departments used to make strategic, tactical and operational decisions. Nowadays, governments are returning to their core business and are leaving the operational and partially the tactical decisions to market parties. They outsource as much as possible through functional contract forms such as DBM and DBFM. Figure 1.4 visualises this trend.

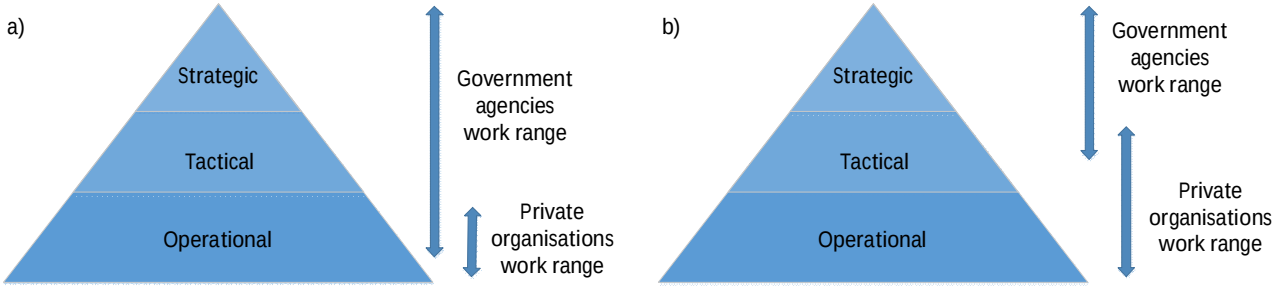


Figure 1.4 Receding governmental responsibility in different decision making levels, with the situation until about 1990 a) and the current situation b)

The space left behind by the governmental agencies is being filled up by market parties. The operational part is converted to market parties by maintenance contracts. This is already more common for more years. In the tactical part of maintenance, the asset manager tries to translate the strategic goals of the asset owner into what has to be done by the service provider. This task is increasingly taken on by market parties.

1.1.6 The use of AM standards

AM has developed in separate organisations within countries worldwide in different ways. Some of these developments resulted in the publication of standards. The first AM guidelines in Australia can be found in the NSW TAM guidelines in 1993 (AMQI, 1997). In New Zealand the Infrastructure Asset Management Manual was published in 1996 (NAMS, 2014). In the United States, the National Property Management Association organised the E53 committee on property management systems. This committee came up with its first standardisation documents in 2000 (NPMA, 2014). In Great Britain the BSI and the IAM developed the Public Available Standard 55 (IAM, 2014) to standardise the implementation of AM and published the first edition in 2004.

Especially the PAS 55 standard has been implemented with success in the years after its publication. The PAS 55 has been developed by the industry, especially the water, gas and electricity branch made an active contribution to the development of the standard. Later, other branches picked up this standard as well. The success of the PAS 55 and the international attention for AM that this standard caused are factors that lead to the development of ISO 55000, based on this PAS 55 (Pouwer, 2014).
The international AM standard ISO 55000 is introduced in January 2014 (TWPL, 2014). This standard resulted from the need for more international standardisation. The next paragraph will describe the ISO 55000 in more detail.

1.2 Problem analysis

This research is carried out within the Roads, Traffic and Information management department of ARCADIS Nederland (Marktgroep Wegen, Verkeer en Informatiemanagement) of which the Advisory Group Asset Management is part. The problem this department of ARCADIS is dealing with is based within the context described in the previous paragraph. The current AM market is developing and infrastructure systems have to deal with increased pressures. This means dealing with assets requires a more professional approach. Due to this, organisations working with infrastructure assets are searching for ways to become better asset managers and some organisations have already started to implement national AM standards, procedures and practices.

The international standardisation organisation (ISO) responded to this need for guidance and came up with the ISO 55000 standard in 2014. This standard promises to be a mean for becoming better asset managers, and to improve the effectiveness of AM in an organisation. The ISO 55000 standard is written as 'the global consensus on what asset management is and what it can do to increase value generated by all organisations' (IAM, 2014). Due to this, the standard is very general and the consequence of this can be that the standard is not easily implementable by the road infrastructure market. ISO 55001 gives requirements for an AM system, but not for specific asset types. It is intended to be used for managing physical assets in particular, but it can also be applied to other assets. Between physical assets, you can still notice many differences since managing a road infrastructure network is something else than managing industrial equipment or an organisations inventory (a more detailed description of the ISO 55000 can be found in Chapter 2).
The clients of ARCADIS are asset owners and service providers. All of these parties already have developed practices to manage assets. In fact, they are unknowingly working with AM for many years. These practices are mostly developed locally and for a specific asset portfolio. Many of these organisations are willing to implement new approaches to AM, if it appears to be beneficial for them.
Many organisations do not know if, and how the ISO 55000 standard can be beneficial for them. The problem is that many current used practices are functioning at an acceptable level and the ISO 55000 standard is not specifically designed for the road infrastructure sector. Therefore organisations are not willing to discontinue all of their current practices and completely rebuild an AM system according to the ISO 55000 standard.
ARCADIS wants to know what the benefits of the ISO 55000 standard are for road infrastructure asset owners and service providers. This includes looking at the possibility of a partial implementation of the standard. This means it will be beneficial to find out what parts of the ISO 55000 standard are applicable to Dutch road infrastructure organisations working currently with AM, and what parts of the standard better cannot be implemented. This leads us to the objective of this research.

1.3 Research objective

The research objective is derived from the problem analysis.
The main objective of this research is to find out what the added value of the ISO 55000 standard is for organisations working in the Dutch road infrastructure sector, asset owners and service providers.

The analysis of the added value of the ISO 55000 standard for the Dutch road infrastructure sector will be based on to what extend it can help in implementing AM in the Dutch road infrastructure sector. It will also be based on to what extend it can help to improve current practices by giving guidance about solving actual issues in current practice.

1.4 Research questions

1.4.1 Research question

The main question arises from the research objective which dictates to find out what the added value of the ISO 55000 standard is for organisations working in the Dutch road infrastructure sector, asset owners and service providers. This results in the following question:

'What is the added value of the ISO 55000 standard for the owners of Dutch road infrastructure AM systems, and how can the ISO 55000 standard contribute to the Dutch road infrastructure sector?'

1.4.2 Sub questions

1.4.2.1 Research question 1

'Which lessons can be learned from the implementation of the PAS 55 in the UK road infrastructure market, and the implementation of the ISO 9000 standard in the Netherlands, applicable to the implementation of the ISO 55000 on the Dutch road infrastructure market?'

The first research question is focussed on the lessons learned during the implementation of two other standards. This research is going to examine how the introduction of the PAS 55 in the UK, and the ISO 9000 in general took place. To learn from the introduction of these standards, examined is what the need of the market was at that time, how the implementation of these standards went and how applicable the standards really were for the road infrastructure market. This has led to insights in which factors influence the success of the implementation of a standard.

1.4.2.2 Research question 2

'Which guidance material is used for the development of current tunnel AM systems, and how compliant to the ISO 55000 will an organisation be using these guidance materials?'

The second research question examines the guidance documents which are being used by the examined tunnel AM systems. The conformity of these documents to the ISO 55000 requirements will be examined. By using these documents, there can be researched which AM system will be developed and to what degree this system will be conform towards the ISO 55000.

1.4.2.3 Research question 3

'What are the differences between the current AM practices in the road infrastructure market, and the recommended AM practices by the ISO 55000?'

The third research question concerns the actual Dutch road infrastructure market, and finds out if, why and how organisations working within road infrastructure AM should implement the ISO 55000 standard.

Every research question corresponds with a part of the research, the different sections of the research are explained below.

1.5 Methodology

To find the answers to the research questions, the research is divided into three parts:

- The first part of this research examined how the introduction of two standards was executed. The introduction of the PAS 55 in the UK and the introduction of the ISO 9000 in general. This has led to insights about which factors influence the successful implementation of a standard.
- The second part of the research, contains the main sources which are being used by organisations to develop a road infrastructure management organisation. The sources were examined and the requirements they contain are compared with the requirements of the ISO 55001 standard. This provides insights in the ISO 55001 compliance of the organisation when one of these sources is implemented.
- The third part of the research describes the examination of actual road infrastructure management organisations and the compliance towards the ISO 55001.

The next paragraphs describe how the different parts are addressed.

1.5.1 Lessons learned

This research will be executed in the Roads, Traffic and Information management department of ARCADIS (Marktgroep Wegen, Verkeer en Informatiemanagement) of which the Advisory Group Asset Management is part. This department is working in the road infrastructure in the Netherlands, and has many experience in this subject. The research will focus on Dutch road infrastructure because this group will expand its knowledge and maintain its leading position in the sector.
The ISO 55000 will be the first widely introduced AM standard in the Netherlands (after incidental use of PAS 55), the best reference situations are the implementation of the previous AM standard PAS 55 in a different country, and the implementation of a different standard in the Netherlands.
This is why this question focuses on the learned lessons during the implementation of the predecessor of the ISO 55000, the PAS 55. This standard is published by the British Standards Institution. The second subject of this question is the introduction of the ISO 9000 for quality management, published by the International Standardisation Organisation.

1.5.1.1 PAS 55

The PAS 55 is first implemented successfully in the electricity, gas, water and rail sectors in the UK. This research subject examined the market conditions during the introduction of the first version (in 2004) and the second version (2008) of the PAS 55. The information necessary to answer the first research question is acquired through interviews, literature, news archives and documents from the Institute of Asset Management. Interviews are executed with two employees of EC Harris, the British subsidiary of ARCADIS (Watts, 2014). EC Harris is working actively with AM since 2008, but has employees with many more years of experience in AM and the PAS 55. Another interview was executed with an employee of the Highways Agency from the UK.

1.5.1.2 ISO 9000

The ISO 9000 (quality management) is called successful (ISO, 2014). The question is what it is, that makes organisations want to use such a standard, and why this standard is being called successful.
To find out which lessons can be learned from the introduction of other standards, the introduction of the ISO 9000 is examined. This standard is chosen because it is known as a successfully implemented standard, and it is being used for a long time (since 1987). This means there is a lot of experience with, and literature about this standard. Unfortunately, there is only a little literature available about the implementation of this standard in the Netherlands. Therefore the international experiences are used and translated towards the Dutch situation.

1.5.2 Documents for standardised AM system implementation

1.5.2.1 Choice of tunnels as case objects

To find the answers to the research questions, a case study is executed. This case study will examine different objects. Speaking from the ISO 55000 key elements the research objects can be found in the

Asset Portfolio (in Chapter 2 the key elements are explained further). A choice is made to investigate only a part of this asset portfolio, this study will focus on specific cases. This is decided because this will sharper define the research scope. It is important that the objects of the study are relatively independent. Sufficient information about the applied management organisation needs to be accessible.

Considering all of the mentioned aspects above, the best object for the research will be a tunnel. Tunnels have to deal with a lot of regulations including a lot of documentation. Which are a good source for the research. Tunnels are relatively independent objects but they fulfil critical functions in their network. When an incident occurs, traffic is immediately jammed and the entire network of which the tunnel is part of, will be affected. Tunnels are complex assets because many safety and other regulations are applicable to them. Tunnels are mostly seen as a separate identity, and therefore their operational management system is mostly separate from other management systems. This makes tunnels most suitable as case subject for this research.

When the ISO 55000 defines the AM system of an organisation, they make this applicable on a demarcated part of the asset portfolio. This can be the entire asset portfolio, but also only a specific part of this portfolio. When you look at road tunnels, these are part of a network but can also be seen as a network on their own. Tunnels are always part of a wider road network, when this road network was not there, the tunnel would not be necessary. But when you look at the tunnel itself, it can also be seen as a system itself. A tunnel contains many components and subsystems. And has many times a specific management organisation.

In order to keep the research manageable, the target group of the infrastructure market is narrowed down to the organisations which are managing tunnels, the tunnels AM system. To find out if the asset owner influences the AM system, tunnels are examined on different governmental levels which are state, province and municipality level. This research includes two state tunnel AM systems, two municipal tunnel AM systems and one tunnel owned by the Province of Noord-Holland. The five different tunnel AM systems examined are listed below, some of the AM systems contain multiple tunnels:

- A73 tunnels; Roertunnel and Swalmentunnel
- Salland-Twentetunnel
- Waterwolftunnel
- Markt-Maastunnel
- Tunnels of Amsterdam; IJtunnel, Piet Heintunnel and the Michiel de Ruijtertunnel

1.5.2.2 Attention for source documents

Most organisations do not start from scratch when developing an AM system. During the selection of the tunnels I noticed that during the design and development of the tunnel AM system some kind of source document is often used. In this part of the research I will find out what these sources are, and examine the correspondence of four of these sources to the ISO 55000 standard. An organisation developed according to a certain source, will be as compliant to the ISO 55000 requirements as these sources are.
The sources which are examined are acquired during interviews. All of the requirements of the ISO 55000 are compared with these documents and the degree of correspondence is listed. In this way it has been made visible what the degree of correspondence of the different source documents with the ISO 55000 requirements is. The key element evaluation will be built upon the fundamentals of AM; context of the organisation, leadership, planning, support, operation, performance evaluation, and improvement as explained in Chapter 2.

For the examination of the sources the requirements of the ISO 55001 are used as basis. Every source is filtered from front to back to find requirements which are corresponding to the ISO 55001 requirements. To indicate the degree of correspondence a colour scale is used (Table 1.2).

Table 1.2 Used colour scale

Green	Means that the ISO 55001 requirement is fully covered by one or multiple requirements in the source document.
Yellow	Means that the ISO 55001 requirement is partially covered by one or multiple requirements in the source document.
Red	Means that the ISO 55001 requirement is not covered by requirements in the source document.

For every requirement is indicated (in Appendix C – F) why a certain degree of correspondence is given and where the corresponding requirements can be found.

1.5.3 Current AM practices

After the examination of the documents that should form the basis of the AM systems, the actual practice will be studied. The third part of the research describes the examination of tunnel AM systems and how compliant these are towards the requirements of the ISO 55001. Five tunnel AM systems are examined for this research. Two of these are state tunnels, one is a tunnel owned by the province and two are owned by a municipality (see Paragraph 1.5.2).
Most of the information is gathered through interviews with members of the tunnel AM systems and the documents they made available for this research.

Every examined tunnel AM system is compared to the way the ISO 55000 prescribes an AM system. This comparison is made on the basis of the key elements of an AM system following the ISO 55000 and the requirements for an AM system stated in the ISO 55001. The key elements and their corresponding chapters can be found in Table 1.2.

Table 1.2 ISO 55000 key elements and their corresponding chapters

Key Element		ISO chapter
1.	**Stakeholder and organisational context**	4.1, 4.2
2.	**Organisational plans and organisational objectives**	5.1, 5.3
3.	**Asset management policy**	5.2
4.	**Strategic asset management plan (SAMP) and Asset management objectives**	4.3, 6.2.1
5.	**Asset management plans**	6.2.2, 8.3
6.	**Plans for developing asset management system + relevant support**	4.4, 6.1
7.	**Asset management system + relevant support elements**	7
8.	**Implementation of asset management plans**	8
9.	**Asset portfolio**	-
10.	**Performance evaluation and improvements**	9, 10

The complete list of questions used can be found in Appendix A. Using this questionnaire made sure the tunnel AM systems were approached in a structured way. To examine each AM system, interviews took place with employees who were involved in the development and implementation of the organisation. For the 9th key element 'Asset Portfolio' there are not any requirements stated in the IOS 55000. The characteristics of the asset portfolio are for this research the characteristics of the examined tunnels.

1.5.3.1 Self-Assessment Methodology

The Self-Assessment methodology (SAM) (IAM, 2014) contains more or less the same as the used list of questions. The SAM is a tool for organisations to test the maturity of their own AM system. The tool is tested during a test interview and it was decided that the SAM would not be used again in this research. Doing an assessment with the SAM is a really time consuming method. Because the tunnel AM systems were participating with the research on a voluntary basis, it was not possible to consume too much of their time or otherwise they would simply not be willing to cooperate anymore. The other reason for not using this tool was that the SAM would not add much new information compared to the knowledge obtained through the interviews.

1.5.3.2 Maturity scale

To indicate the degree of correspondence, the AM maturity scale is used (figure 1.5). The colour transitions indicate the boundaries of the maturity scale are not hard values. Compliance with ISO 55001 is within Maturity level 3 and there is no upper limit to excellence.

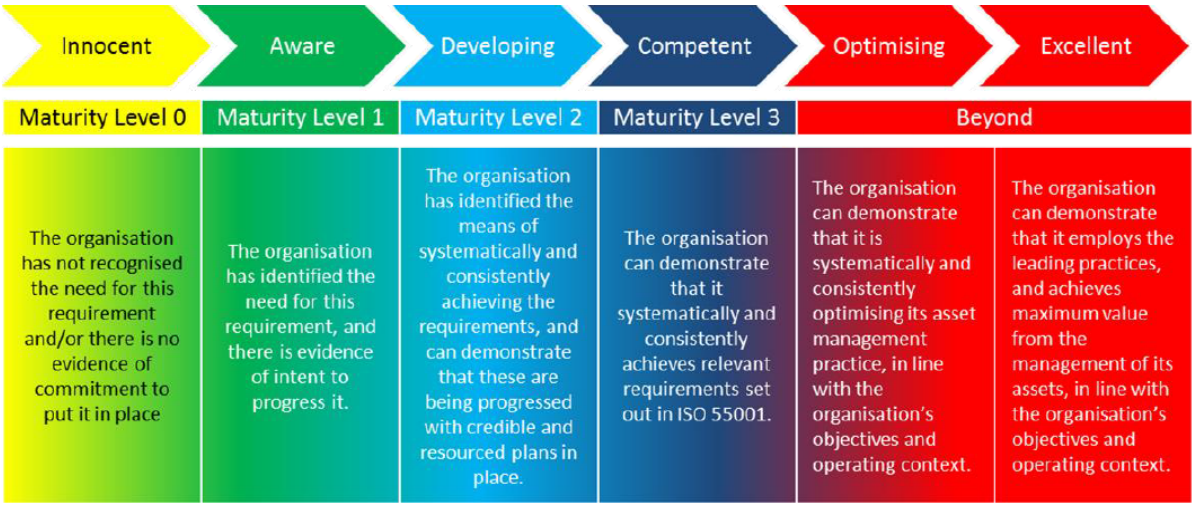


Figure 1.5 AM maturity scales (IAM, 2014)

Using this scale has resulted in a list for each tunnel AM system with the correspondence with each key element of the ISO 55000, substantiated with the requirements of the ISO 55001. When this is done, conclusions are drawn of the current AM practices and their correspondence with the ISO 55000. This can then be used to find the best combination of today's practices in road infrastructure AM, and the practices described by the ISO 55000.

The coherence between the different research parts is visualised in Figure 1.6. The different parts of the research (literature study, case study, interviews and analysis) are made visible. The numbers represent the research questions.

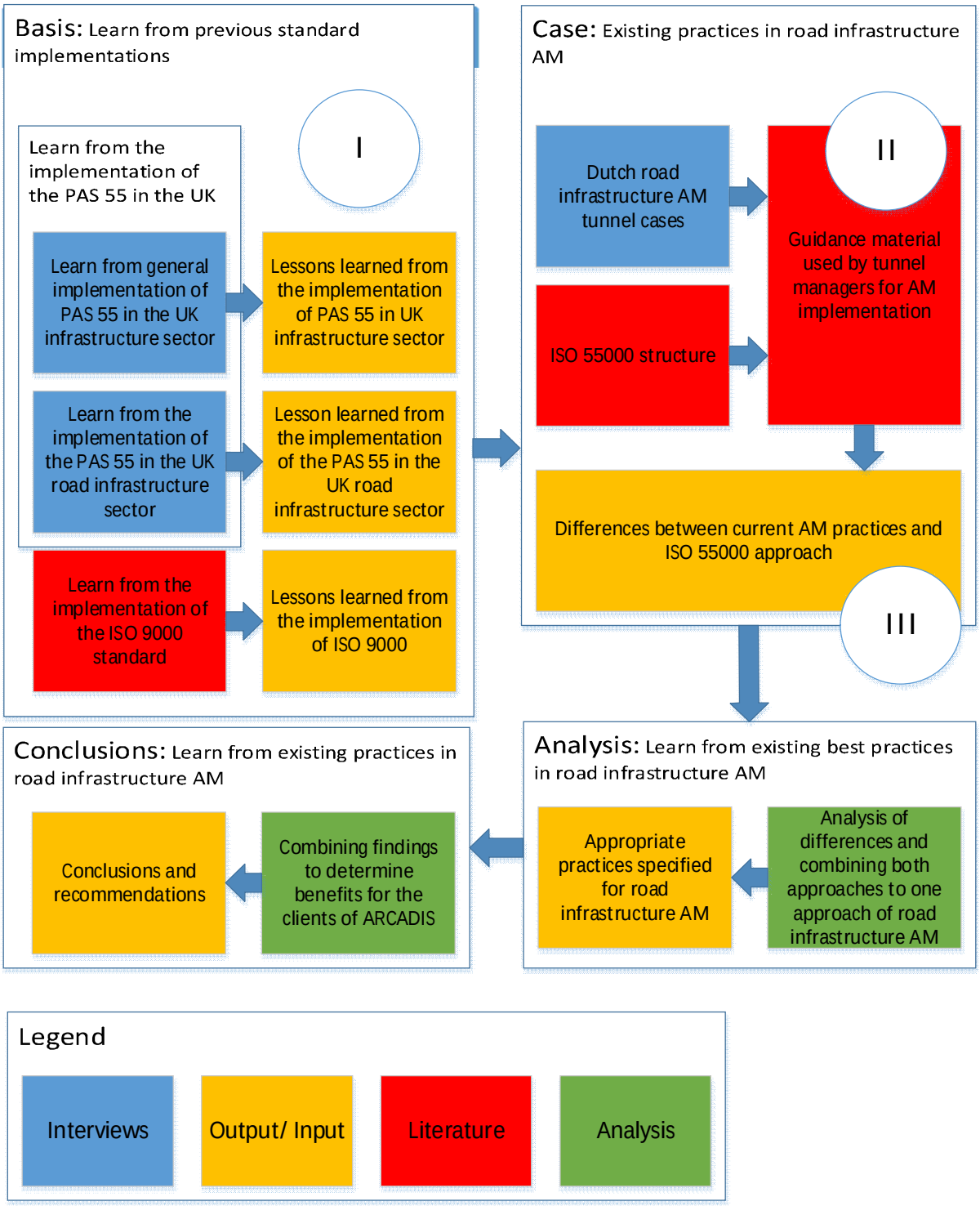


Figure 1.6 Research methodology

1.6 Reading guide

This thesis is structured as follows. This first chapter introduced the problem, provided relevant background information and clarified the used methodology of the research. In Chapter 2 the subjects of AM and the ISO 55000 will be explained. Chapter 3, 4 and 5 will show the results of the research, were Chapter 3 will give insights in factors that influence the successful implementation of standards. Chapter 4 will examine the conformity of the documents, used for implementing a tunnel AM system, and Chapter 5 will compare current tunnel AM systems, with the requirements of the ISO 55001 standard. Chapter 6 formulates and discusses the conclusions. Chapter 7 will discuss the value of this research for ARCADIS and will provide recommendations.

2. THEORETICAL FRAMEWORK

2.1 Asset Management

This research examines the subject of Asset Management and the ISO 55000 standard for Asset Management. It is not yet made clear what Asset Management is. This paragraph provides information about the subject of Asset Management.

The ISO 55000 standard for AM states that AM is:
"The coordinated activities of an organisation to realize value from assets";

The definition of an asset is:
"An item, thing or entity that has potential or actual value to an organisation"

When searching for AM, the management of financial assets is mentioned a lot but this research concentrates on the management of physical assets with the intention to realise value from them.
In the past, utilities tended to plan for maximum performance, minimum risk, and the least-cost way to achieve these ends. Asset management changes this mindset. Instead of maximum performance, organisations identify minimum acceptable performance targets. Instead of avoiding risk, organisations actively manage risk. Instead of a rate-base mentality, organisations justify all spending decisions based on performance improvement and risk mitigation. (Energycentral, 2015) Asset management involves the balancing of costs, opportunities and risks against the desired performance of assets, to achieve the organisational objectives. (figure 2.1)

Figure 2.1 The balancing act of value realisation (Jordaan, 2014)

This act of balancing is illustrated by the AM policy of the Washington Metropolitan Area Transit Authority (Roberts, 2014), they want to get it right: "It is about doing the right amount of work, at the right time, to achieve the right level of service for the right cost."

AM is based on a set of fundamentals, value, alignment, leadership and assurance (ISO, 2014):

2.1.1 Value

Assets exist to provide value to the organisation and its stakeholders. Asset management does not focus on the asset itself, but on the value that the asset can provide to the organisation. The value (which can be tangible or intangible, financial or non-financial) will be determined by the organisation and its stakeholders, in accordance with the organisational objectives. This includes:

- a clear statement of how the asset management objectives align with the organisational objectives,
- the use of a life cycle management approach to realize value from assets,
- the establishment of decision-making processes that reflect stakeholder need and define value.

2.1.2 Alignment

Asset management translates the organisational objectives into technical and financial decisions, plans and activities. Asset management decisions (technical, financial and operational) collectively enable the achievement of the organisational objectives. This includes:

- the implementation of risk-based, information-driven, planning and decision-making processes and activities that transform organisational objectives into asset management plans,
- the integration of the asset management processes with the functional management processes of the organisation, such as finance, human resources, information systems, logistics and operations,
- the specification, design and implementation of a supporting asset management system.

2.1.3 Leadership

Leadership and workplace culture are determinants of realization of value.
Leadership and commitment from all managerial levels is essential for successfully establishing, operating and improving asset management within the organisation. This includes:

- clearly defined roles, responsibilities and authorities,
- ensuring that employees are aware, competent, and empowered,
- consultation with employees and stakeholders regarding asset management.

2.1.4 Assurance

Asset management gives assurance that assets will fulfil their required purpose.
The need for assurance arises from the need to effectively govern an organisation. Assurance applies to assets, asset management and the asset management system. This includes:

- developing and implementing processes that connect the required purposes and performance of the assets to the organisational objectives,
- implementing processes for assurance of capability across all life cycle stages,
- implementing processes for monitoring and continual improvement,
- providing the necessary resources and competent personnel for demonstration of assurance, by undertaking asset management activities and operating the asset management system.

An organisation uses an AM system to coordinate and control AM activities, this is explained in more detail in Paragraph 2.2.

2.2 The ISO 55000 Standard series

This paragraph provides insight in the ISO 55000 standard series. First, the publishing organisation ISO is described, next the need for the standard is explained shortly. Finally the structure of the standard with its more detailed content will be explained.

2.2.1 The International Standardisation Organisation (ISO)

The ISO 55000 standard series is published by the International Standardisation Organisation (ISO). This organisation is an independent, non-governmental membership organisation and the world largest developer of voluntary international standards. They have 165 member countries and published more than 19500 international standards. With these standards they want to ensure quality, safety and efficiency. ISO standards help to harmonize technical specifications of products and services making industries more efficient and breaking down barriers to international trade. Conformity to international standards helps reassure consumers that products are safe, efficient and good for the environment (ISO, 2014).

2.2.2 The need for the ISO 55000

The need for an international standard arose during the implementation of the PAS 55:2004 in some sectors in the UK, and the subsequent implementation of the PAS 55:2008 in 15 different industries in 10 different countries. This made the potential of AM, and a matching international standard clear. The PAS 55 standard was written by, and for, organisations from a restricted number of industries and countries. Therefore industries and countries outside the scope encountered difficulties when they want to implement AM through implementation of this standard. This development urged for a new standard, what was then found in the PAS 55:2008. Regulatory bodies in the UK, Netherlands, Canada and parts of Asia are increasingly recognizing the benefit of this approach and are either mandating, or strongly encouraging, their regulated companies to adopt these kind of approaches. (Davies, 2011) During the development of PAS 55:2008 there were already calls for a more widely recognized standard under the ISO banner. Shortly after the publication of PAS 55:2008 in November 2008, the IAM began an engagement with BSI to understand how PAS 55 could eventually be used as a basis to build upon the already considerable international consensus to develop a formal international standard. More about the PAS 55 standard can be found in Chapter 3.

2.2.3 Structure of the series

In this research is spoken about 'the ISO 55000', this is short for the ISO 55000 standard series. The ISO 55000 standard series consist of three parts:

- ISO 55000 is an overview of the subject of AM and it provides the principles and the terminology of AM,
- ISO 55001 describes the requirements specification for an integrated, effective management system for asset management, but does not address the design of the system,
- ISO 55002 provides guidance for the implementation of such a system.

2.2.3.1 ISO 55000: Overview, Principles and Terminology

ISO 55000 gives first an overview of what AM is, the principles and terminology used and what the benefits of AM are. AM translates the organisation's objectives into asset-related decisions, plans and activities, using a risk based approach. The standard can be applied to every type of asset, regardless their nature or size. The ISO states that the ISO 55000 standard contains added value to an organisation who will implement this standard. The possible benefits stated in the ISO 55000 (ISO, 2014) are:

Improved financial performance: improving the return on investments and reducing costs can be achieved, while preserving asset value and without sacrificing the short or long-term realization of organisational objectives.
Informed asset investment decisions: enabling the organisation to improve its decision making and effectively balance costs, risks, opportunities and performance.

Managed risk: reducing financial losses, improving health and safety, good will and reputation, minimizing environmental and social impact, can result in reduced liabilities such as insurance premiums, fines and penalties.
Improved services and outputs: assuring the performance of assets can lead to improved services or products that consistently meet or exceed the expectations of customers and stakeholders.
Demonstrated social responsibility: improving the organisation's ability to, for example, reduce emissions, conserve resources and adapt to climate change, enables it to demonstrate socially responsible and ethical business practices and stewardship.
Demonstrated compliance: transparently conforming with legal, statutory and regulatory requirements, as well as adhering to AM standards, policies and processes, can enable demonstration of compliance.
Enhanced reputation: through improved customer satisfaction, stakeholder awareness and confidence.
Improved organisational sustainability: effectively managing short and long-term effects, expenditures and performance, can improve the sustainability of operations and the organisation.
Improved efficiency and effectiveness: reviewing and improving processes, procedures and asset performance can improve efficiency and effectiveness, and the achievement of organisational objectives.

Definitions
The most important definitions used in the ISO 55000 standard series are:
Asset: item, thing or entity that has potential or actual value to an organisation.
Asset management: coordinated activity of an organisation to realize value from assets.
Management system: set of interrelated or interacting elements of an organisation to establish policies and objectives and processes to achieve those objectives.
Asset management system: management system for asset management whose function is to establish the asset management policy and asset management objectives.

Fundamentals
Asset management is based on a set of fundamentals.
Value: Assets exist to provide value to the organisation and its stakeholders.
Alignment: Asset management translates the organisational objectives into technical and financial decisions, plans and activities.
Leadership: Leadership and workplace culture are determinants of realization of value.
Assurance: Asset management gives assurance that assets will fulfil their required purpose.

Asset management system
An asset management system is used by the organisation to direct, coordinate and control asset management activities. It can provide improved risk control and gives assurance that the asset management objectives will be achieved on a consistent basis. However, not all asset management activities can be formalized through an asset management system. For example, aspects such as leadership, culture, motivation, behaviour, which can have a significant influence on the achievement of asset management objectives, may be managed by the organisation using arrangements outside the asset management system. The relationship between key asset management terms is shown in Figure 2.2.

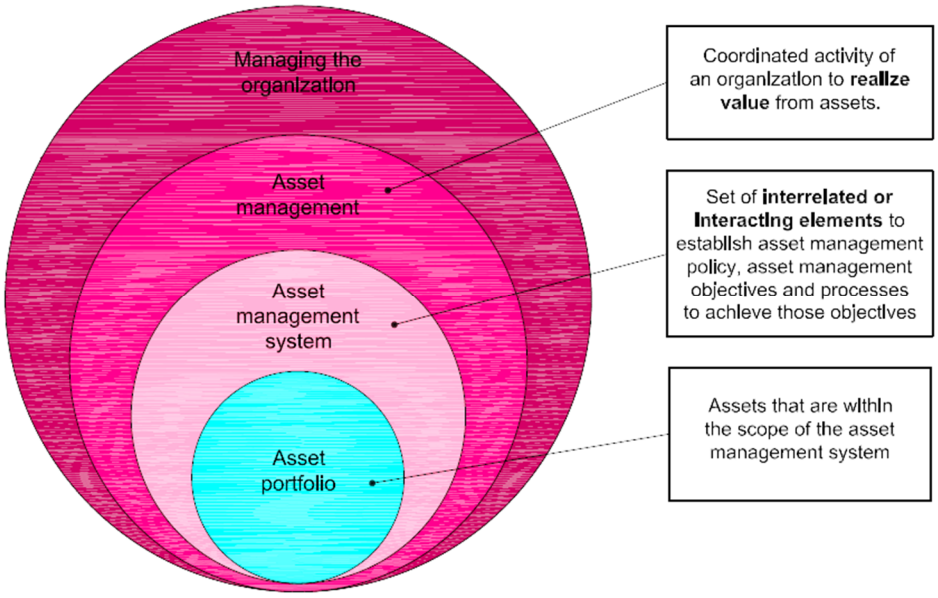


Figure 2.2 Relationships between key terms (ISO, 2014)

An asset management system is a set of interrelated and interacting elements of an organisation, whose function is to establish the asset management policy and asset management objectives, and the processes, needed to achieve those objectives. In this context, the elements of the asset management system should be viewed as a set of tools, including policies, plans, business processes and information systems, which are integrated to give assurance that the asset management activities will be delivered. Figure 2.3 shows the relationship between the key elements of an AM system, a well-functioning AM system must contain all these individual steps in a certain way. The grey highlighted box designates the boundary of the asset management system.

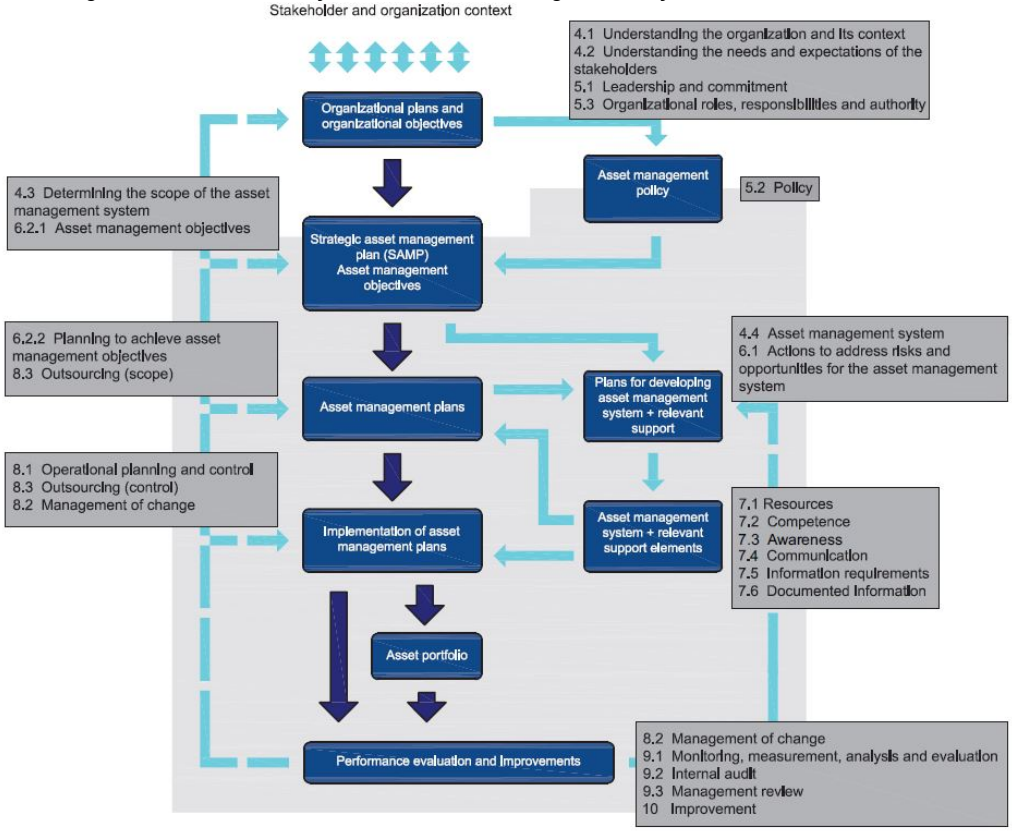


Figure 2.3 Relationship between the key elements of an asset management system, together with the related clauses in ISO 55001. (ISO, 2014)

The requirements for an AM system described in ISO 55001 are grouped in a way that is consistent with the fundamentals of AM; context of the organisation, leadership, planning, support, operation, performance evaluation, and improvement. These do all have to be taken into account to achieve a working AM system.

2.2.3.2 ISO 55001: Management Systems - Requirements

The different elements of an asset management system need to comply with the requirements stated in the ISO 55001 standard. These requirements are grouped in a way that is consistent with the fundamentals of AM; context of the organisation, leadership, planning, support, operation, performance evaluation, and improvement. The numbers display the chapters of the ISO 55001.

4 Context of the organisation: When establishing or reviewing its asset management system, an organisation should take into account its internal and external contexts.
5 Leadership: Top management is responsible for developing the asset management policy and asset management objectives and for aligning them with the organisational objectives.
6 Planning: The organisational objectives provide the overarching context and direction to the organisation's activities, including its asset management activities. The organisational objectives are generally produced from the organisation's strategic level planning activities and are documented in an organisational plan.
7 Support: The asset management system will require collaboration among many parts of the organisation. This collaboration often involves the sharing of resources. Coordinating these resources and applying, verifying and improving their use should be objectives of the asset management system. It should also promote awareness of the asset management objectives across the whole organisation.
8 Operation: The organisation's asset management system can enable the directing, implementation and control of its asset management activities, including those that have been outsourced. Operation of the asset management system can sometimes require planned changes to asset management processes or procedures, which can introduce new risks. Risk assessment and control in the context of managing change is an important consideration in operating an asset management system.
9 Performance evaluation: The organisation should evaluate the performance of its assets, its asset management and its asset management system. Performance measures can be direct or indirect, financial or non-financial.
10 Improvement: An organisation's asset management system is likely to be complex and continually evolving to match its context, organisational objectives and its changing asset portfolio. Continual improvement is a concept that is applicable to the assets, the asset management activities and the asset management system, including those activities or processes which are outsourced.

2.2.3.3 ISO 55002: Management Systems - Guidelines for the implementation of ISO 55001

This international standard contains explanatory text necessary to clarify the requirements specified in ISO 55001 and provides examples to support implementation. It does not provide guidance for managing specific asset types. It does shows the relationship between the key elements of an asset management system, together with the related clauses in ISO 55001. This is shown in figure 2.3.

In the next chapter the implementation of other standards will be examined and boundary condition which influence the success of implementation are describes. Then the implementation of the ISO 55000 will be examined using these boundary conditions.

2.2.4 Added value

The ISO states that the ISO 55000 standard contains added value to an organisation which will implement this standard. Many companies such as consultancy firms and certifying organisations try to convince asset owners to implement the ISO 55000 standard by numerating the possible benefits stated in the ISO 55000:

Improved financial performance: improving the return on investments and reducing costs can be achieved, while preserving asset value and without sacrificing the short or long-term realization of organisational objectives.
Informed asset investment decisions: enabling the organisation to improve its decision making and effectively balance costs, risks, opportunities and performance.
Managed risk: reducing financial losses, improving health and safety, good will and reputation, minimizing environmental and social impact, can result in reduced liabilities such as insurance premiums, fines and penalties.
Improved services and outputs: assuring the performance of assets can lead to improved services or products that consistently meet or exceed the expectations of customers and stakeholders.
Demonstrated social responsibility: improving the organisation's ability to, for example, reduce emissions, conserve resources and adapt to climate change, enables it to demonstrate socially responsible and ethical business practices and stewardship.
Demonstrated compliance: transparently conforming to legal, statutory and regulatory requirements, as well as adhering to AM standards, policies and processes, can enable demonstration of compliance;
Enhanced reputation: through improved customer satisfaction, stakeholder awareness and confidence.
Improved organisational sustainability: effectively managing short and long-term effects, expenditures and performance, can improve the sustainability of operations and the organisation.
Improved efficiency and effectiveness: reviewing and improving processes, procedures and asset performance can improve efficiency and effectiveness, and the achievement of organisational objectives.

3. LESSONS LEARNED FROM THE PAS 55 AND THE ISO 9000

To find out what the influence is of the implementation of the ISO 55000, this research has paid attention to the past to see if there can be lessons learned from other experiences with the implementation of standards applicable to the current situation of the new ISO 55000 standard. This chapter has been written to present the results of the first part of the research. In this chapter it is examined how the introduction of these two standards went, which are the introduction of the PAS 55 in the UK and the introduction of the ISO 9000 in general.
The first paragraph of this chapter will describe how the implementation went of the PAS 55 standard in the UK. The second paragraph will zoom in on the role of the UK road infrastructure sector from the first publication of the PAS 55 until now. The third paragraph describes the lessons learned by the users of the ISO 9000 standard. This standard is implemented worldwide in a large variety of sectors and therefore many knowledge about its implementation is available. The examination of these standard implementations have led to insights about what factors influence the success of the implementation of a standard.

3.1 Lessons learned during the implementation of the PAS 55 in the UK

The ISO 55000 standard is based on the PAS 55, this standard is first published in 2004 which means this standard is at time of writing available for circa eleven years. Many organisations are working according to the PAS 55 (Woodhouse, 2011). Because the PAS 55 is developed in the UK, and first implemented in the UK, many experience is available in there. The PAS 55 is adopted by organisations from several sectors (BSI, 2007). This paragraph first explains what the needs were of the organisations who started to develop the PAS 55, it then describes how the implementation of the first version of the PAS 55 went, and the implementation of the second version published in 2008. Finally, examples are given of achievements due to PAS 55 implementation and there is described what the main impacts are of the implementation of an AM system according to the PAS 55.

3.1.1 Market need

People own assets for a long time and all this time they managed their assets in a certain way. These practices were mostly not based on risk based asset management or were these owners knowingly approaching the asset to obtain maximum value these assets. It took until the eighties for AM to develop. During these years there was an oil crisis and the government of the British government decided the country has to become energy independent. This crisis can be seen as a wakeup call to this industry, because the oil was simply too expensive. In these years British Petroleum (BP) and Shell started to implement a structured AM approach. The Australian public sector started in 1985 to implement the principles of AM. North American industries also became aware of the need of asset centric management and added the decommissioning of departmental silos and the change from short term, into long term thinking to the development. (Woodhouse, 2014)

After the first steps by the oil industry, other companies became interested in AM. This was encouraged by the privatisation policy of the British government. This started in 1979 in the UK when Margaret Thatcher began with the policy of selling of many governmental owned businesses. In the years after, many of these new private companies did not handle their assets with care. Shareholder dividends went up and operational expenses went down. Budget cuts were made on many operational tasks such as vermin control in the water industries. In 1995 alone, capital spending on infrastructure maintenance and modernization fell nearly a fifth, in the now mostly privatised gas, electricity and water sectors. It did not took long until the consequences became visible. There were more waterborne diseases, rising dead rates and rat infestations. By 1995, whole areas of Britain had water shortages, which had nothing to do with the weather. In the summer, despite adequate rainfall, reservoirs were empty and water had to be trucked in to consumers at exorbitant costs. There were also more problems in the winter with the water companies. (Meny Baker & Burdman, 1996).

A tragic example of the consequences of these budget cuts in the privatised UK sectors is the Hatfield rail crash. The rail sector was privatised during the nineties. British Rail became divided in multiple sections, including a party which is responsible for the infrastructure, train operators, rolling stock and regulatory bodies (Pettinger, 2014). The division of responsibilities, including the responsibility for the safety of passengers, was also divided between these parties, this was one of the reasons for the Hatfield rail crash in 2000. Four people were killed when an express train of the East Coast Main Line derailed after traveling over a broken rail. Investigators revealed the engineers knew the rail was in poor condition but they neither replaced it nor imposed a speed restriction. The faulty rail had been spotted 21 months earlier but it was left unrepaired even though a replacement rail had been delivered and left alongside it for six months. (NCE, 2012) This incident indicated the privatisation of the UK Rail infrastructure, which started with the Railways Act in 1993, was not going as intended.
These examples from the different sectors show these companies were struggling with the management of their assets. Many of these companies started to implement a more structured AM approach but could definitely use some guidance.

3.1.2 PAS 55:2004

In the years before 2002, a lot of organisations in many sectors worldwide were working with AM and at the same time developing practices which worked for them. These organisations wanted to learn from each other, but there was confusion about the terminology and the best way to approach AM, and so a need for a general uniform approach for AM arose.

The Institute of Asset Management (IAM) began the development of an AM standard in 2002. The first version of PAS 55 was published two years later in 2004 and included content from nine main sponsors and 13 organisations in the review panel (Woodhouse, 2011). Input to this original 2004 edition of PAS 55 was almost entirely from the UK, except one Belgium brewery (IAM, PAS55:2004, 2004). The first aim of PAS 55 is to provide a common language that enables people in the same organisation to talk about AM related problems, from senior managers to accountants to engineers to technicians to stewards. Moreover this common language should facilitate an asset manager or engineer in a power generation station talking to their counterpart in a railway or a pharmaceutical plant or an offshore drilling platform. The gas and electricity sector in the UK was also involved in the development of the first PAS 55 version.

The office of gas and electricity markets (Ofgem) is since 1999 responsible for the protection of the interests of consumers, doing this trough promoting competition within the gas and electricity market in the UK (Ofgem, 2014). Ofgem is convinced that the PAS 55 can help the gas and electricity providers in improving themselves, and is since 2005 encouraging network companies to become certified (Watts, 2014). Since then, all distribution network operators in the UK applied for PAS 55 accreditation. Due to this, the demand for standardisation was growing in the international community and more and more industrial sectors were following the lead set by the utility sectors in adopting the PAS 55 as a tool for improving their approach to asset management.

Woodhouse (2014) states the PAS 55 is a fast track of getting something in the public domain, because it is a checklist with requirements which need to be fulfilled. When Ofgem more or less demanded from the gas and electricity providers to meet the requirements of the PAS 55, these organisations first thought it was only going to be a lot of paperwork and bureaucracy. But after six months they had all figured out that following this standard would actually improve their performance. In this way the PAS 55 was the catalyst within these organisations which forced the right questions to be asked and enforced a change in the psychology within these organisations. (Woodhouse, 2014)

After the implementation of the PAS 55, the electricity distributors had little drive to improve further. The electricity transmission companies on the other hand, do have a strong drive for continuous

improvement. Gas distribution companies have obtained a growing interest in the PAS 55 since the selloff of 4 of the 5 distribution zones by National Grid in 2005. (Watts, 2014)

3.1.3 PAS 55:2008

In an attempt to increase international participation and sectorial uptake, the IAM undertook a review activity in 2007 and 2008. This resulted in the PAS 55:2008. The intent was to increase international participation and cross-sector input. This revised standard is the result of the work of 49 organisations from 15 industries in 10 countries (see figure 3.1).

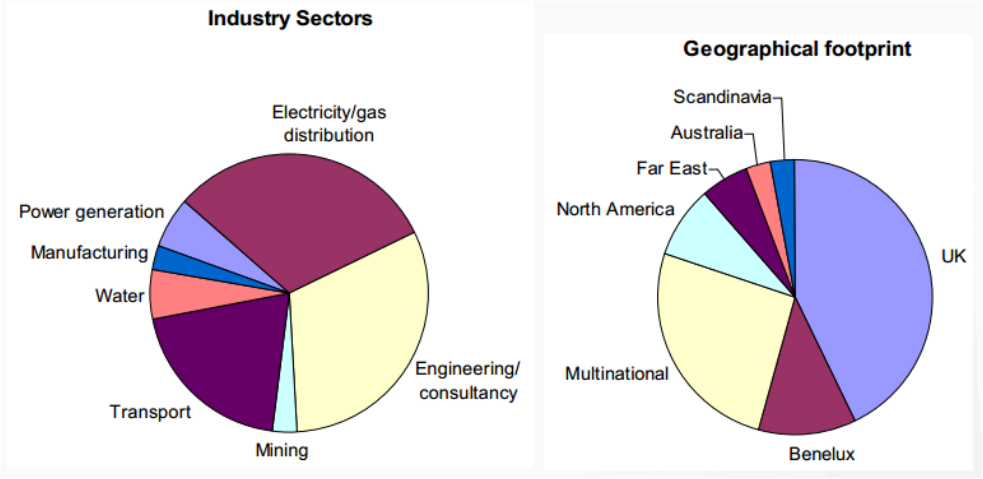


Figure 3.1 Origin of PAS55:2008 contributing organisations per industry sectors and country or region (Davies, 2010).

The UK water and waste water companies are being reviewed on their efficiency every 5 year. This review is the basis of the determination of the water rates for the next five years. Due to poor performance between 2005 and 2010 many water companies had to deal with budget cuts. This is the cause of their drive since then for continuous improvement what led to their interest in the PAS 55.

The PAS 55 provides a framework for the management of assets. This is different from a guideline which tells 'how to' implement such a management system. Due to this, additional guidance material is published such as the International Infrastructure Management Manual (IIMM) developed jointly by Australian, New Zealand' and UK AM authorities. This manual contains case studies, gives guidance on implementation and country specific information (Davies, 2011) which suggests the implementation of the PAS 55 requires a different approach between countries.

3.1.4 Achievements with the PAS 55

Since the PAS 55 standard is published ten years ago, a lot of experience with the implementation of this standard is available. Some organisations have shown what improvements they have made by adapting their organisation to the requirements of the PAS 55. During the presentation of the PAS 55:2008, the IAM stated that an oil company had made a 50% reduction in operating costs with 15% increase in output, an electricity network had 21% reduction in costs with 27% improvement in quality and reliability, and a transport provider achieved 25% reduction in unit costs with 41% improvement in customer service. (Davies, 2010)

The IAM (BSI, 2007) has held a survey amongst PAS 55 users and found out the main benefits of the standard for its users were; increased control and efficiency, increased confidence of senior executives, increased stakeholder confidence, improved quality services and an enhanced reputation. Scottish Power accomplished a £2m reduction in insurance premiums, 20% reduction in operation and maintenance costs, 22% increase in plant availability and a 25% reduction in plant forced outage rates (Griffin D. , 2010). Steve Arthur (2008) claims Wessex Water's PAS 55 certification has brought them a high level buy-in to structured AM systems, a greater awareness of risk at every level of AM (strategic,

tactical and operational) and an ability to demonstrate to the regulators that they have structured systems in place and a means of getting external surveillance and monitoring in addition to internal approaches.

Watts (2014) states there are some main subjects of change due to the use of the PAS 55. First of all there are the primary impacts:

- capital investment savings,
- operations and maintenance cost savings,
- life cycle cost savings,
- lower inventory costs,
- lower fixed costs.

The second subject is the performance gains:

- service level improvements,
- service quality improvements,
- risk reduction.

The third change is the change in culture, the standard promotes:

- staff motivation,
- creativity,
- continual improvement.

The final change is the improvement of the organisations credibility:

- by regulatory approvals,
- costumer impression,
- company reputation.

To improve the credibility even further, an organisation can decide to get assessed by an assessment authority in order to become certified. Becoming certified can show the organisation is a good asset manager, a certificate can be the differentiating factor during a tender, some organisations want to obtain status through this certification and companies expect to obtain the benefits resulting from the implementation of the AM system itself.

3.2 Applicability of the PAS 55 standard for the road infra sector

Road infrastructure asset owners and managers around the world did not had special attention for the PAS 55 until recent years. As can be seen from figure 3.2 in 2010 the PAS 55 is taken up globally and it is widely spread in many different sectors. Nonetheless, the road infrastructure sector has not taken up the PAS 55 in 2010.

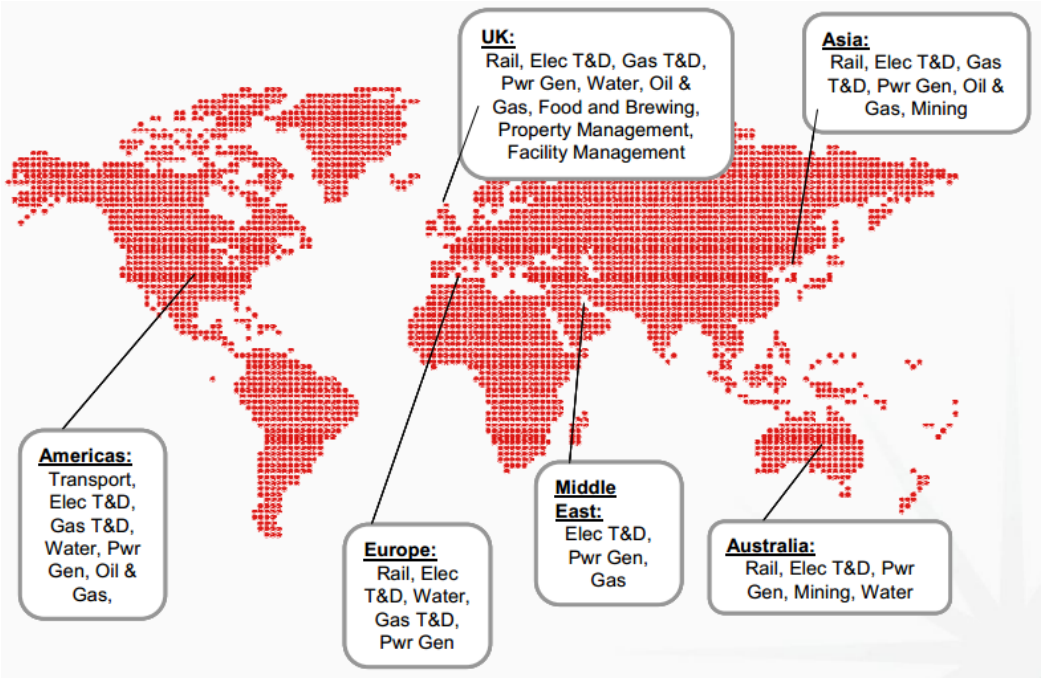


Figure 3.2 Uptake of PAS 55:2008 globally (Davies, 2010)

3.2.1 The UK Highways Agency

The UK Highways Agency is the organisation in England who is responsible for the operation, maintenance and improvement of the strategic road network (Highway Agency, 2014). Watts (2014), states there is a growing interest from the road infrastructure sector in the UK and in particular the Highways Agency, in deploying improved AM to optimize investment and operational efficiency.

The agency has 14 different road areas. The responsibilities for the maintenance of these areas is accommodated at different contractors (network operators). In 2010 two of these contractors decided to implement the PAS 55 standard in their areas. (Cook, 2011). The Highways Agency is aware that asset management is an evolving discipline and recognises the benefits that an AM approach can bring to road infrastructure organisations. Key reports have supported the agency with embedding a structured approach to AM. These reports are the National Audit Office report, the Cook report, the governmental response to the Cook report and the Highways Agency's AM vision.

The agency has undertaken pockets of good asset management activity prior to 2010, but it was following a National Audit Office report (NAO, 2009) where asset management as an approach and discipline within the agency started to gain momentum (Griffin C. , 2014). In 2011 Alan Cook, who was the non-executive chairman of the Highways Agency, came up with the report 'Strategic road network: a fresh start' (Cook, 2011). The relevant recommendations he made are stated below:

- The Highways Agency should embed an optimum whole-life approach to AM throughout the business.
- The Department for Transport (DfT) should challenge their different road area network managers on an ongoing basis to ensure that its specification is consistently achieved, 'aiming to provide similar pressures to those on comparable infrastructure companies in the regulated sectors'. According to Cook the pressure from regulation in sectors such as the water, gas and

electricity is necessary for successful implementation of AM and this should be generated by ongoing challenging the network managers.

- The DfT should set out a funding package for the road network. In this way the network manager should be given the commercial freedom to manage its own budget, including access to a working capital reserve, allowing the smoothening of investment and expenditure between budgetary periods and effectively ending the constraint of annuality. In this way the network manager is able to apply AM on the complete (area of the) AM system.
- The Highways Agency should work towards PAS 55 certification.

The DfT came one year later up with an official governmental response. In this response the government promised to implement many of Cook's recommendations. (DfT, 2012) Following the governmental response was the management vision of the DfT about the Highways Agency. The management vision of the DfT concerning the Highways Agency has been built around 'the vital role that the Strategic Road Network (SRN) and the network operator play in delivering key governmental priorities on:

- Facilitating and promoting economic growth and competitiveness.
- Driving efficiency and best value for the taxpayer.
- Enhancing the road user experience, whilst minimising the impacts of the SRN on local communities and the environment'.
- The network operator should enhance its AM capability and skills to become a high performing AM organisation.
- The network operator should be able to forecast the levels of future investment needed in maintenance, and model how the condition of the SRN will change with levels of investment in maintenance and renewals.
- To implement this, the network operator should first develop decision support tools (DfT, 2013).

Cook states that the Highways Agency, and their network managers should work towards PAS 55 certification. But neither in the response, or in the management vision, the management standard ISO 55000 nor its predecessor PAS 55 is mentioned. The Highways Agency states that this does not mean that they do not know these standards, or that they do not want to use them. Within the agency both standards are referred for good practice AM. The agency says it has recognised the value good practice of AM can bring to the organisation and is looking at developing and embedding an AM approach that is aligned with these standards but they do not have the intention to work towards certification. In 2013 a PAS 55 gap analysis was executed in order to develop AM maturity. Currently the agency is improving their AM maturity and have published the agency's AM policy, strategic documents and AM planning. (Griffin C. , 2014)

3.2.2 Local UK road infrastructure organisations

The smaller local authorities, responsible for the regional road network, lack maturity in AM practices and for many years lacked funding and capable resource to maintain their assets. The Roads Liaison Group publishes AM guidance (Pendlebury, 2013) specifically to be used by highway local authorities which takes into account the principles of PAS 55 and the ISO 55000 standard. As this is specifically developed for local road authorities, these organisations are more likely adopting this and not the PAS 55 or the ISO 55000 standard. (Vassou, 2014)

3.3 Implementation of the ISO 9000

Next to looking at the implementation of the PAS 55 in the UK, it can also be helpful to examine the implementation of other ISO standards. This paragraph will examine the ISO 9000 standard which has many similarities with the ISO 55000.

The ISO 9000 is a widely adopted standard for the implementation of a quality management system, it is just like ISO 55000 a list of requirements for a management system and also based on a standard of the BSI. The first publication of the ISO 9000 was in 1987, and twelve years later there were more than 400.000 certified organisations in 158 countries. (Guler, Guillén, & Macpherson, 2002) In 2010 there are more than a million certified organisations in 178 different countries (Priede, 2012). In these years, a lot has been written about the implementation of the ISO 9000, most of these researches investigate the certification process. This does not mean every organisation who is implementing AM will become certified. This paragraph will describe the major findings of examining the ISO 9000 implementation literature.

3.3.1 Motivation for standard implementation

Singels et al (2001) state that the motivation of the organisation determines whether becoming ISO 9000 certified will result in better performance. They indicate that the organisations that are involved in quality management out of an internal motivation, such as improving their organisational structure, improvement of their competitive position, improvement of their running and trading results, etc., profited most in terms of performance outcomes. This in contrast to those organisations that were externally motivated and adopted the quality system because of an experienced external pressure, such as meeting the demands from government regulation, inspections, etc. The more "internally motivated" organisations experienced more improvement of their production process, more cost reduction, less customer complaints, and more motivated personnel than the organisations that were externally motivated.

Implementing a standard successfully is an equivalent challenge as is the challenge with every implementation of an innovation. Klein & Sorra (Klein & Sorra, 1996) state that when organisations adopt innovations, they do so with high expectations, anticipating improvements in organisational productivity and performance. However, the adoption of an innovation does not ensure its implementation; adopted policies may never be put into action, and adopted technologies may sit in unopened crates on the factory floor.

3.3.2 Involvement of institutions

Guler et al (2001) states that the distribution of a standard is largely being influenced by institutions, both governmental and private. Their findings highlight that the diffusion of practices in the global economy is shaped by the activities of large organisations as the state and multinational firms and that cross-national isomorphism follows trade relationships, especially cohesive ones. These results have implications for both governments and organisations. Governments can affect rates of diffusion of innovative practices not only as purchasers of goods and services, but also through trade policy. In the global economy, organisations wishing to adopt the most innovative practices should look to the state, multinational firms, and their foreign trade partners and competitors for new models and opportunities. When implementing a standard is mandatory this can be seen as a top-down innovation. Implementing an innovation can also be bottom-up, this can be the case when within an organisation the principles of the standard are firstly being implemented. When this seems successful the used practices can be made more formalised and documented until the system reaches a certain level of maturity.

3.3.3 Benefits of ISO 9000 for certified companies

Some authors conclude that there is a positive relationship between ISO 9001 certification and companies' financial improvement, while others do not find evidence to support such a relationship. The purpose of the paper of Sampaio et al (2012) is to present the main results derived from a research project developed in order to analyse the economic impact of a quality management system implementation and certification on the performance of companies. They have found out that it is not unanimous that certified companies would be less profitable if they had not implemented their quality management systems.

Fernández et al (2001) state that certification helps in terms of being a management tool, a source of competitive advantages and its potential to stimulate the company transition towards total quality

management. Sansalvador & Brotons (2014) state that the implementation of a standardised quality management system has become a determining factor in business culture by providing double confidence. First, for clients and consumers, by assuring them that the business utilises processes that guarantee the quality of the final product. Second, for certified organisation, since the existence of a regulated and documented organisational method may help reduce internal costs, optimise the use of labour and production equipment, increase production, and ultimately ensure greater efficiency.

3.4 Conclusions

This chapter has examined the implementation of the PAS 55 and the ISO 9000 in different contexts. There is shown that the implementation of a standard is influenced by several factors. These factors, and their implications towards the ISO 55000 are stated below.

3.4.1 Demand for improvements

A standard can only become successful if there is a demand for a structured approach to a certain subject, and organisations think implementing the standard will reduce their problems and enhance their current situation. The development of the PAS 55 has shown for a standard to become successful it is necessary that there is a need for a certain innovation. The need for the PAS 55 developed during years of financial straits and the subsequent governmental budget cuts and the privatisation of utility sectors. These organisation started to implement AM because they faced difficulties. AM became a subject of interest for different sectors at different moments. The implementation of AM was for several sectors a necessary step. Because production costs were too high, maintenance was too expensive, or lacking maintenance forced organisations to implement AM.
The road infrastructure sector did not encounter problems of the same level of other industries until the last years so there was not a need for change. Due to budget cuts in the last years, the Highways Agency face some of the problems the other industries went through before them and nowadays it has become beneficial for these organisations to implement AM. To implement AM some of the contracted network managers are using the PAS 55. The Highways Agency was not the driving force in this development but they are planning to elaborate this further.

Looking at the ISO 55000 in the Dutch road infrastructure sector, there is also a demand for improvements. Most Dutch road infrastructure asset owners do encounter budget cuts, and are aware that they have to implement a smarter way of managing their assets. This awareness is also due to stricter regulations, less public acceptance for mistakes and higher performance requirements. The difference with the UK situation lies in the fact that at the time of the PAS 55 publication, there was not much other guidance material. Last years there has been much written about the subject of AM, this means the ISO 55000 has to 'compete' with these other sources.

3.4.2 Demand for standardisation

There has to be a demand for standardisation. A need for a more structured and broadly supported language resulted in the implementation of the PAS 55. First, organisations from a limited number of sectors in the UK was involved during the development of the first PAS 55 publication. This standard became soon popular amongst organisations from other sectors which resulted in a standard that is supported by many sectors in many different countries.

Looking at the ISO 55000 in the Dutch road infrastructure sector, there is some demand for standardisation. This is really visible in the area of road tunnels because the new tunnel legislation prescribes a standardised tunnel design. Other areas are not that progressive but asset owners do outsource more and more of the AM activities. This results in a need for more standardisation since this will improve the interaction between the asset owner and the contracted party. More standardisation will also make the supervision on an outsourced AM system easier.

3.4.3 The degree of regulation

Organisations in heavy regulated sectors more easily choose to standardise their processes. In some sectors, companies implemented the PAS 55 simply because it was mandatory. This is the case when the regulating bodies recognize the need for the implementation of AM before the individual organisations do. The road infrastructure sector has its regulations, but until recently there was not much regulated about the operations and maintenance of roads.

Looking at the ISO 55000 in the Dutch road infrastructure sector, large differences can be found about the degree of regulation. Critical objects with many safety implications are heavily regulated, road tunnels are a good example of this. The other end of this are non-critical elements such as municipal roads. In between these two extremes are a range of different objects with different criticalities. Critical objects will be subject of standardisation before the non-critical objects. This can be seen with the road tunnels which are already heavily regulated and a standardised design is obliged by the WARVW. Most road infrastructure, especially the critical objects, are owned by the government. This makes regulation an obvious tool.

3.4.4 The motivation of the organisation for implementing a standard

The change of a successful implementation is largely influenced by what motivation an organisation has to implement the ISO 9000. The more internal this motivation is, the more the standard will help to improve the organisational performance. When an organisation has only external motivation, it will most likely not improve its performance.

Looking at the ISO 55000 in the Dutch road infrastructure sector, the motivation of the asset manager is most likely to have impact on the AM systems performance. The major part of the asset owners in the Dutch road infrastructure market is a governmental organisation. Governments mostly do not need to prove their correctness of action through committing to some kind of standard. Governmental departments are more likely to implement a standard through internal motivations, or because they are obliged to do this (Paragraph 3.4.3). When parts of the AM system are outsourced to market parties, these parties can benefit more from so called ‘window dressing’. In this way they have an external motive in order to win contracts.

3.4.5 The involvement of countries and multinational organisations

Capital intensive organisations, and other influential organisations can accelerate or slow down the implementation of standards. When these organisations demand or reward the implementation of a standard, its clients and suppliers will react to this.

Looking at the ISO 55000 in the Dutch road infrastructure sector, governments and multinationals do have the power to influence the uptake of the ISO 55000 standard. As said in Chapter 3.4.4, governments own most of the road infrastructure and can therefore demand from or encourage their contractors to implement a standard. Large organisations such as multinationals do also have this power to boost the implementation of a standard.

3.4.6 Sufficient potential benefits

The last subject which helps to facilitate worldwide adoption of a standard is the potential benefits which can be achieved from implementing a standard. As can be found in Paragraph 3.1.4, the benefits of the PAS 55 can be as much as dozens percent of cost and risk reductions and it is proven that implementing this standard can also deliver many other benefits.

Looking at the ISO 55000 in the Dutch road infrastructure sector, the standard promises many benefits for its users. It is still too early to examine the actual benefits which can be achieved by implementing this standard but the similarities with the PAS 55 promises similar benefits from ISO 55000 implementation.

4. GUIDANCE MATERIAL FOR STANDARDISED AM IMPLEMENTATION

4.1 Introduction

During the conversation with the members of the different tunnel AM systems, the interviewees indicated that they had used different sources from which they claimed they have learned the principles of AM and the principles of designing an AM system which would meet (part of) the requirements from the ISO 55001. De following documents are mentioned:

- The tunnel law WARVW (WARVW, 2006) and its derivatives RARVW (RARVW, 2013) and the Tunnelstandaard (RWS, 2013),
- The ISO 9001 standard for Quality Management (ISO, 2008),
- Contractual documents (written by the client or the asset owner),
- Leidraad Risicogestuurd Beheer en Onderhoud (Bogaard & Akkeren, 2011),
- Project Management Plan written by the different contractors.

To find out to what degree an organisation is ISO 55001 compliant, four of the above mentioned (sets of) documents are compared to the requirements of the ISO 55001. The tunnel law WARVW and its derivatives RARVW and de Tunnelstandaard, de ISO 9001, the requirements specification written by ARCADIS for the Markt-Maastunnel and the 'leidraad Risicogestuurd Beheer en Onderhoud' van RWS. The Project Management Plan written by a contractor for a maintenance performance contract is in fact the answer to the requirements specification of the client and will only result in a complete AM system if these requirements demand so. Therefore the Project Management Plan will not be examined. The next paragraphs will explain what the four examined relevant sources encompass.

4.2 WARVW, RARVW and the Tunnelstandaard

New road tunnels of RWS have to comply with a package of rules described in:

- The WARVW (Wet Aanvullende Regels Veiligheid Wegverkeerstunnels) (WARVW, 2006)
- The RARVW (Regeling Aanvullende Regels Veiligheid Wegverkeerstunnels) (RARVW, 2013)
- The Tunnelstandaard (RWS, 2013)

The WARVW and the RARVW are obligatory for all Dutch tunnels with a closed section longer than 500m, and it will become obligatory for tunnels longer than 250m from the first of May 2019. The Tunnelstandaard is obligatory for all state tunnels (these are managed by RWS). The WARVW contains different demands for tunnels longer than 250m and no longer than 500m, and tunnels longer than 500m. A total overview of the laws a tunnel has to comply to is shown in Appendix B. The next paragraphs explains first what the WARVW, RARVW and the Tunnelstandaard entails. Then the conformity of this legislation package with the ISO 55001 is examined.

4.2.1 Demands in WARVW and RARVW

The WARVW is written as the consequence of the guideline 2004/54/EG from the European Parliament and the Counsel of the European Union at 29 April 2004 concerning minimum safety requirements for tunnels in the Trans-European road network. The RARVW is based on the WARVW. The demands from the WARVW are elaborated further in the next sections of the RARVW:

1. Limitative list of facilities for tunnels from 250m to 500m, and for tunnels longer than 500m (Art. 13 and 13a)
2. QRA tunnels (Appendix 1)
3. Guideline safety documentation for road tunnels (Appendix 2)
4. Scenario analyses for VBP/CBP (Appendix 2a)
5. Principles operating processes (Appendix 3)
6. Performance requirements facilities (Appendix 4,5,6)

The limitative list of facilities for tunnels which is written to set the standard had to be further elaborated. To do this RWS established the National Tunnel Director (Landelijke Tunnelregisseur). The

National Tunnel Director came up with a technical tunnel standard and a standardised tunnel management and organisation process.
RWS instructed this Tunnel Director to work fast. They wanted to protect the ongoing projects such as A2 Maastricht, Twente-Sallandtunnel and A4 Delft-Schiedam for the problems that bothered the A73 tunnels and the A2 Leidsche Rijn. Because of this there was no time to talk with provinces and municipalities what has resulted in a distrust of these parties in the Tunnelstandaard. Provinces and municipalities think that the standard is too heavy. They think that using the standard will result in increasing construction costs. (Gram, 2014) Gram also states that the Tunnelstandaard is in fact really suitable for city tunnels. During the specification of these tunnels many elements of the standard are already being used in new city tunnel projects.

4.2.2 Technical tunnel standard

The Technical tunnel standard is in fact the elaboration of the set of installations of the WARVW. It describes the specifications and design considerations for the RWS Tunnel systems.
Gram (2014): "In concrete terms the Tunnel law provides clearness about when a tunnel is safe enough and the Tunnelstandaard about what to do to get there."

The prescribed tunnel system in the Tunnelstandaard covers the entire tunnel object (the civil construction and the technical installations) and the corresponding processes, organisation, additional techniques and the ICT resources by which the services in the tunnel are being offered. Both standards consist of a set of documents. Figure 4.1 displays the documents of the standard and their mutual relations.

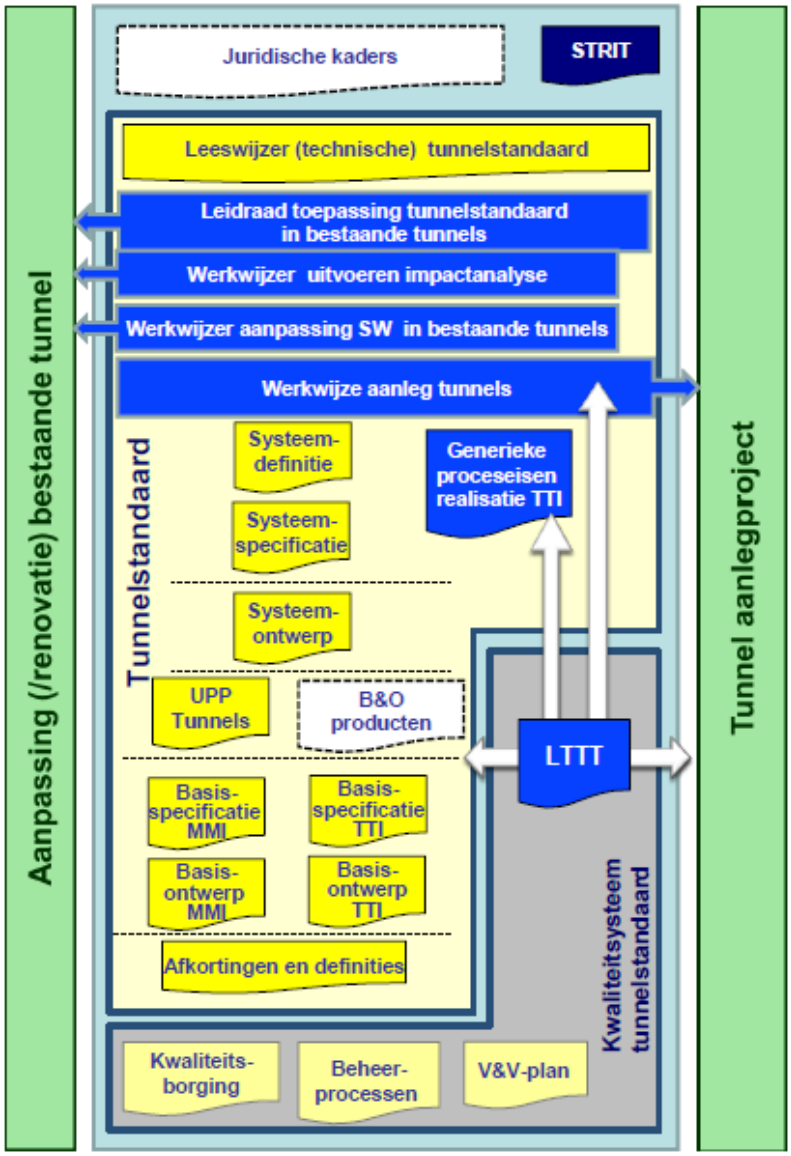


Figure 4.1 Documents of the Tunnelstandaard and their relations (RWS, 2013)

4.2.3 Management and organisation standard

The management and organisation standard, 'B&O producten' in figure 4.1, is the most interesting for this research. As you can see this is only a small part of the extensive Tunnelstandaard. To open a tunnel for traffic, it is obligatory to have a safety management plan (veiligheidsbeheerplan). The goal of this plan is to secure the level of safety during the operations phase. This plan consist of the following subjects:

- Safety management
- Education, Training and Practice (OTO)
- Emergency management
- Conservation and maintenance (Asset Management)
- Traffic management
- General tunnel management

4.2.4 Conformity of the Tunnelstandaard towards the ISO 55001

Implementing this Management and Organisation standard should result in a complete tunnel AM system. After examination of the different documents it was clear that implementing the documents 'Leidraad instandhouding tunnels' (Guidance upkeep tunnels) and the 'Operationele tunnelbeheer processen' (Operational tunnel management processes) would result in an AM system which would meet the vast majority of the requirements of the ISO 55001. Within the context of demonstrating compliance, the document 'Leidraad kwaliteitsmanagement tunnels' (Guidance quality management tunnels) contains a number of requirements which will cover the ISO 55001 requirements about demonstrating compliance. The complete analysis of conformity of the ISO 55001 with the WARVW, RARVW and the Tunnelstandaard can be found in Appendix C.

When a tunnel AM system is developed and implemented according to the Tunnelstandaard, the tunnel AM system will also have a working AM system. Meeting the requirements of the Tunnelstandaard will result in meeting almost all requirements of the ISO 55001 standard. State tunnels do already have to meet the WARVW and RARVW and at the first of May 2019, all Dutch tunnels have to meet these requirements. This will not make much difference about the ISO 55001 compliancy since these laws contain requirements regarding the safety, and not about the AM system. The Tunnelstandaard is also focussed on the tunnel safety. Nevertheless, there are three documents with requirements that will help the tunnel AM system to implement a solid AM system which will meet the vast majority of ISO 55001 requirements.

4.3 ISO 9000

The ISO 9000 (ISO, 2008) is the international standard for quality management. During the different interviews the question arose if the ISO 55001 requirements could be in correspondence with the requirements stated in the ISO 9001. This paragraph will provide the answer to that question.

4.3.1 The ISO 9001

The International Standardisation Organisation has multiple standards for the implementation of management systems, such as the ISO 50001 for energy management, and the ISO 14000 family for environmental management (ISO, 2015). The ISO 9001 is the most implemented standard for many years already, and over a million organisations worldwide are certified to this standard. The current version (2008) is the fourth version.

The management standards of the ISO all have the same structure and it is possible to integrate different management systems. The question here is in which extend implementing a quality management system according to the ISO 9001 will help meeting the requirements of an asset management system according to the ISO 55001.

The requirements for the implementation of a quality management system can be found in ISO 9001. The requirements in this standard can be applied on every organisation which delivers a product or service. The standard contains requirements about the following subjects:

- Setting up quality management system
- The responsibilities of the management
- Resource management
- Product realization
- Measurement, analysis and improvement

4.3.2 Conformity of the ISO 9001 towards the ISO 55001

The requirements of the ISO 9001 are for the implementation of a quality management system. The ISO 55001 specifies the requirements of an asset management system. This means both standards contain specifications about a management system, and comparing the two standards shows many similarities in the process of setting up such a management system. This does not mean that meeting the quality management system requirements results in an asset management system. Requirements about policy, goals, strategies, resources, competences, awareness, operations and performance evaluation are quite similar in the ISO 9001 and the ISO 55001. The difference is that the requirements in the first documents are specific written for a quality management system, so they require a quality management policy, and quality management goals etc. The requirements in the ISO 55001 require an asset management policy and asset management goals etc. This means meeting the requirements of one standard is not the same as meeting the requirements of both. This is of course the cause of the different subjects of the standards. The positive side of these different subjects is that it will be relatively simple to integrate the two management standards.
Next to these two standards there are also requirements in the standards which cover each other's connotation such as the requirements for the documented information, performance evaluation and improvements.
The reason for the correspondence of the performance evaluation requirement in both documents lies in the fact that in both standards the principles of the Deming Circle are used (Plan-Do-Check-Act). This is a process-oriented approach which stimulates continuous improvement.
There are also asset management requirements which are not at all mentioned in the ISO 9001. In the ISO 9001 is no such thing as stakeholder management and the internal and external context are not taken into account. The only stakeholder that matters in quality management is the customer. Risk management is also not incorporated in the requirements of the ISO 9001. In fact, it refers to other management systems for requirements about risk management.
A remarkable difference is the statement in the ISO 9001; 'It is not the intent of this International Standard to imply uniformity in the structure of quality management systems or uniformity of documentation.' One of the main goals of the development of the ISO 55001 was to streamline the AM systems across different sectors and countries. The complete analysis of conformity of the ISO 55001 with the ISO 9001 can be found in Appendix D.

4.4 Requirements Specification

The third source used to develop a tunnel AM system is the requirements specification written by asset owners to specify the tunnel they envision. While writing a requirements specification, the asset owner tries to specify as complete as possible. For this process, the municipality have used input from previous contracts, learned from other tunnel AM systems and hired external experts. A requirement specification like the one in this research can be seen as the assembly of all the best practices and knowledge known to the authors of the document.

4.4.1 The requirements specification of the Markt-Maastunnel long term maintenance

The municipality of Maastricht has hired asset managers of ARCADIS to write the requirements specification for the long term maintenance of the Markt-Maastunnel. The authors of ARCADIS have gathered the information necessary to specify a complete tunnel AM system from all different kinds of sources such as RWS specifications and the old specification of the previous contract of the Markt-Maastunnel.

The functional specification what has been put out for tendering consist of (Maastricht, 2014):

- A basis agreement based on the UAV-GC 2005
- Requirements specification 1: requirements for the installations
- Requirements specification 2: requirements for the processes
- Multiple annexes

Included in the specification was the displacement of the command post of the tunnel, this is not taken into account during the following analysis because it is not a part of the AM system.

4.4.2 Conformity of the requirements specification towards the ISO 55001

Implementing the functional specification requirements will result in a tunnel AM system which is largely corresponding to the requirements in the ISO 55001. The major deviations can be found in the supporting requirements. The resources and competences are partially covered and there are no requirements about the awareness of the employees.

One of the requirements demands a certified quality management system, the ISO 9001. This means the management system is being developed according to an ISO management system standard. Due to this, the other requirement what was missing, outsourcing, is still covered since the ISO 9001 contains corresponding requirements. The same applies to the requirements about preventive action.

4.5 Leidraad Risicogestuurd Beheer en Onderhoud

The final examined document is the 'Leidraad Risicogestuurd Beheer en Onderhoud'. This document is developed by RWS and published in 2011. This document is developed to make the so called 'ProBO' method applicable for the management and maintenance of the infrastructure portfolio of RWS.
In the introduction of this guidance document is stated; 'this guidance should be read in conjunction with Assetmanagement, the Leidraad Systems Engineering and the Leidraad RAMS.
This indicates that this document cannot be seen on its own and should be used together with other guidance material. However, in this chapter we will examine this document on its own and investigate its conformity towards the requirements of the ISO 55001.

4.5.1 The Leidraad Risicogestuurd Beheer en Onderhoud

The term ProBO stands for Probabilistic Management and Maintenance (Probabilistisch Beheer en Onderhoud). This expression is adopted from the designers of the water defence systems. ProBO is the fully risk based management and maintenance method what makes it possible to develop the entire management and maintenance process in a structured way. (Bogaard & Akkeren, 2011)
In this method:

- Management and maintenance is based on risks which influence the performance of an object or system;
- the asset performance is constantly controlled by using the Plan-Do-Check-Act cycle;
- there is an focus on Technique, Organisation (operational-, management-, and supporting processes) and Contracts (purchase and management process);
- objects are seen as separate entities, and as part of a network. The network approach is more difficult but can deliver substantial benefits.

4.5.2 Conformity of the Leidraad Risicogestuurd B&O towards the ISO 55001

The examined document is partially corresponding to the requirements of the ISO 55001. Overall, there can be seen that the strategic level of the AM system is not covered well, the tactical requirements score a little better and the operational key elements are covered for a large part. This is in line with the statement in the Leidraad about this. The authors state the Leidraad is developed for the operational level of an AM system, and AM should link the operational Management and Maintenance to the tactical and strategic goals of an organisation. There are almost no links between the requirements in the Leidraad, and organisational goals, policy or strategy.

There are four ISO 55001 requirements which are not at all covered in the Leidraad. Two of these requirements are strategic elements, which should normally being implemented by the asset owner. The other two fully uncovered ISO 55001 elements are the requirement for awareness and the management review. These requirements can easily be introduced if necessary.

4.6 Summary

This chapter has discussed four different source documents which are used by organisations to design their tunnel AM systems. The examined state tunnel AM systems use the legal requirements from the Leidraad risicogestuurd Beheer en Onderhoud, WARVW, RARVW and the Tunnelstandaard. The Tunnelstandaard holds requirements for a standardized tunnel, and also for a standardized tunnel AM system. When a tunnel AM system is compliant with the requirements of the Tunnelstandaard, this will also mean that the tunnel AM system is compliant with almost every requirement stated in the ISO 55001.

The ISO 55000 is one of a series of ISO management standards, ISO 9000 is another of those and contains requirements for a quality management system. Many of the asset owners and managers were ISO 9001 compliant. The requirements of the ISO 9001 were compliant to some of the ISO 55001 requirements but that is only a small part. However, the different ISO management standards can be integrated easily and ISO 9001 compliancy is a good basis to build an AM system upon.

The requirements specification, as a part of a construction or maintenance contract, can contain specific requirements about an AM system. The requirements specification examined here, is issued by the municipality of Maastricht for the long-term maintenance of the Markt-Maastunnel. These specifications are a conglomeration of requirements, and together they do meet many of the requirements of the ISO 55001.

The requirements in the Leidraad Risicogestuurd Beheer en Onderhoud cover part of the ISO 55001 requirements. It is clearly visible that this Leidraad is developed as operational guidance material. The operational elements of the AM system are covered for a large part, there are hardly any requirements for strategic elements of the AM system. Due to this, there is not at all a line of sight or awareness within a system, developed according to this document.

Table 4.1 visualises the correspondence of the different documents with the requirements from the ISO 55001. There are clear differences between the different documents, the Tunnelstandaard covers by far the most ISO 55001 requirements. It can be seen that the operational (lower) part of the AM system has gotten more attention by these standards. The strategic subjects are in many cases uncovered. The last interesting thing made visible in Table 4.1 is that there are some outliers, the most visible is the requirement about awareness (7.3), because it is not covered by any of the examined documents.

Table 4.1 This table visualises the conformity between the ISO 55001 and the four examined documents. If the ISO 55001 requirement is covered by the requirements from the examined document, then this is made clear with the colour green. Partial correspondence is indicated with the colour yellow and if requirements cannot be found in the examined documents, this is indicated in red. More detailed information can be found in Appendix C until F. For the calculation of the part of the requirements covered, the values of 1 (green), 0,5 (yellow) and 0 (Red) are used. For example, the correspondence of the requirements of the ISO 9000 to the ISO 55000 is: (7x1 (green) + 17 x 0,5 (yellow) + 3 x 0 (red))/ 27 x 100% = 57%.

ISO 55000 paragraph	Subject	Tunnelstandaard	ISO 9000	Vraagspecificatie	Leidraad Risicogestuurd Beheer en Onderhoud
4.1	Understanding the organisation and its context				
4.2	Understanding the needs and expectations of stakeholders				
4.3	Determining the scope of the asset management system				
4.4	Asset management system				
5.1	Leadership and commitment				
5.2	Policy				
5.3	Organisational roles, responsibilities and authorities				
6.1	Actions to address risks and opportunities for the asset management system				
6.2.1	Asset management objectives				
6.2.2	Planning to achieve asset management objectives				
7.1	Resources				
7.2	Competence				
7.3	Awareness				
7.4	Communication				
7.5	Information requirements				
7.6.1	Documented information: General				
7.6.2	Documented information: Creating and updating				
7.6.3	Documented information: Control of documented information				
8.1	Operational planning and control				
8.2	Management of change				
8.3	Outsourcing				
9.1	Monitoring, measurement, analysis and evaluation				
9.2	Internal audit				
9.3	Management review				
10.1	Nonconformity and corrective action				
10.2	Preventive action				
10.3	Continual improvement				
	Part of requirements covered (%)	96	57	81	63

5. CURRENT ASSET MANAGEMENT PRACTICES

In this chapter the actual comparison between the tunnel AM systems and the requirements of the ISO 55001 is done. The following tunnels are examined:

- A73 tunnels; Roertunnel and Swalmentunnel
- Salland-Twentetunnel
- Waterwolftunnel
- Markt-Maastunnel
- Tunnels of Amsterdam; IJtunnel, Piet Heintunnel and the Michiel de Ruijtertunnel

For every tunnel its characteristics are shown, information about the tunnel AM system is given, the involved parties and their cooperation are examined and the correspondence of the tunnel AM system with the ISO 55001 requirements using the IAM maturity scale is shown.

5.1 A73 tunnels Roertunnel and Swalmentunnel

Table 5.1 Characteristics of the Roertunnel

	Roertunnel
Owner	'State' tunnel, owned by the ministry of Infrastructure & Environment
Manager	Rijkswaterstaat (RWS)
Length	2400 m
Lanes	2 x 2 lanes
Location	Part of A73 at Roermond, below residential and nature area including the river Roer
Situation	Partial opening in 2008, total opening in 2009
Source of AM system	RWS' Leidraad Risicogestuurd Beheer en Onderhoud

Table 5.2 Characteristics of the Swalmentunnel

	Swalmentunnel
Owner	'State' tunnel, owned by the ministry of Infrastructure & Environment
Manager	Rijkswaterstaat (RWS)
Length	1000 m, 400 m fully enclosed
Lanes	2 x 2 lanes
Location	Part of A73 at Swalmen, below residential area and the river Swalm
Situation	Partial opening in 2008, total opening in December 2009
Source of AM system	RWS' Leidraad Risicogestuurd Beheer en Onderhoud

The Roer- and Swalmentunnel (Figure 5.1) are state tunnels which are located in the Trans-European Road Network. These tunnels were one of the first in the Netherlands which fulfilled the requirements of the European tunnel law which came into force in 2004. The first stages of the construction went without major problems, but during the installation of the TTI, many problems occurred. The complicity of the TTI was heavily underestimated in the design phase. The Roertunnel opened more than a year later than planned, and the Swalmentunnel did open almost two years after the scheduled opening.
The many difficulties the tunnel management organisation had to encounter had a large influence on this organisation. The minister of Transport, Public works and Water Management (now Infrastructure and the Environment) was personally involved in the decision making process (ANP, 2009). National media were following every step of the organisation, and many stakeholders made their voices heard.

The interviewees of the tunnel AM system indicated that all this attention gave an enormous pressure on the organisation to develop a complete tunnel management system which would demonstrable ensure the tunnels would be able to meet their requirements. The way this organisation addressed the AM of these tunnels is now almost completely in correspondence with the requirements of the ISO 55001. However, the organisation was built before the ISO 55000 was published. They indicated that their main source was 'leidraad risicogestuurd beheer en onderhoud', a document developed within RWS. This guidance document is linked to other RWS policies such as the AM policy (Rijkswaterstaat, 2011) which makes sure the organisation will be built in correspondence to the ISO 55001. There is no ambition to become ISO 55001 certified. The characteristics of the A73 tunnels can be found in Table 5.1 and 5.2.

Figure 5.1 Swalmentunnel (Heijnen, 2014)

5.1.1 Relationships within the AM system

The AM system of the A73 tunnels is mainly controlled by RWS. The official asset owner is the Ministry of Infrastructure and the Environment. RWS has extended internal programs (Leidraad Systems Engineering, Leidraad RAMS, etc.) from where its stakeholders and the organisational context are

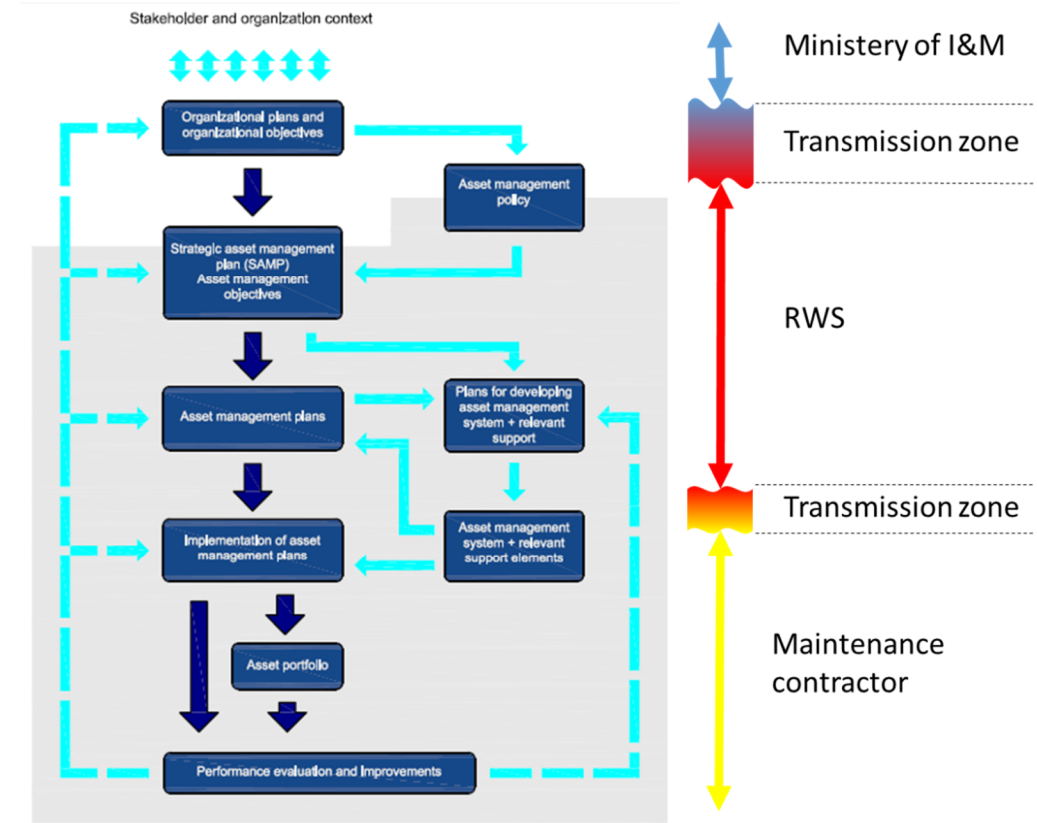


Figure 5.2 Global distribution of responsibilities in the AM system of the A73 tunnels

examined. There are also general AM policies, AM objectives and objectives in form of KPI's. At high strategic level, the minister of I&M is responsible for setting up policy targets. The actual policy is written by RWS. RWS does also have internal organisational plans and objectives, this results in an area were both parties are active in the AM system. RWS is also responsible for the tactical framework and tactical plans. At an operational level, RWS writes methodologies and develops different models and standards. (Rijkswaterstaat, 2011) The actual implementation of these AM plans is then outsourced to market parties. The division of responsibilities is visualised in Figure 5.2.

In table 5.3 the correspondence of the tunnel AM system with the key elements of the ISO 55000 is further elaborated. The specified maturity level is approximately the real maturity level of that element. This is caused by two things;

- The AM system is examined during an interview. Because the interview is voluntarily attended by two RWS employees, the interview can only take an hour or two. Due to this it was not possible to get a confirmation about all the claims that the tunnel AM system employees did. This means that it can be possible that some of the claims are (partially) incorrect.
- The analysis of the tunnel AM system's correspondence with the ISO 55001 requirements is based on the statements of the members of the organisations and on documents provided. It has not been checked if the things they say and write down are true and are actually being implemented.

Table 5.3 Correspondence of the tunnel AM system of the A73-tunnels with the key elements of the ISO 55000

Interviewee(s)	Safety Officer Road infrastructure at RWS, and Coordinator tunnel management A73 tunnels	
	Correspondence of tunnel AM system with the requirements of ISO 55001 using the IAM maturity scale	
Key element (ISO 55000)	**Maturity level**	**Explanation**
Stakeholder and organisational context	Beyond	RWS has many documents which describe how a project organisation should involve the internal and external context. This is developed beyond the ISO requirements
Organisational plans and organisational objectives	3	The project organisation is build up in a structured way, and the authority and responsibilities of every member of this organisation are described
Asset management policy	Beyond	An AM policy is determined and is coordinated with the plans and objectives of the organisation
Strategic asset management plan (SAMP) and Asset management objectives	3	The boundaries of the AM system are determined, there are goals determined through Key Performance Indicators (KPI's) which are being monitored on a dashboard. These goals are linked to the AM policy and the organisational goals
Asset management plans	3	Plans are developed about how the AM goals should be achieved. These plans emerge from the AM goals. The tunnel AM system can demonstrate what processes are performed by what party because they outsource sharply defined work packages to their contractors. These packages also contain requirements about the type and form of information which should travel from the contractor to the tunnel AM system
Plans for developing asset management	3	The organisation has deliberately set up and implemented an AM system, and is maintaining and continuously improving this AM system. There are RWS documents were

system + relevant support		is documented how the AM system contributes to reaching the AM goals. There is a procedure to make sure the risks are taken care of and chances can be exploited
Asset management system + relevant support elements	3	There are policies for the number and qualifications of resources necessary. There are policies about the competencies of the employees, to make sure they know what their role is in the AM system. Requirements are defined about communication and (documented) information
Implementation of asset management plans	3	Criteria are specified to make sure the necessary processes are planned, implemented and controlled. And the processes are also really managed according to these criteria. There are procedures in place to manage risks which emerge due to changes. There are procedures to manage the outsourcing of activities
Performance evaluation and improvements	3	Requirements are specified about what should be monitored and measured including asset performance, AM performance and effectiveness of the AM system. Internal audits and management reviews are performed on regular basis. When nonconformities occur, the tunnel AM system will react to the nonconformity and evaluate their reaction and the AM system afterwards. Preventive action will be taken when there is the suspicion of a nonconformity. The organisation strives after continuous improvement.

5.1.2 Summary

The A73 tunnels are owned by the ministry of I&M and managed by RWS. Because RWS is working with AM for several years, they have a lot of AM knowledge and have developed programs and guidance material for the implementation of AM. The tunnel AM system encountered many problems during the A73 tunnels development. The organisation encountered large internal and external pressure in this period and this resulted after two years in a complete AM system. The development of the A73 tunnels was before the implementation of the ISO 55000 and the Tunnelstandaard. Still, the tunnel AM system is conform to the ISO 55001 requirements. This is partially due to the use of the Leidraad Risicogestuurd Beheer en Onderhoud. Following only this Leidraad will already result in a tunnel AM system which is for a part (11 out of 27 ISO 55001 requirements are fulfilled) corresponding to the ISO 55001.

The AM system of the A73 tunnels is at the tactical level and a large part of the operational level managed by RWS. The Ministry of I&M delivers its goals and RWS will elaborate these to tactical and operational plans. Only the operational part of the AM system is outsourced to market parties, this does make these parties part of the AM system and responsible for part of the AM system, among others for the performance evaluation and improvements.

5.2 Salland-Twentetunnel

Table 5.4 Characteristics of the Salland-Twentetunnel

	Salland-Twentetunnel
Owner	'State' tunnel, owned by the ministry of Infrastructure & Environment
Manager	Rijkswaterstaat (RWS)
Length	1000 m, 500 m fully enclosed
Lanes	1 x 1 lanes + separate train tunnel with 2 tracks
Location	This tunnel is situated in the N35 in Nijverdal and goes through residential area
Situation	Opening scheduled in 2015
Source of AM system	The tunnel AM system design is based on the Tunnelstandaard

The Salland-Twentetunnel is a new tunnel what still has to be put into operation. The tunnel is situated in the centre of Nijverdal (Figure 5.3). This combined road and rail tunnel is expected to be finished in 2015. The tunnel is one of the test cases of the first version of the 'Tunnelstandaard' of RWS. This means that the equipment in the tunnel consists of the standardised equipment which is globally described in the RARVW (Regeling Aanvullende Regels Veiligheid Wegverkeerstunnels) and the subsequent internal elaboration by RWS in the 'Tunnelstandaard'.

Figure 5.3 Salland-Twentetunnel under construction (RTV Oost, 2014)

The Tunnelstandaard is linked to other policies such as 'Risicogestuurd Beheer en Onderhoud' and the AM policy of RWS. Because these policies are consistent with many of the requirements of the ISO 55001, the Tunnelstandaard is also for a large part in line with the requirements of the ISO 55001. More about the Tunnelstandaard can be found in Chapter 4.

Within the context of demonstrability, some of the documents were shown. This included their tunnel management plan (tunnelbeheerplan) and the maintenance management system (Beheersmanagementsysteem). This system included a breakdown of the entire structure. Of every element of the tunnel there was information available about the condition and the functionality. Knowing this and the objects lifecycle resulted automatically in a maintenance planning.

A number of the employees of this AM system was also involved in the process of the implementation of the AM system in the A73 tunnels. In this way the knowledge obtained in Roermond will be used to

improve the effectiveness of the AM system of the Salland-Twentetunnel. The characteristics of this tunnel can be found in Table 5.4.

5.2.1 Relationships within the AM system

The AM system of the Salland-Twentetunnel is very similar to the AM system of the A73 tunnels. As every state tunnel, the owner is the ministry of I&M, and RWS manages the tunnel. The distribution of responsibilities between the different involved organisations looks therefore a lot like that of the A73 tunnels. The same policy targets are applicable on this tunnel, the difference is that this tunnel is one of the test cases for the implementation of the Tunnelstandaard. This means this tunnel, and the corresponding AM system, have to comply with this standardised design. RWS has its own policies and organisational goals. The main difference between the distribution of responsibilities between the AM system of the Salland-Twentetunnel and the AM system of the A73 tunnels lies within the involvement of the contractor. The consortium of contractors who build the tunnel, is also responsible for the maintenance of the tunnel and has a clear role in the AM system. This clearness results in small transmission zone between the responsibilities of the contractor and RWS. Many operational activities are outsourced to market parties. This distribution of responsibilities is displayed in Figure 5.4.

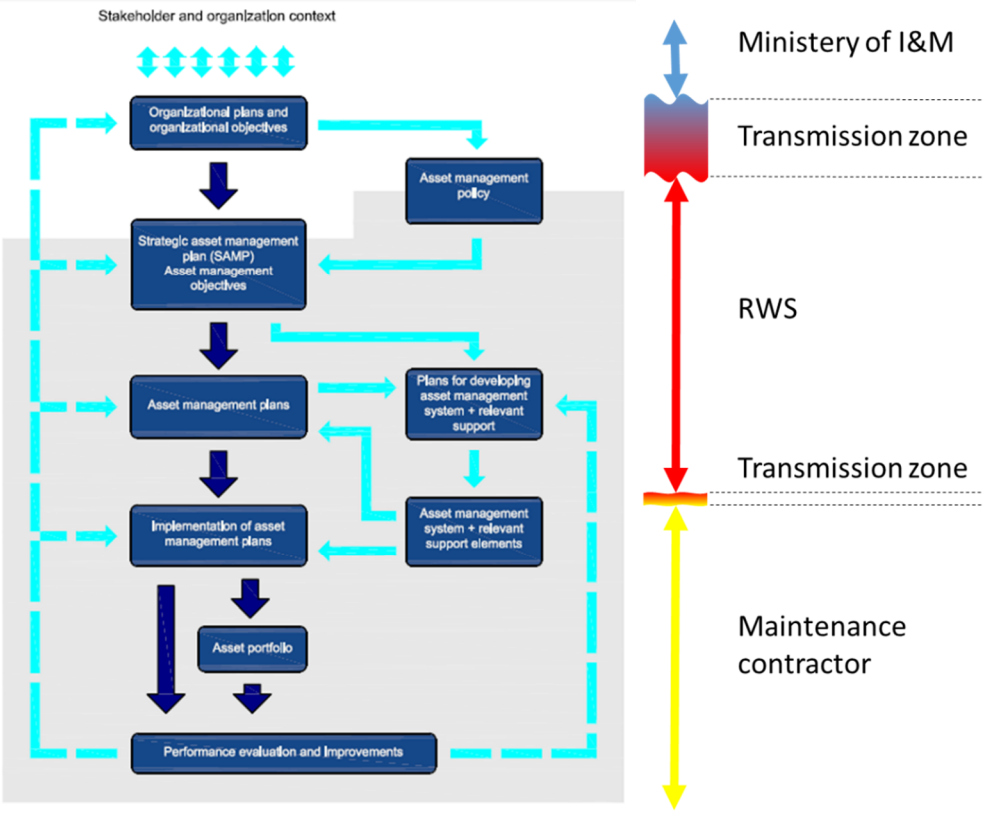


Figure 5.4 Global distribution of responsibilities in the AM system

In table 5.5 the correspondence of the tunnel AM system with the key elements of the ISO 55000 is further elaborated. The specified maturity level is approximately the real maturity level of that element. This is caused by two things;

- The tunnel AM system is examined during an interview. Because the interview is voluntarily attended by an RWS employee, the interview can only take an hour or two. Due to this it was not possible to get a confirmation about all the claims that the tunnel AM system employees did. This means that it can be possible that some of the claims are (partially) incorrect.
- The analysis of the tunnel AM system's correspondence with the ISO 55001 requirements is based on the statements of the members of the organisations and on documents

provided. It has not been checked if the things they say and write down are true and are actually being implemented.

Table 5.5 Correspondence of the tunnel AM system of the Salland-Twentetunnel with the key elements of the ISO 55000

Interviewee(s)	Consultant Asset Management at RWS	
	Correspondence of tunnel AM system with the requirements of ISO 55001 using the IAM maturity scale	
Key element (ISO 55000)	**Maturity level**	**Explanation**
Stakeholder and organisational context	Beyond	RWS has many documents (such as the Leidraad Systems Engineering, Leidraad RAMS, Handreiking Stakeholderstrategie bij Vitale Infraschakels (Veenswijk, 2013), etc) which describe how a project organisation should involve the internal and external context. Corresponding requirements can also be found in the Tunnelstandaard. This key element is developed beyond the ISO requirements
Organisational plans and organisational objectives	Beyond	The project organisation is build up in a structured way, and the authority and responsibilities of every member of this organisation are described
Asset management policy	3	An AM policy is determined and is coordinated with the plans and objectives of the organisation
Strategic asset management plan (SAMP) and Asset management objectives	3	The boundaries of the AM system are determined, there are goals determined through Key Performance Indicators (KPI's) which are being monitored on a dashboard. These goals are linked to the AM policy and the organisational goals
Asset management plans	Beyond	Plans are developed about how the AM goals should be achieved. These plans emerge from the AM goals. The tunnel AM system can demonstrate what processes are performed by what party because they outsource sharply defined work packages to their contractors. These packages also contain requirements about the type and form of information which should travel from the contractor to the tunnel AM system
Plans for developing asset management system + relevant support	Beyond	The organisation has deliberately set up and implemented an AM system, and is maintaining and continuously improving this AM system. There are RWS documents were is documented how the AM system contributes to reaching the AM goals. There is a procedure to make sure the risks are taken care of and chances can be exploited
Asset management system + relevant support elements	Beyond	There are policies about the number and qualifications of necessary resources. There are policies about the competencies of the employees and they know what their role is in the AM system. Requirements are defined about communication and (documented) information
Implementation of asset management plans	Beyond	Criteria are specified to make sure the necessary processes are planned, implemented and controlled. These processes are managed according to these criteria. There are procedures in place to manage risks which emerge due to changes. There are procedures to manage the outsourcing of activities

Performance evaluation and improvements	Beyond	Requirements are specified about what should be monitored and measured including asset performance, AM performance and effectiveness of the AM system. Internal audits and management reviews are performed on regular basis. When nonconformities occur, the tunnel AM system will react to the nonconformity. Their reaction and the AM system will be evaluated afterwards. Preventive action will be taken when there is the suspicion of a nonconformity, and continual improvement will be strived after.

5.2.2 Summary

At the time of the interview the design was not yet completed and the tunnel AM system was not yet fully implemented. However, it is clear that the tunnel AM system is being designed according to the Tunnelstandaard and the implementation was also at an advanced stage. This is why for this case the Tunnelstandaard is included in the examination of the correspondence with the ISO 55001 requirements, as if it was fully implemented. The AM system is developed according to the Tunnelstandaard, together with the other RWS AM documents this results in an AM system for the Salland-Twentetunnel that is corresponding to, and in many elements beyond the ISO 55001 requirements. Following only the Tunnelstandaard will already result in a tunnel AM system which is almost completely (25 out of 27 ISO 55001 requirements are fulfilled) corresponding to the ISO 55001.

The AM system of the Salland-Twentetunnel is owned by the ministry of I&M and managed by RWS. Only the operational part of the AM system is outsourced to market parties, this does make these parties part of the AM system and responsible for part of the AM system, among others for the performance evaluation and improvements. Due to timely arrangements, the overlap between RWS and the contractor consortium is confined. This results in less confusion and a better cooperation.

The AM system of the Salland-Twentetunnel is designed according to the Tunnelstandaard. The few ISO 55001 requirements that are not covered due to the implementation of the Tunnelstandaard are covered in other RWS documents. This results in a complete AM system which is beyond ISO 55000.

5.3 Waterwolftunnel

Table 5.6 Characteristics of the Waterwolftunnel

	Waterwolftunnel
Owner	Province of Noord-Holland
Manager	ARCADIS as Managing Agent
Length	670 m fully enclosed
Lanes	2 x 2 lanes
Location	Part of N201 at Oude Meer, close to Schiphol. The tunnel goes underneath the canal of the Haarlemmermeer polder
Situation	Opened in April 2013
Source of AM system	No general source

The Waterwolftunnel (Figure 5.5) is part of the N201, an important road near Schiphol and Aalsmeer. The tunnel AM system is managed by ARCADIS, who is for ten years responsible for the management of the tunnel. The first two years the owner of the tunnel, the province of Noord-Holland, has arranged the maintenance of the tunnel. This is mainly done according to the information which is given by the suppliers of the different systems. These systems are delivered with a maintenance prescription, and until the time of the interview these prescriptions are the main source of information for the composition of work packages.

This research has examined the Waterwolftunnel in December 2014. At time of writing the management of this tunnel is being redesigned and upgraded. The Waterwolftunnel management organisation is currently searching for the right interpretation of the managing agent role. They have indicated that they meet part of the requirements of the ISO 55001. But they know that the interdependencies between the different strategies, goals and (asset management) plans do not satisfy the ISO 55001 requirements. Another major issue is the lack of information exchange between the different actors in the system.

One of the reasons the tunnel managers put forward is the agreement between the asset owner and the asset manager. The asset manager (ARCADIS) experiences the contract they have with the asset owner (Province of Noord-Holland) not as stimulating for them to implement AM. They do not have the authority to make investment decisions, but they do get judged about the asset performances. There is currently a process going on to change this situation. The characteristics of this tunnel can be found in Table 5.6.

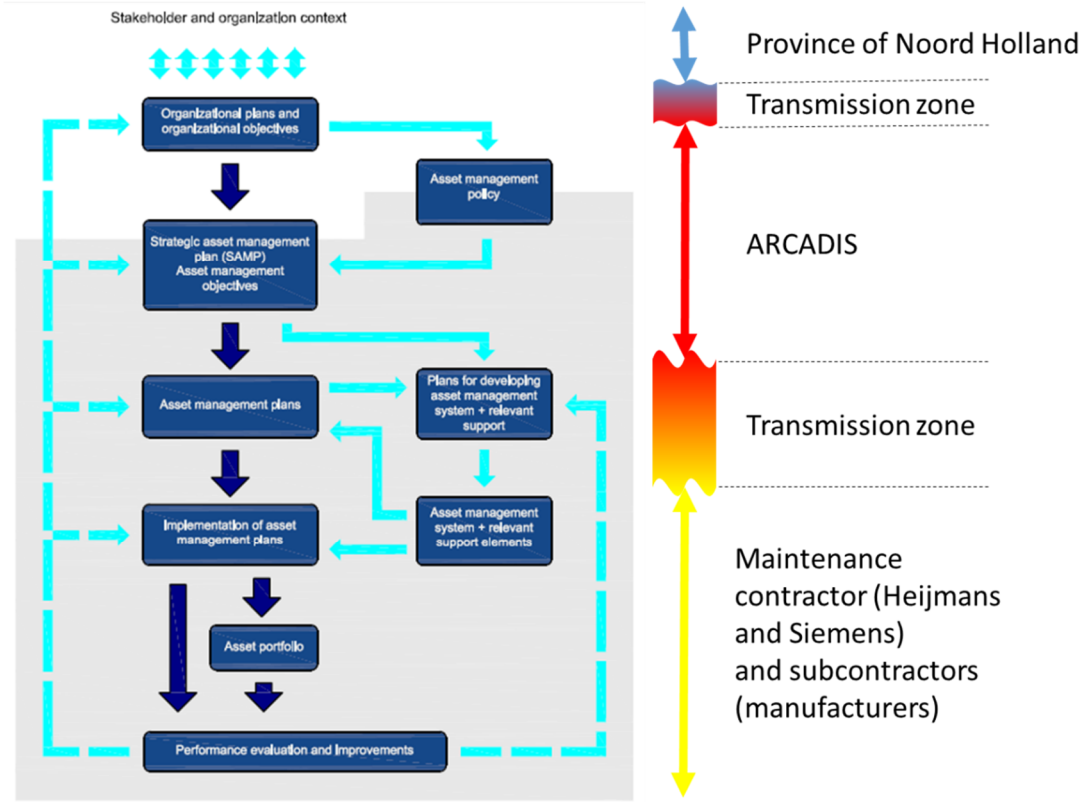
Figure 5.5 Waterwolftunnel (Noord-Holland, 2015)

5.3.1 Relationships within the AM system

The AM system of the Waterwolftunnel has a division between the strategic, tactical and operational part of the AM system. The owner, in this case the Province of Noord-Holland, has written requirements to which the asset manager should make sure the AM system complies to. ARCADIS is appointed as the 'Managing Agent'. In this role ARCADIS should take over most of the tasks of the province, this is currently not the case. In the previous phase, the province has contracted the current contractor. In this way this contractor is accountable by the province, and is being controlled by ARCADIS as the Managing Agent.

The contractors Heijmans and Siemens are responsible for the operational part of the AM system and write AM plans. Heijmans is responsible for the civil part of the tunnel and Siemens is responsible for the maintenance of the TTI. In their turn, they have contracted subcontractors, mostly the manufacturers of objects in the tunnel. All these organisations together result in an AM system including two major transmission zones, and an implementation phase were the different parties work adjacent. All these overlap results in confusion, coordination problems and responsibility problems. ARCADIS as the Managing Agent does not have much authority here. Currently the tunnel AM system is being redesigned because the maintenance contracts will expire soon and ARCADIS is not satisfied with the current contract what results for them in high risks against a limited return. The distribution of responsibilities in the tunnel AM system is displayed in Figure 5.6.

Figure 5.6 Global distribution of responsibilities in the AM system of the tunnel AM system of the Waterwolftunnel



In table 5.7 the correspondence of the tunnel AM system with the key elements of the ISO 55000 is further elaborated. The specified maturity level is approximately the real maturity level of that element. This is caused by two things;

- The AM system is examined during an interview. Because the interview is voluntarily attended by an ARCADIS employee, the interview can only take an hour or two. Due to this it was not possible to get a confirmation about all the claims that the tunnel AM system employee did. This means that it can be possible that some of the claims are (partially) incorrect.
- The analysis of the tunnel AM system's correspondence with the ISO 55001 requirements is based on the statements of the members of the organisations and on documents provided. It has not been checked if the things they say and write down are true and are actually being implemented.

Table 5.7 Correspondence of the tunnel AM system of the Waterwolftunnel with the Key Elements of the ISO 55000

Interviewee(s)	Consultant mechanical engineering at ARCADIS	
	Correspondence of tunnel AM system with the requirements of ISO 55001 using the IAM maturity scale	
Key element (ISO 55000)	**Maturity level**	**Explanation**
Stakeholder and organisational context	1	The asset owner has indicated the need for a tunnel. There is probably information gathered about stakeholders and their requirements but this is not known in the project organisation. Also, organisational context (of the province) is not communicated to the tunnel AM system.

Organisational plans and organisational objectives	2	The province of Noord-Holland has determined KPI's (Key Performance Indicators) and the asset manager needs to demonstrate the tunnel AM system's compliance to these KPI's. The asset manager has not lead the implementation of an AM system but they are currently working on this implementation.
Asset management policy	2	A plan of approach is written which shows what the tunnel AM system wants to achieve and how they will do this. This plan does not correspond to the organisational plans and is not wide spread through the organisation.
Strategic asset management plan (SAMP) and Asset management objectives	2	There are AM objectives in the form of KPI's. Not all boundaries are determined and communicated, for instance the financial boundaries. The AM objectives are not derived from the organisational objectives.
Asset management plans	2	The asset owner has written AM plans and has hired ARCADIS to orchestrate this. These plans are linked to the AM objectives. For the asset manager it is not clear what processes and activities are outsourced, and there are no clear arrangements about how, and what information should be exchanged. They developed different maintenance strategies. And ARCADIS is trying to improve the current plans.
Plans for developing asset management system + relevant support	2	There are ideas and goals for the development of a complete AM system, but this is not yet elaborated in a structured plan.
Asset management system + relevant support elements	2	There are no clear requirements about the resources necessary for this project. The tunnel AM system members are not fully aware about their position in the AM system. There are demands about documentation and information.
Implementation of asset management plans	2	Criteria are developed to make sure the necessary processes are planned, implemented and controlled. This is mainly done by the service provider but the asset manager and asset owner are aware of this. There is no clear policy to diminish risks that occur during changes. However, critical functions are determined which are taken into account during reliability and availability analysis.
Performance evaluation and improvements	3	Periodic evaluations are executed, there is an audit program and there is a safety plan what dictates what to do during an incident or deviation. Continual improvement is pursued.

5.3.2 Summary

The first two years of the managing agent contract of ARCADIS are almost over. The end of this period is also the end of the maintenance contracts of the service providers. This means there is a chance now to improve the AM system. This is quite necessary, the tunnel AM system has many improvement points. Currently, the managing agent is working on new contracts and is trying to implement a working AM system.

The main reason for the minimal developed AM system is the structure with the different contracts concerning the management of the Waterwolftunnel. The Province of Noord-Holland is the asset owner and ARCADIS is hired as an orchestrator. The province has also hired Heijmans and Siemens to become the service provider which in their place hired multiple subcontractors. All of this together leads to a tunnel AM system consisting of many organisations and because of unclear agreements there is no such thing as a line of sight. For many actors it is not clear what their exact role in the total picture is and this results to confusion, coordination problems and responsibility problems.

The other possibility of the lack of cohesion in the AM system is the fact that the tunnel AM system did not used a clear source when implementing the AM system. Using guidance material during the development of the new AM system will result in a more structured approach.

5.4 Markt-Maastunnel

Table 5.8 Characteristics of the Markt-Maastunnel

	Markt-Maastunnel or Maasboulevardtunnel
Owner	Municipality of Maastricht
Manager	Heijmans
Length	500 m, 400 m fully enclosed
Lanes	1 x 1 lanes
Location	This tunnel is built to minimize traffic at the Maasboulevard in the centre of Maastricht, the tunnel is situated next to a parking garage which can be entered via the tunnel
Situation	Opened in 2003
Source of AM system	Requirements specification written by the municipality and ARCADIS

The Markt-Maastunnel is situated in the centre of Maastricht (Figure 5.7). The tunnel helps to redirect a large part of the inner city car traffic. In the tunnel you can find the only entrance and exit of a parking garage. ARCADIS has written the requirements specification for the long-term maintenance of this tunnel, and is contracted by the municipality to manage the contract when a maintenance party is chosen. In this requirements specification many requirements can be found about the implementation of an AM system. The contractor Heijmans has been awarded the contract for the maintenance of the tunnel for ten years. Due to the detailed specifications the maintenance contractor has to meet many requirements. Together, these requirements result in a relative complete AM system which is almost in correspondence to the

Figure 5.7 Location Markt-Maastunnel (Maastricht, 2014)

requirements of the ISO 55001. One of the specifications is the implementation of the ISO 9001, this will result in a good basis for developing an AM system. More information about the requirements specification can be found in Paragraph 4.4.
The ARCADIS authors of the requirements for the tunnel AM system have developed these requirements by looking at other requirements specifications from RWS, and the requirements specification of other tunnels wherein ARCADIS is working. There is not a main source for this requirements specification. These authors are currently being hired by the municipality as a contract manager and point of contact for the contractor. The characteristics of this tunnel can be found in Table 5.8.

5.4.1 Relationships within the AM system

The Markt-Maastunnel is owned by the municipality of Maastricht. They are being assisted by AM consultants of ARCADIS. They have written the specifications for long term maintenance, and have contracted Heijmans as the organisation who will be responsible for the (lower) tactical and operational part of the AM system. The municipality has stated requirements for the organisations, and has stated AM objectives and strategies. Heijmans has to come up with an interpretation of this and is therefore working on the (lower) tactical level of the AM system. As a contractor, Heijmans is also responsible for the operational part of the AM system. The distribution of responsibilities is displayed in Figure 5.8.

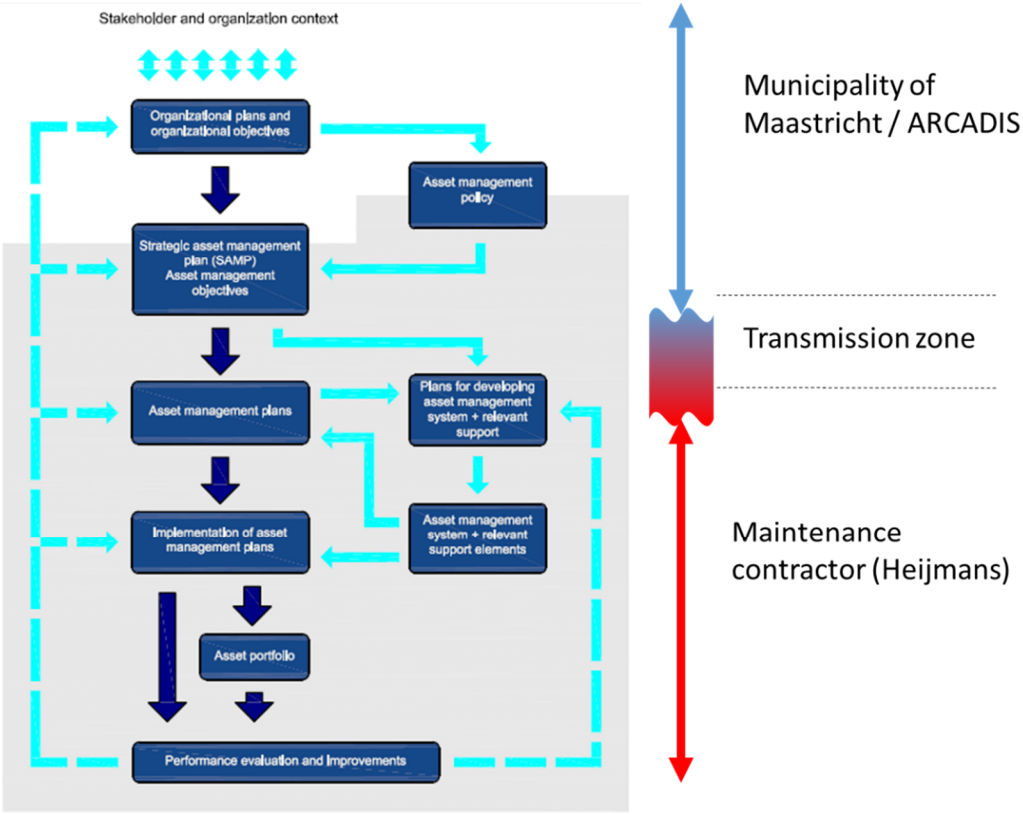


Figure 5.8 Global distribution of responsibilities in the AM system of the A73 tunnel AM system

In table 5.9 the correspondence of the tunnel AM system with the key elements of the ISO 55000 is further elaborated. The specified maturity level is approximately the real maturity level of that element. This is caused by two things;

- The AM system is examined during an interview. Because the interview is voluntarily attended by an ARCADIS employee, the interview can only take an hour or two. Due to this it was not possible to get a confirmation about all the claims that the tunnel AM system employee did. This means that it can be possible that some of the claims are (partially) incorrect.

- The analysis of the tunnel AM system's correspondence with the ISO 55001 requirements is based on the statements of the members of the organisations and on documents provided. It has not been checked if the things they say and write down are true and are actually being implemented.

Table 5.9 Correspondence of the tunnel AM system of the Markt-Maastunnel with the Key Elements of the ISO 55000

Interviewee(s)	AM consultant ARCADIS	
	Correspondence of tunnel AM system with the requirements of ISO 55001 using the IAM maturity scale	
Key element (ISO 55000)	**Maturity level**	**Explanation**
Stakeholder and organisational context	2	Stakeholders and their expectations are taken into account, but the organisational context of the municipality is not determined.
Organisational plans and organisational objectives	3	The tunnel AM system meets the requirements which demand that the asset manager is involved and will lead this project independently.
Asset management policy	2	The tunnel AM system does not have an AM policy but the Project Management Plan (PMP) does cover a large part of the AM policy requirement.
Strategic asset management plan (SAMP) and Asset management objectives	2	A scope is stated of the AM system using a WBS and a SBS, there are also goals in the form of KPI's. However, there is no clear link between these goals and the stakeholder expectations.
Asset management plans	Beyond	The tunnel AM system works with multiple plans to implement the different subjects of AM. The goals consist of the KPI's, goals stated by the municipality and a goal specific from Heijmans.
Plans for developing asset management system + relevant support	3	The tunnel AM system is aware that it is implementing an AM system and dealing with risks for the AM system is elaborated in processes.
Asset management system + relevant support elements	Beyond	The organisation of the tunnel AM system is described, their competences comply too the requirements and there are back-up organisation members. Requirements for communication and information are determined.
Implementation of asset management plans	Beyond	Criteria are developed by the tunnel AM system to make sure the necessary processes are planned, implemented and controlled. There is a clear policy to diminish risks that occur during changes. Because the asset manager and the service provider role are incorporated in the same organisation (Heijmans), the alignment between the tactical and operational part is really fluent.
Performance evaluation and improvements	3	The Demming circle is used multiple times in the Project Management Plan and dictates the use of evaluation and improvement processes.

5.4.2 Summary

The Markt-Maastunnel is a tunnel in the centre of Maastricht and is owned by the Municipality of Maastricht. With ARCADIS as a contract manager the municipality has hired Heijmans as an asset manager and service provider. The management of the tunnel is outsourced for ten years to Heijmans.

To make sure the tunnel management and maintenance would be executed in accordance to the expectations of the municipality, they have written an extensive requirements specification with requirement for the AM system that has to be developed.
The distribution of responsibilities is relative straightforward. The municipality of Maastricht is the asset owner, they have contracted Heijmans to develop and implement this AM system. The municipality has already adduced a large part of this AM system in the requirements specification.

The tunnel AM system is during the research in place for almost a year. The tunnel AM system is obliged to meet the requirements from the requirements specification and is developed according to a Project Management Plan developed by Heijmans. Following only the requirements specification will already result in a tunnel AM system which is for a large part (19 out of 27 ISO 55001 requirements are fulfilled) corresponding to the ISO 55001. Implementing the ISO 9001 results in correspondence to 7 of the 27 requirements. Because of the contributions of Heijmans the correspondence of the AM system to the ISO 55001 requirements becomes even larger.

5.5 Tunnels of Amsterdam; IJtunnel, Piet Heintunnel and the Michiel de Ruijtertunnel

Table 5.10 Characteristics of the IJtunnel

	IJtunnel
Owner	Municipality of Amsterdam (Mayor and Alderman)
Manager	Municipality of Amsterdam (DIVV)
Length	1682 m, 1039 m fully enclosed
Lanes	2 x 2 lanes
Location	This tunnel is situated in the S116 underneath the IJ in Amsterdam, it connects the centre of Amsterdam with Amsterdam-Noord
Situation	The tunnel was opened in 1968
Source of AM system	No general source, there are some internal AM sources

Table 5.11 Characteristics of the Piet Heintunnel

	Piet Heintunnel
Owner	Municipality of Amsterdam (Mayor and Alderman)
Manager	Municipality of Amsterdam (DIVV)
Length	1900 m, 1490 m fully enclosed
Lanes	2 x 2 lanes + separate tram tunnel with 2 tracks
Location	This tunnel is situated in the S114 underneath the Amsterdam-Rijnkanaal in Amsterdam, it opens up the centre of Amsterdam to the east
Situation	The tunnel was opened in 1997
Source of AM system	No general source, there are some internal AM sources

Table 5.12 Characteristics of the Michiel de Ruijtertunnel

	Michiel de Ruijtertunnel
Owner	Municipality of Amsterdam (Mayor and Alderman)
Manager	Municipality of Amsterdam (DIVV)
Length	360 m
Lanes	2 x 2 lanes
Location	This tunnel is situated in the S100 underneath the De Ruijterkade next to Amsterdam central train station
Situation	Opening scheduled in 2015
Source of AM system	No general source, there are some internal AM sources

In Amsterdam the Department of Infrastructure, Traffic and Transportation (Dienst Infrastructuur Verkeer en Vervoer) is responsible for the maintenance of the municipal infrastructure, including a number of tunnels. The tunnels mentioned are the IJtunnel (Figure 5.9), Piet Heintunnel and the Michiel De Ruijtertunnel (not yet opened). These tunnels are currently the most important tunnels of the municipality of Amsterdam. Other tunnels are the Arenatunnel, the wiring and piping tunnel in the Zuidas and the Spaarndammertunnel, of which the construction started in January 2015.

From the interview became clear that the municipality is busy reforming their current way of AM. The current way of infrastructure maintenance can be seen as the 'old' way of maintenance. (DIVV, 2010) The DIVV writes compete work packages which can then be implemented by a contractor or their own crew. Little information about asset performance and condition is returning to the asset managers. So the line of sight is interrupted and continues improvement is not effective.

It was mentioned that the municipality, especially the maintenance department, is not keen on changes. The management division of the DIVV consist of seven areas (such as pavements, traffic control systems and tunnels. Above these areas of maintenance, an overarching process was going on to implement AM. Another factor that slowed down the change was the politics. The interviewee told that in the municipality of Amsterdam, politicians are not keen on talking about LCC and other investments which will pay off in the next decade(s).

Figure 5.9 Entrance of the IJtunnel (Parool, 2015)

The DIVV is not worried about reaching the requirements for the WARVW but implementing AM will be harder. Currently they are trying to get a grip on the financial implications of their AM policy. There are already calculations about the value of the tunnels per open hour. This resulted in insights about the value of each tunnel for the network and this automatically results in insights in the maintenance strategy. For example the value of the IJtunnel for the city is about seven times as high as the value of the Piet Heintunnel, but the maintenance budgets of the two tunnels are equal. The municipality now knows that this is happening but an optimal AM strategy is not yet developed. Speaking in terms of the IAM maturity schale, the Municipality of Amsterdam is 'aware' of their shortcomings, and is 'developing' an AM system. The characteristics of these tunnels can be found in Table 5.10, 5.11 and 5.12.

5.1.1 Relationships within the AM system

The AM system of the tunnels of the municipality of Amsterdam is owned by the municipality itself. The municipality determines the organisational context of the AM system, they determine their own strategy, objectives and write the AM plans for their assets. Inspections and minor repairs are also executed by employees of the municipality. Most major maintenance and construction activities are outsourced to market parties. This is currently done in a traditional way which means that the entire AM system is controlled by the municipality.

However, within the municipality, different roles can be discovered. The major and Alderman are the owners of the assets. They develop organisational plans and objectives and have different policies. The DIVV is the manager of the assets. This organisation is divided into different areas and they are currently working on an overall AM policy and strategy. They do have AM goals and plans but these are not linked to strategy or policy.

The operational part of the AM system is managed by employees of the DIVV. This is currently managed in a traditional way and part of the work is outsourced to contractors. Most of these employees are working in a traditional way and are not aware of their role in the AM system. Due to this, everybody is just doing their own job and there is not much evaluation and improvement.

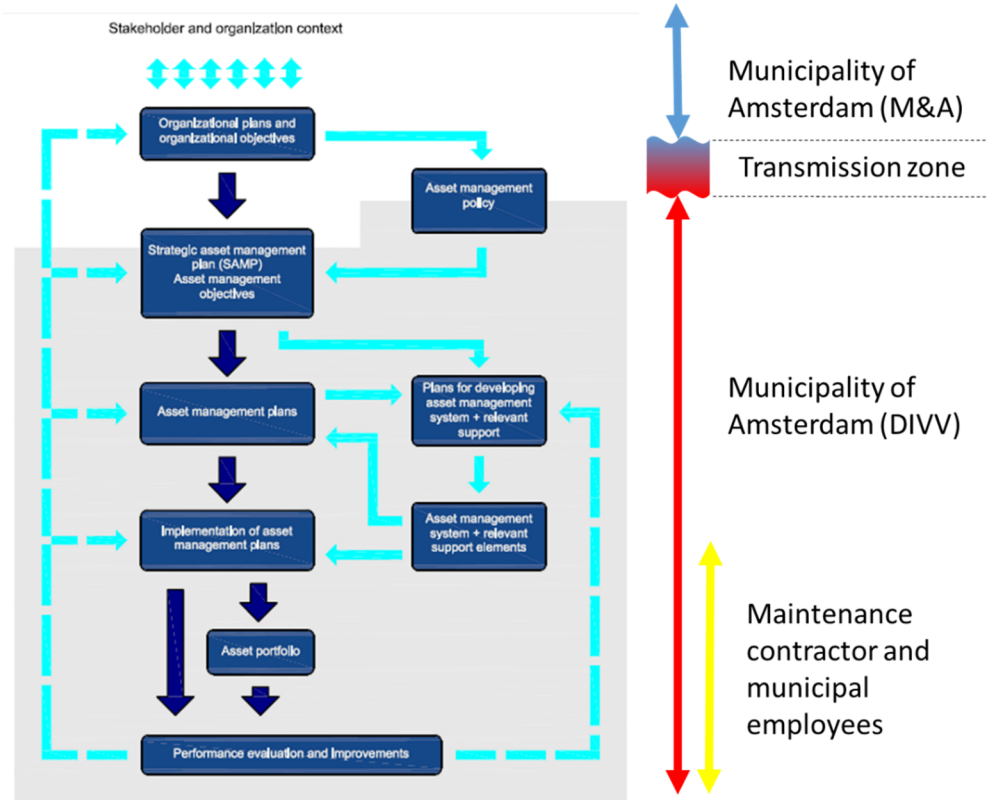


Figure 5.10 Global distribution of responsibilities in the AM system of the tunnel AM system of the municipality of Amsterdam

The AM system of the municipality of Amsterdam is divided between three different 'organisations'. A municipality is divided in a political section, and a section which is filled in by civil servants. The Major and Alderman, and the City Council are the people who determine policy and the civil servants have the duty to implement this policy. However, the composition hereof changes with every election. This means that every four years the civil servants face directors with a different view and there is most of the time not enough attention for long term (> 4 years) AM policy. The distribution of responsibilities is displayed in Figure 5.10.

The municipality is the owner of the AM system, and they are responsible for almost the entire system. However, this does not mean that the internal line of sight is fluently and every employee responsible for a part of the AM system is aware of his place in the system.

In table 5.13 the correspondence of the tunnel AM system with the key elements of the ISO 55000 is further elaborated. The specified maturity level is approximately the real maturity level of that element. This is caused by two things;

- The AM system is examined during an interview. Because the interview is voluntarily attended by a DIVV employee, the interview can only take an hour or two. Due to this it was not possible to get a confirmation about all the claims that the tunnel AM system employee did. This means that it can be possible that some of the claims are (partially) incorrect.
- The analysis of the tunnel AM system's correspondence with the ISO 55001 requirements is based on the statements of the members of the organisations and on documents

provided. It has not been checked if the things they say and write down are true and are actually being implemented.

Table 5.13 Correspondence of the tunnel AM system of the tunnels of Amsterdam with the Key Elements of the ISO 55000

Interviewee(s)	Municipal maintenance manager of the tunnels of Amsterdam, DIVV	
	Correspondence of tunnel AM system with the requirements of ISO 55001 using the IAM maturity scale	
Key element (ISO 55000)	**Maturity level**	**Explanation**
Stakeholder and organisational context	2	There are KPI's related to stakeholder requirements. It is not known if stakeholders' requirements are taken into account in all elements of the AM system. The organisational context is in some aspects really rigid, such as the bureaucratic processes. But if you look at the politics, with changing actors every four years, you can say the organisational context is really flexible. Nevertheless, not all context is taken into account.
Organisational plans and organisational objectives	2	There are plans from the municipality to implement AM, these are at the time of the research not fully elaborated.
Asset management policy	2	There is an AM policy, this policy is not completely linked to the organisational goals
Strategic asset management plan (SAMP) and Asset management objectives	2	The scope of the AM system for the tunnels of Amsterdam is clear. The AM program they are trying to implement is meant for the entire municipal infrastructure assets of the city. It is not known if this is also clear. There are AM goals and KPI's.
Asset management plans	3	In the current way of working, the DIVV is already making maintenance plans. There are KPI's and goals that have to be reached.
Plans for developing asset management system + relevant support	2	The DIVV is consciously searching for the right way of implementing an AM system.
Asset management system + relevant support elements	2	The DIVV builds on the current approach to AM. In this way there are for the operational part enough resources available and there are clear arrangement about communication and information. For the tactical and especially the strategic part of the system the DIVV is still searching for the right approach. This is also the case with the awareness of the employees about the AM system they are part of.
Implementation of asset management plans	2	The implementation of the AM plans is partially traditionally outsourced to contractors, and partially implemented by municipal workers. These operations are controlled according to know methods. There are no clear arrangements about the information that has to be delivered by these contractors.
Performance evaluation and improvements	3	The municipality is really aware of the performance of their tunnels. Audits are take place and nonconformities are dealt with in accordance to established procedures.

5.5.2 Summary

The municipality of Amsterdam is the owner of a number of tunnels, and the next years there will be constructed multiple new tunnels. The most important tunnels of the municipality are the IJtunnel, the Piet Heintunnel and the almost finished Michiel de Ruijtertunnel. These tunnels are until now maintained in a traditional way. The result of this is that the municipality does not has a complete AM Strategy, AM policy, AM objectives and AM plans. Recently the municipality has decided to develop an AM system and at a high level there are some plans now for the implementation of such a system. The DIVV as the asset manager has to deal with politicians as the asset owner which results often in changed plans and a short term vision.

The municipality owns most of the AM system but this does not mean the line of sight is communicated through the entire organisation. Because of the political asset owner, decisions regarding the AM system can sometimes be seen as illogical. For the implementation of AM plans the municipality hires contractors and has its own crew,

The AM system of the DIVV corresponds too few of the requirements from of the ISO 55001. This is because the municipality is currently still working as a traditional maintenance organisation. Because they are now in a transition phase, the DIVV is aware of most ISO 55001 requirements and is working towards the implementation of an AM system.

5.6 Other

For this research, information was also gathered about the Boxemtunnel, situated in Zwolle. This tunnel is owned by the Municipality of Zwolle. The entire management organisation for this tunnel is outsourced to an engineering organisation (Westenberg Harderwijk) as an asset manager. This organisation has delivered a management system were the constructing contractor has filled in the specifications of the entire object. After the acceptance, the engineering firm will inspect the tunnel, and outsource work packages to the market. The municipality receives only periodic updates about the tunnel. The asset manager of the tunnel was not able to give specific information about how they managed the tunnel and therefore this tunnel is not included in the research.

5.7 Case comparison

Table 5.14 summarizes the different tunnel AM systems and their ISO 55001 correspondence. It can be seen that the tunnel AM systems of the examined state tunnels meet most of the requirements of the ISO 55001. The main reasons for this are the initial problems at the A73 tunnels, and the new legislation on tunnel safety and tunnel management. RWS has also the advantage of being a large organisation which can start up and implement programs like the Asset Management Implementation Programme. The other main reason for the current leading position of RWS is the publication of the WARVW and subsequently the Tunnelstandaard. The RWS AM systems meet almost every requirement of the ISO 55001.

Provinces and municipalities do not have all the possibilities an organisation like RWS has. In two cases the governmental department outsourced the asset manager role of the management system. The province of Noord-Holland has contracted ARCADIS to act as a Managing Agent for the Waterwolftunnel. The municipality of Maastricht has hired ARCADIS to assist them in outsourcing the tunnel management activities to a contractor. The AM system of the Markt-Maastunnel meets almost every requirement. The AM system of the Waterwolftunnel on the other hand does not corresponds to the requirements of the ISO 55001, this can be explained by the limited amount of freedom left in the contract for the managing agent.

The municipality of Amsterdam has its own department (DIVV) which is now implementing AM. Due a number of reasons this is going not really smoothly. The municipality also claims that the political part of their organisation has an inhibitory effect on the development of a working AM system.

Table 5.14 Summary of tunnel cases

Tunnel Management Organisation	Owner	Manager	ISO 55001 correspondence	Source for implemented AM system
A73 tunnels	National government	RWS	Beyond ISO 55001	Leidraad Risicogestuurd Beheer en Onderhoud
Salland-Twentetunnel	National gouvernement	RWS	Beyond ISO 55001	WARVW and Tunnelstandaard
Waterwolftunnel	Province	ARCADIS	Little ISO 55001 correspondence	No specific source
Markt-Maastunnel	Municipality	Heijmans	Large ISO 55001 correspondence	Contractual documents and specifications
Tunnels of Amsterdam	Municipality (Major and Aldermen)	Municipality (civil servants)	Partial ISO 55001 correspondence	No specific source

In Table 5.15 the correspondence of the different tunnel AM systems with the ISO 55001 requirements are put together. The average maturity towards the requirement of the ISO 55001 is 2,8. This is of course a really high score if you know that a tunnel AM system has to reach a maturity level of 3 to be ISO 55001 compliant. To be ISO 55001 compliant the organisation has to reach maturity level 3 on every requirement and an average of 3,0 will not be sufficient.
The average of 2,8 is also relative high because the two tunnels managed by RWS score multiple times 'Beyond ISO'. Once more I want to indicate that these scores are based on interviews, and that it was not possible for the interviewees to substantiate all their claims with the relevant documents. It is also sometimes difficult to assign the correct maturity level. For example the difference between ISO compliant and 'Beyond ISO' is sometimes hard to tell and even harder to prove.
However, there is clearly shown that the state tunnels are ISO 55001 compliant and that the Markt-Maastunnel is also for a large part compliant. You can also see that the other two tunnels are not yet that mature. The maturity level 'Innocent' is not applicable for any of these organisations, and the level 'Aware' is awarded only once. This means all of these tunnels are really 'developing' there AM systems.
Another interesting conclusion what can be drawn from this table is the fact that all of the tunnel AM systems are developed further at operational level than at the strategic level. This can be explained by the traditional way of tunnel maintenance. During this maintenance contractors implemented work packages but did not have extensive strategies and policy.

Table 5.15 Comparison of tunnel AM system correspondence with the ISO 55001 requirements. For the maturity level 'Beyond' the maturity score of 4 is used.

Key element (ISO 55000)	A73 tunnels	Salland-Twentetunnel	Waterwolftunnel	Markt-Maastunnel	Tunnels Amsterdam	Average
Stakeholder and organisational context	4	4	1	2	2	2,6
Organisational plans and organisational objectives	3	4	2	3	2	2,8
Asset management policy	4	3	2	2	2	2,6
Strategic asset management plan (SAMP) and Asset management objectives	3	3	2	2	2	2,4
Asset management plans	3	4	2	4	3	3,2
Plans for developing asset management system + relevant support	3	4	2	3	2	2,8
Asset management system + relevant support elements	3	4	2	4	2	3
Implementation of asset management plans	3	4	2	4	2	3
Performance evaluation and improvements	3	4	3	3	3	3,2
Average	3,2	3,8	2	3	2,2	2,8

Role of asset manager

When looking at the role of the asset manager in the different tunnel AM systems it can be concluded that for the examined cases the degree of AM maturity is influenced by what part of the AM system is controlled by the asset manager. The two state tunnels are managed by RWS, who will also write the AM plans and controls the implementation of these plans, only the actual implementation of these plans is outsourced. The municipal owned Markt-Maastunnel has outsourced the AM role to a party which is also able to perform the role of service provider.

The Waterwolftunnel has an asset manager with the role of orchestrator who has to deal with requirements of an asset owner, and with a service provider who in his turn should control multiple subcontractors. This AM system contains many interfaces, and together these are the cause of a incomplete AM system.

The Municipality of Amsterdam is developing its AM system at this very moment. The implementation of their AM system is delayed by the inconsistency of politicians on one side and the stubbornness of the maintenance employees of the DIVV on the other side. The DIVV as asset manager is still searching for the optimal approach to this.

6. CONCLUSIONS AND DISCUSSION

This research is executed to answer the main question:
'What is the added value of the ISO 55000 standard for the owners of Dutch road infrastructure AM systems, and how can the ISO 55000 standard contribute to the Dutch road infrastructure sector?'

The added value of the ISO 55000 results from the fact that it offers a structure which can be used by an organisation to develop an AM system. It is suitable for every asset type, and every asset portfolio. Furthermore the process of standardisation delivers added value to an organisation.

There are three major downsides to the ISO 55000; the fact that the specified requirements are written for an AM system which is owned by the same party as the owner of the assets; the ISO 55000 is applicable to every conceivable asset and therefore too general for specific situations and the fact that this generality has already resulted in sector specific guidance material which is capable of replacing the ISO 55000 for AM system development.

The ISO 55000 can contribute to the Dutch road infrastructure sector when its benefits are being exploited and the downsides avoided. The ISO 55000 cannot contribute much to the area of tunnel management, however it can be used in other areas of the Dutch road infrastructure, especially for the management of complete infrastructure networks.

This chapter will elaborate this answer in three paragraphs. In Paragraph 6.1 the added value of the ISO 55000 will be displayed. Paragraph 6.2 discusses the less positive characteristics of the ISO 55000 standard. The third paragraph will elaborate on the possible contributions of the standard to the Dutch road infrastructure sector.

6.1 Added value of the ISO 55000

The added value of the ISO 55000 is not he same for every organisation. It depends on the type and structure of the organisation, and on the characteristics of its asset portfolio. The different ways of how the ISO 55000 can provide added value to a (road infrastructure) asset owner are explained below:

6.1.1 The ISO 55000 offers a structure for the development of an AM system

The ISO 55000 specifies a structured way of obtaining the maximal value of an organisations assets. Many infrastructure AM system owners are searching for the right approach to develop an AM system, they can use the ISO 55000 and the requirements of the ISO 55001 to develop such a system. The AM system specified in the ISO 55000 visualises the different key elements of an AM system, makes clear what these elements should contain and how the different elements are connected to each other. The ISO 55000 is developed in a way what makes it is easy to integrate this AM system with other management systems. Many organisations are working according to the requirements of the ISO 9001 for a quality management system, this is a good basis for the implementation of the ISO 55000. It is also possible to implement the ISO 55000 partially, as a supplement to the current practices.

6.1.2 The ISO 55000 can be used for the development of an AM system for the management of specific objects, or an entire (infrastructure) network

In this research, the applicability of the ISO 55000 to the AM systems of specific tunnels is examined. The management organisation of these tunnels is considered as complete management systems. The ISO 55000 can also be used for the management of a network from which a tunnel should only be part of. In fact, the considerations necessary between risks, performance and costs are becoming more valuable when the AM system is developed for the management of a more extensive asset portfolio, and an AM system according to the ISO 55000 is really suitable for a road infrastructure network. The ISO 55000 has more added value for an asset portfolio which includes a lot of, and different types of

assets. For separate objects, additional guidance material is easier to develop and is already developed for some types of objects, such as tunnels.

6.1.3 The standardisation of processes of an organisation delivers added value

The ISO has developed many standards. Standards can help an organisation to implement general accepted and approved processes. The ISO standards help to harmonize technical specifications of products and services making an organisation more efficient by breaking down barriers to international trade. Conformity to a standard helps to reassure that the organisation has developed demonstrably functioning processes for that specific area. This delivers mutual trust, the organisation knows that they are doing well, and the clients of this organisation can trust that their processes are structured in a right way. When an organisation does not have the internal motivation of improving their processes, the standard can still be beneficial when the organisation has an external motive. When this occurs, the organisation pursues ISO 55001 certification and will only use this for commercial reasons, or so called 'window dressing'. Implementing the ISO 55000 with purely external motivations will not improve the processes of the organisation but it can be beneficial for obtaining assignments.

6.2 Downsides of the ISO 55000

In this research it has been shown that the ISO 55000 standard does not always add value to an organisation, the following paragraph will discuss the three main downsides of the ISO 55000.

6.2.1 The ISO 55000 standard is developed for AM system owners who also own the (major part of the) asset portfolio

It is important to make the distinction between the owner of the asset portfolio, and the owner of the AM system. The owner of the asset portfolio, is not always the owner of the AM system. In many cases the development, implementation and management of the AM system is outsourced by the asset owner. Sometimes this is done with detailed specifications, in other cases the contractor has to specify the system by itself. Another possibility is to outsource the AM system to multiple parties or only put a specific part of the AM system out on the market.

The ISO 55000 assumes that the AM system is managed by the same organisation who is also the owner of the asset portfolio. There are requirements for outsourcing in the ISO 55000, but these are meant for outsourcing operational activities. The ISO 55000 does not take outsourcing of (part of the) tactical or strategic elements of the AM system into account. Because these processes are not structured, problems occur within the interfaces between the involved parties. Most problems occur during the exchange of information between the involved parties, and in maintaining the 'line of sight' or 'awareness' within the different elements of the AM systems. When this awareness is not present, the AM elements are developed separately what leads to an AM system what will not be able to fulfil its function in an optimal way. This is also possible when an AM system is managed by a contractor, and this contractor wants to implement the ISO 55000. The organisation needs to ensure the line of sight within the AM system, the cooperation of the asset owner is therefore crucial.

6.2.2 The ISO 55000 is too general

Because the ISO 55000 is developed for every possible asset, the used terminology is very general. There are no specific requirements for infrastructure, or even for physical assets. The predecessor of the ISO 55000, the PAS 55, was less general and was specifically developed for the management of physical assets. The reason for the developers of the ISO 55000 to make the standard more general is that the standard should be applicable on every type of asset, in every type of organisation, in every sector all over the world. Most organisations working in the road infrastructure sector are focussed locally and do not intend to start international collaborations or work in international projects.

The general approach of the standard leaves a lot of room for sector specific guidance material. During the research, the examined tunnel AM systems were developed according to specific guidance material. Some of this material was developed so well that it can make the ISO 55000 superfluous. Some organisations that were already working with the PAS 55 have indicated that they will continue

to use the standard. This can be beneficial on short term, but on long term it is not recommendable since the PAS 55 will not be developed further, and the PAS 55 is hard to integrate with other (international) standards.

6.2.3 More specific documents are available for the development of an tunnel AM system

The ISO 55000 is the first worldwide attempt to capture the generically applicable 'must do' items for the management of any asset type. It does not attempt to define the 'how to', as this depends on organisational context and the assets to be managed. For the specific subject of tunnel management and maintenance, there is a lot of guidance material available. This is due the fact that there are many safety requirements for tunnels, and these tunnels have the statutory obligation to be demonstrably safe. Different asset managers use different guidance material for the development, implementation and management of their tunnel AM systems.
In this research, some of the material is examined for the development of an AM system for tunnels. There is already a lot of guidance material available what is being applied in many cases. The Dutch road infrastructure sector did not use the PAS 55 much, there is a little interest in the ISO 55000, and as shown in this research the current tunnel AM systems are developed according to other documents. The Tunnelstandaard is being applied in three tunnels at the moment, and other future tunnel AM systems of RWS will be developed according to the Tunnelstandaard. This research has proven that an AM system developed according to this Tunnelstandaard, will be ISO 55000 compliant. Concluding there can be said that the Tunnelstandaard will make the ISO 55000 superfluous for the specific area of developing tunnel AM systems.

6.3 The contribution of the ISO 55000 to the Dutch road infrastructure sector

The goal of this research was to find out how the ISO 55000 standard can contribute to the Dutch road infrastructure sector. First, the contribution to the Dutch road infrastructure sector in general will be described. Second, more specific conclusions are drawn for the area of Dutch road tunnels.

6.3.1 Contribution of the ISO 55000 to the Dutch road infrastructure sector

The ISO 55000 can contribute to the development of AM in the Dutch road sector. The specified structure can be implemented for the management of an organisation's asset portfolio which can lead to the initial quick wins and the long term benefits of a well-established AM system. The standardisation of processes will be beneficial because the organisation can more easily seek alliance with other organisations. There is however also other guidance material available. There are documents with specifications for a part of an AM system, and there are documents specifically for certain assets, who do cover an entire AM system.
The Dutch road infrastructure sector can be divided in three different parts. There is the national road network, owned by the Ministry of I&M and managed by RWS. Other asset owners are the provincial and municipal road network, owned by respectively the different provinces and the municipalities. The management of these networks is executed by the owners, or this is outsourced to market parties. Most of these asset owners have to deal with decreasing budgets, increasing performance, increasing legal requirements and less public acceptance.
RWS is already working on the implementation of AM for their entire asset portfolio and is developing a lot of guidance material. Other governmental asset owners are also noticing the added value of AM and are searching for the right approach to implement this. RWS is an organisation, which is able to accelerate the implementation of the ISO 55000. RWS is working on the implementation of AM, but they have indicated already that they will not implement the ISO 55000. This is mainly caused by the fact that they have developed their own AM guidance material, simultaneously with the development of the ISO 55000. In this research it appeared that RWS is really progressive. It has to be taken into account that there might be some bias by the interviewees. An organisation that strives to be progressive, can think they are further developed than they are really. There is a fair possibility that these interviewees do overestimate their own maturity. Underestimation is less likely.

Most provincial and municipal asset owners still have to decide about implementing the ISO 55000. Many of these organisations are not capable of developing their own methodology so they will have two options; they can join the lead of the AM implementation of RWS, or implement the ISO 55000 standard. I think the degree of collaboration of RWS will influence this, and the degree of cooperation between the different provinces and municipalities. Since (almost) all road infrastructure is owned by governments, I assume there will not be external motivation. The Dutch road infrastructure sector has to deal with a lot of regulations. Many of these regulations are developed for specific elements such as tunnels and bridges. These regulations demand that assets are demonstrable meeting safety requirements. AM is able to demonstrate that a system is constantly meeting its requirements. When an AM system is certified towards ISO 55000, an organisation assures its requirements are fulfilled. In this way, regulations are stimulating the implementation of the ISO 55000.
Some of the factors that influence the implementation of a standard, are beneficial for the implementation of the ISO 55000. There is a demand for improvement and standardisation. The standard can provide benefits for many organisations, and the governmental asset owners have the right motivation. The less positive factor is that RWS will not implement the ISO 55000, and the general road infrastructure sector's regulation does not demand standardisation.

6.3.2 Contribution of the ISO 55000 to Dutch road tunnels

In this research the AM systems of different tunnels are examined. Concluding I can say that the internally developed AM system, captured in the Tunnelstandaard, for tunnels managed by RWS is already ISO 55000 compliant and in many areas beyond the ISO 55000. The Tunnelstandaard is developed without consultation of provinces and municipalities. This has until now resulted in an aversion from these parties towards the Tunnelstandaard, but this will probably evaporate next years. The Tunnelstandaard is an almost complete package which is already developed as a template. Municipal and provincial governments would do well if they would develop AM systems for their tunnels by using the Tunnelstandaard. After this first AM system, these systems can then be developed to an AM system for all of their (infrastructure) assets. In the ideal situation, the asset owner has developed an AM system which will manage all of their assets, in this way the optimal balance of costs, risks and performance can be achieved.

7. RECOMMENDATIONS

This research has examined the added value of the ISO 55000 for the Dutch road infrastructure market at the request of ARCADIS Nederland; Market group Roads, Traffic, and Information management; Advisory Group Asset Management. This research is executed because ARCADIS wants to know what they can offer (potential) clients with regards to the ISO 55000, published in 2014.
From the results of this research is concluded that there are multiple advantages, but also disadvantages when implementing the ISO 55000 in the Dutch road infrastructure sector. Nevertheless, the ISO 55000 can contribute to implement AM in the road infrastructure sector. This chapter will first give recommendations about what to do with the ISO 55000 in combination with Dutch road tunnels, the second paragraph gives recommendations about what can be done with the ISO 55000 in combination with the general road infrastructure sector. Next, recommendations about accreditation are given. The last two paragraphs give other recommendations and guidance for future research.

7.1 Tunnel Asset Management

Dutch road tunnels are owned by the Ministry of I&M, provinces and municipalities. RWS is the organisation who manages the tunnels of the Ministry. Because they are obliged to use a standardised tunnel design they have developed the Tunnelstandaard. This Tunnelstandaard contains the standardised specifications for the installations of a tunnel and specifications for the management and maintenance organisation of a tunnel. Implementing the Tunnelstandaard will result in an AM system that will be further developed than an AM system developed according to the ISO 55000. RWS is very progressive in this area of AM and does not need external parties for developing or implementing their tunnel's AM systems.
Other Dutch tunnel owners are the provinces and municipalities. None of these asset owners are already working with the Tunnelstandaard. Specifically looking at the management of tunnels, the best option for these asset owners is to implement the Tunnelstandaard. When an organisation has the intention to develop an AM system for all of their assets, the Tunnelstandaard has to be incorporated into this system. ARCADIS is currently engaged in some tunnel AM systems. These experiences can be applied to other municipalities and provinces that own tunnels. In 2019, every tunnel (>250m) in the Netherlands has to comply with the WARVW and the task of maintaining these tunnels demonstrably in a safe manner will be enormous.
Together, this leads to the following recommendations for tunnel AM:

- ARCADIS should become proficient in the Tunnelstandaard.
- ARCADIS should advise municipal and provincial tunnel owners in implementing the Tunnelstandaard for the development of an AM system.

7.2 Road infrastructure in general

Many Dutch road infrastructure owners are willing to implement AM. The conditions for implementing AM are positive and AM is in many of these organisation still in its earliest stage. This offers many opportunities for ARCADIS. Developing an AM system for other assets of the road infrastructure next to tunnels, must be done with far less guidance material. RWS has published some documents such as the Leidraad Risicogestuurd Beheer en Onderhoud, but implementing this will not result in a complete AM system. In fact, for more general AM, the ISO 55000 is the most sophisticated source at this moment. I do not consider the PAS 55 as an option because this standard will not be maintained any longer, what means it will be outdated in several years. The structure offered by the ISO 55000 should be the basis for an AM system. The asset managers of ARCADIS work at all three levels of the AM system, and fulfil different roles on these levels; the strategic level, assisting the asset owner; the tactical level, assisting an asset manager or conducting the role of asset manager (Managing Agent); and the operational level, assisting the service provider.

7.2.1 Strategic level

The state assets in the Netherlands are owned by the ministry of I&M. Provinces and municipalities in the Netherlands own local road assets. Each of these governments is managing their assets in a different manner. Some are managing the entire portfolio internally, others try to outsource the management tasks and the accompanying responsibilities. Other governments will probably be interested in implementing the ISO 55000 standard to demonstrate their ongoing compliance to performance criteria. The asset managers of ARCADIS can help these governments with the implementation of the ISO 55000 if these organisation are interested in this standard. The tasks of these asset managers could exist of elaborating the ISO 55000 structure, and guiding the organisation in developing the different plans and documents required for the AM system.

7.2.2 Tactical level

The manager of the state assets is RWS. RWS manages the entire Dutch national road network and has decided not to implement the ISO 55000. They did develop an AM implementation program, they introduced the ProBO procedure and they are working with Systems Engineering. This does not mean that they have developed a complete AM system for their entire asset portfolio. Because RWS will outsource many more activities in the future, ARCADIS can probably obtain assignments in the tactical level of the AM system.

The other opportunity for ARCADIS is the role of managing agent. This role can be fulfilled for provincial and municipal asset owners. As a managing agent, ARCADIS will develop and implement the tactical elements of the AM system and is accountable to the asset owner. The operational part will be outsourced. This is also a possibility for low tactical elements.

7.2.3 Operational level

Playing a key role in an AM system and meeting the expectations of the asset owner and asset manager requires a lot from the service provider. ARCADIS can help these service providers to meet their requirements and help developing for instance a Maintenance Management System (OMS). Service providers can profile themselves as a skilled partner in an AM system. When a certain contractor can prove its value in an AM system, he will probably have a head start on its competitors. A possibility to prove its capabilities, is to obtain an ISO 55000 certificate. When asset owners or managers recognise the value of this certain service provider, they will be more confident in implementing an AM system, according to ISO 55000. I have noticed that service providers are motivated externally, this is because the service provider depends largely on the asset manager, who is mainly responsible for the AM system. Because of this, the focus of most service providers is on obtaining assignments and not on improving their internal processes.

Together, this leads to the following recommendations for the road infrastructure sector:

- Organisations who manage assets which are part of a wider network, should implement the structure of the ISO 55000 for their entire asset portfolio.
- For assets were there is no sufficient AM guidance material, the ISO 55000 should be used for the implementation of AM. Especially in road networks, the entire network of a organisation should be managed by a single AM system.
- ARCADIS should assist asset owners with AM. This does not necessarily has to be according to the ISO 55000.
- ARCADIS should obtain assignments from RWS at the tactical level of the AM system and as a managing agent.
- Help service providers in presenting themselves as trustworthy partners in an AM system, possibly by using the ISO 55000.

7.3 Accreditation

As with other ISO standards, organisations intend to become certified to the ISO 55000. Currently, there are some organisations that have a provisional ISO 55000 certificate. ARCADIS gets many questions about these certificates and is not sure how to deal with this. ARCADIS has already decided

not to become an accreditor themselves. It will be beneficial for ARCADIS when they implement the ISO 55000 entirely in at least one project, with the accompanying accreditation. This way ARCADIS shows they understand the ISO 55000 and is capable of implementing this standard. When doing this, ARCADIS has to ensure that the AM system is beneficial for that specific case. The accreditation will be interpreted as useless when improvements fail to occur.
There is still much uncertainty about ISO 55000 accreditation in the Dutch road infrastructure sector. It is not necessary for an organisation to own an entire AM system, but the organisations influence on the complete system needs to be present. Exact demarcations about whether an organisation can become certified or not, are missing.
Clients of ARCADIS have the objective of obtaining an ISO 55000 certificate. Some organisation who fulfil the service provider role have specifically requested this. These organisations are externally motivated, and ARCADIS should advise them to improve their AM processes to achieve better results. ARCADIS can help these organisation in becoming accredited if that is their main priority. ARCADIS better not refuses this, the clients will simply find another organisation who will help them.
Together, this leads to the following recommendations:

- Implement the ISO 55000 at least once to learn from it and use it as a reference.
- Raise clients' awareness about the minor impact of external motivated accreditation.
- Follow the developments closely concerning the opinions and actions of accrediting bodies towards the different roles in an AM system.
- Advise customers in AM implementation but do not be reluctant concerning external motivated accreditations.

7.4 Other

All of the above mentioned organisations have to deal with the involvement of politicians. These political administrators set out policy in their term of office and try to make the most out of it. For ARCADIS it is important to be flexible and follow trends regarding AM so they can capitalise temporary opportunities. At time of writing, the tunnels managed by RWS in Noord-Holland got a lot of media attention about possible safety issues. This is such a political issue that can result in changing requirements and eventually in opportunities for ARCADIS.
The last opportunity for ARCADIS is the possibility of secondment of employees. If the employees of ARCADIS will stay the progressive asset managers they are now, they can always assist asset owners, asset managers and service providers in developing and improving their AM systems.

7.5 Future research

There must be emphasised that the research has examined the tunnel AM systems by means of the statements of the interviewees, and the relevant documents available for each case. This way this research can only make statements about what the interviewees say, and have documented. If and how their plans and procedures work out in practice, was not part of the research scope. During this research I have received signals that the differences between the development of the plans, and the implementation can be different from each other. Examining the actual implementation of an AM system can give insights into this subject.
Another point of interest is the fact that the research focussed on the AM systems of tunnels, in order to draw conclusions about the entire road infrastructure sector. The tunnels are heavily regulated and their management is more advanced than other road infrastructure objects. The focus on tunnels may cause a distorted view and therefore similar research with different case studies is recommended. I think that the degree of available guidance material for other road infrastructure elements determines the need for the ISO 55000, and therefore the opportunity for its successful implementation.
Finally, the cases examined for this study were acknowledged by the asset managers of ARCADIS. There is a fair chance that tunnels which are not known to ARCADIS are less developed than the examined tunnels. This can result in a distorted view, probably lesser known tunnels are managed in a different way. It is recommendable to examine more cases, especially those who have managed to stay unnoticed until now.

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APPENDIX A: INTERVIEW SCHEDULE

Introductie:

- Mijzelf voorstellen
- De deelnemer(s) laten vertellen over zijn/haar functie, de organisatie en de te beheren objecten
- Het onderzoek toelichten
- De ISO kernelementen visualiseren en de opbouw van het interview toelichten

Kern:

Vragen bij de kernelementen van het AM systeem volgens de ISO 55001. Aan het eind van elke vraag zijn de bijbehorende paragrafen weergeven tussen vierkante haken [-]. In sommige gevallen zijn voorbeelden en handvaten weergeven om het gesprek te vergemakkelijken. Deze zijn te vinden tussen ronde haken (-).

1. Context van organisatie en stakeholders [4.1, 4.2]

Is er rekening gehouden met de interne context? (bedrijfswaarden, organisatiedoelstellingen) [4.1]
Is er rekening gehouden met de externe context? (stakeholder analyse en prioritering) [4.2]

2. Plannen van de organisatie en doelstellingen van de organisatie [5.1, 5.3]

Heeft de directie de ontwikkeling van het AM systeem geleid en gezorgd voor het vaststellen van AM beleid, strategieën en doelstellingen? [5.1]
Heeft de directie de rollen, verantwoordelijkheden en bevoegdheden verdeeld binnen het AM systeem? [5.3]

3. Asset management beleid [5.2]

Is er AM beleid vastgesteld? (beknopte verklaring met beginselen, aan de hand waarvan de organisatie voornemens is AM toe te passen om haar organisatiedoelstellingen te bereiken) [5.2]
Is dit beleid gekoppeld aan de plannen en doelstellingen van de organisatie? [5.2]

4. Strategisch AM plan en AM doelstellingen [4.3, 6.2.1]

Zijn de grenzen van het AM systeem vastgesteld? (welke assets, risico kaders, financiële kaders) [4.3]
Is er een strategie opgesteld waarin staat hoe AM moet worden ingevoerd? [4.3]
Zijn er AM doelstellingen opgesteld? (KPI's, dashboard voor monitoring prestaties) [6.2.1]
Zijn deze gekoppeld aan het AM beleid en de plannen en doelstellingen van de organisatie? [6.2.1]

5. AM plannen [6.2.2, 8.3]

Zijn er plannen gemaakt om de AM doelstellingen te bereiken? [6.2.2]
Zijn deze ook daadwerkelijk gekoppeld aan de AM doelstellingen? [6.2.2]
Is er duidelijkheid over welke processen en activiteiten er uitbesteedt worden en hoe informatie en kennis uitgewisseld word? [8.3]

6. Plannen voor het ontwikkelen van een AM systeem + relevante ondersteuning [4.4, 6.1]

Is er bewust een AM systeem ingericht, geïmplementeerd, onderhouden en wordt deze continu verbeterd? (AO en AM afstemming, AM prestaties meten, identificatie en waardering van risico's, genereren van maatregelen, waardering van maatregelen t.o.v. risico reductie en selectie maken) [4.4]
Is er een SAMP ontwikkeld waarin onder meer wordt gedocumenteerd hoe het AM systeem bijdraagt aan het bereiken van de AM doelstellingen? [4.4]
Zijn er maatregelen genomen waardoor er risico's voor het AM kunnen worden aangepakt en kansen worden benut? [6.1]

7. AM systeem + relevante ondersteuning [7]

Is er voldoende ondersteuning aanwezig in de vorm van mensen en middelen. [7.1]
Zijn deze mensen competent en zijn ze bewust van hun rol in het geheel? (ieder persoon die effect kan hebben op het bereiken van een AM systeem) [7.2, 7.3]
Is de behoefte aan communicatie vastgesteld? [7.4]
Zijn er eisen vastgesteld aan (gedocumenteerde) informatie? [7.5, 7.6]

8. Implementatie van AM plannen [8]

Zijn er criteria opgesteld om de benodigde processen te plannen, implementeren en beheersen? [8.1]
Worden de processen aan de hand van deze criteria beheerst? [8.1]
Hoe worden risico's beheerst die ontstaan door wijzigingen? [8.2]
Is er vastgesteld hoe en wat voor informatie wordt uitgewisseld met Service Providers? [8.3]
Hoe worden risico's beheerst die ontstaan door het uitbesteden van processen en activiteiten? [8.3]

9. Asset Portfolio [-]

- (Er worden geen eisen gesteld aan het asset portfolio, daarom kan ik er hier niets over vragen. Het is zeker wel belangrijk om te weten wat de precieze portfolio is)

10. Prestatie- evaluatie en verbeteringen [9,10]

Is er vastgesteld wat en hoe er moet worden gemonitord en gemeten? (Asset prestaties, AM prestaties, effectiviteit van AM systeem) [9.1]
Worden er interne audits uitgevoerd? (audit programma) [9.2]
Wordt het AM systeem met geplande tussenpozen door de directie beoordeeld? (de directie van het AM systeem) [9.3]
Wat wordt er bij een afwijking of incident gedaan? (Maatregel tegen afwijking, of de consequenties aanpakken; maatregelen implementeren, doeltreffendheid maatregel beoordelen) [10.1]
Wat wordt er gedaan om herhaling van afwijkingen of incidenten te voorkomen? (beoordelen, oorzaken vaststellen, kijken of dit ook elders kan gebeuren) [10.2]
Wordt er proactief gezocht naar tekortkomingen in de assetprestaties? (continue verbetering) [10.3]
Hoe wordt deze informatie teruggekoppeld naar strategisch niveau? [10.3]

Afsluiting:

- Vragen of de deelnemer(s) denkt dat we nu het hele AM systeem hebben besproken
- Vragen of de deelnemer(s) nog extra opmerkingen of vragen heeft
- De deelnemer(s) bedanken voor de tijd en moeite

APPENDIX B: ACTUAL LEGISLATION TUNNELS

Wegtunnels	
> 250 m [1]	≤ 250 m
Wegenverkeerswet	Wegenverkeerswet
Wabo *(omgevingsrecht)*	Wabo *(omgevingsrecht)*
Woningwet *(met name art. 7, toepassen innovatieve veiligheidsvoorzieningen of innovatieve veiligheidsprocedures)*	Woningwet *(algemeen)*
Bouwbesluit 2012	Bouwbesluit 2012 *(bouwwerk geen gebouw zijnde)*
Regeling Bouwbesluit 2012	Regeling Bouwbesluit 2012
Europese richtlijn 2008/96/EG *(> 500m)*	
WARVW 2013 – Wet Aanvullende Regels Veiligheid Wegtunnels + ministeriële regeling. *Voor renovatie tunnels en "bestaande tunnels", zie opmerking 2,3 onderaan.*	
RARVW 2013 – Regeling aanvullende regels veiligheid wegtunnels. *Voor renovatie tunnels en "bestaande tunnels", zie opmerking 2,3 onderaan.*	
RVV Reglement verkeersregels en verkeerstekens *(RVV 1990) (Versie geldig vanaf: 01-09-2005)*	RVV Reglement verkeersregels en verkeerstekens *(RVV 1990) (Versie geldig vanaf: 01-09-2005)*
U BABW – *(Uitvoeringsvoorschriften BABW inzake verkeerstekens (Versie geldig vanaf: 01-08-2004)) (BABW - Besluit - administratieve bepalingen inzake het wegverkeer).*	U BABW – *(Uitvoeringsvoorschriften BABW inzake verkeerstekens (Versie geldig vanaf: 01-08-2004)) (BABW - Besluit - administratieve bepalingen inzake het wegverkeer).*
Tunnelstandaard: • Voor nieuwe rijkstunnels is dat de RWS tunnelstandaard 1.2 *(LTS 1.2)* • Voor bestaande rijkstunnels[3] is toepassing van de standaard niet verplicht, maar wel aanbevolen. *(LTS 1.2)* • Voor overige tunnels moet de standaard nog bepaald worden.	
Tunnelboekje zwaailichten *(Model voor opstellen CBP)*	
Vervoer gevaarlijke stoffen en tunnels	Vervoer gevaarlijke stoffen en tunnels
SATO	SATO
VRC [4]	VRC [4]

wetgeving richtlijnen informatie

Figure B1 Laws and regulations for tunnels in the Netherlands, current situation since new WARVW 1
General: 250m is defined to be the length of the longest closed section,
2 Renovation: in the WARVW and RARVW is indicated what requirements apply during the renovation of a tunnel,
3 "existing tunnels": tunnels which are already in use and tunnels which at the moment of commencement of the WARVW already have been subject to a urban planning degree,
4 LTS 1.2 and the Building Code are aligned to each other, the VRC is incorporated in the LTS 1.2 and will not be maintained anymore. (Groeneweg, 2014)

APPENDIX C: CONFORMITY BETWEEN ISO 55001 AND THE WARVW, RARVW AND THE TUNNELSTANDAARD

This appendix visualises the conformity between the ISO 55001 and the WARVW, RARVW and the Tunnelstandaard. The location were the relevant passage can be found is included in the table. The last column gives an explanation about each requirement and its correspondence. (Table C.2) Table C.1 shows the used colour scale.

Table C.1 Used colour scale

Green	Means that the ISO 55001 requirement is fully covered by one or multiple requirements in the source document.
Yellow	Means that the ISO 55001 requirement is partially covered by one or multiple requirements in the source document.
Red	Means that the ISO 55001 requirement is not covered by requirements in the source document.

Table C.2 Conformity between the ISO 55001 and the WARVW, RARVW and the Tunnelstandaard

ISO 55000 paragraaf	**Onderwerp**	**Tunnelwet/ WARVW**				**Toelichting**
		WARVW	RARVW	B&O standaard	Overige bronnen	
4.1	Inzicht in de organisatie en haar context			2.5.0 leidraad instandhouding tunnels: Paragraaf 2.4.2		Deze paragraaf licht toe wat de connectie is tussen dit document en de algemene visie van RWS op AM
4.2	Inzicht in de behoeftes en verwachtingen van de stakeholders			2.5.0 leidraad instandhouding tunnels: Paragraaf 3.2, Paragraaf 3.4		In 3.2 moeten de raakvlakken met aangrenzende beheerders worden beschreven, dit is echter geen complete stakeholder analyse. In 3.4 worden de prestatie eisen beschreven, deze zijn landelijk vastgelegd. Deze eisen zijn afkomstig van stakeholders
4.3	Vaststellen van het toepassingsgebied van het assetmanagementsysteem			2.5.0 leidraad instandhouding tunnels: Hoofdstuk 3.2		Deze paragraaf eist dat de systeemgrenzen mbt instandhouding, de onderhoudsgrenzen en de raakvlakken met andere beheerders in kaart worden gebracht (interactie met andere management systemen)
4.4	Assetmanagement systeem	Beschikbaar in artikel 7 lid 1				Eist dat de tunnel beheerder een veiligheidsbeheersplan schrijft, inclusief het beheer van de tunnel en de instandhoudingsactiviteiten.
5.1	Leiderschap en betrokkenheid			2.2 Leidraad kwaliteitsmanagement systeem tunnels		De tunnelbeheerder moet zorgen dat zijn de TBO waar hij verantwoordelijk voor is voldoet aan de Tunnelstandaard, en dat dit zonder het tonen van leiderschap en betrokkenheid niet gaat lukken

5.2	Beleid				Programma Asset Management RWS	RWS heeft beleid opgesteld om AM in te voeren
5.3	Rollen, verantwoordelijkheden en bevoegdheden binnen de organisatie			2.1 Leidraad tunnelbeheerorganisatie, Paragraaf 3.1 sleutelrollen		Beschrijving rollen tunnelbeheerorganisatie
6.1	Maatregelen om risico's en kansen vast te stellen voor het assetmanagementsysteem		Leidraad Veiligheids-documentatie paragraaf 2.4.5. van “deel B - Veiligheids-beheersplan”	2.5.0 leidraad instandhouding tunnels: H4		1.Eist plannen over hoe men gebruik gaat maken van inspecties, tests, preventief en correctief onderhoud om risico's te verminderen en de veiligheid te vergroten. 2. Instandhoudingsstrategie, hierin wordt geëist dat alle risico's en kansen op falen moeten worden beschreven en in acht worden genomen
6.2.1	Assetmanagement doelstellingen			2.5.0 leidraad instandhouding tunnels: Paragraaf 3.4		In 3.4 worden de prestatie eisen beschreven, deze zijn landelijk vastgelegd. De prestatie eisen zijn geformuleerd volgens de RAMSHEEP aspecten
6.2.2	Planning voor het bereiken van de assetmanagement doelstellingen			2.5.0 leidraad instandhouding tunnels: H5		In Hoofdstuk 5 worden eisen gesteld aan hoe, wanneer en wat er gedaan wordt om de doelstellingen te bereiken. Onderhoudsplanning, inspectieplanning, programmering (budgettering vast- en variabel onderhoud), hoe om te gaan met reserve onderdelen, testen, goed huisvaderschap en overige risico's
7.1	Mensen en middelen				3.1 Werkwijze aanleg tunnel	In paragraaf 1.4 wordt beschreven dat de projectmanager moet zorgen dat bij elke gestelde mijlpaal de benodigde processen, organisatie, mensen en techniek beschikbaar zijn
7.2	Competentie			2.2 Leidraad kwaliteitsmanagementsysteem tunnels, en 2.3 Leidraad opleiden, trainen, oefenen		Door middel van kwaliteitsmanagement en een OLO programma wordt gezorgd dat de medewerkers competent zijn
7.3	Bewustzijn				In andere RWS documenten	Dit staat niet in de onderzochte documenten, toch is er een sterke veronderstelling dat hier eisen voor opgesteld zijn in documenten die relevant zijn tijdens het opzetten van de Tunnelbeheerorganisatie
7.4	Communicatie			2.5.0 leidraad instandhouding tunnels: Paragraaf 6.4		Paragraaf waarin eisen worden gesteld aan de communicatie en rapportage

7.5	Eisen aan informatie			2.5.0 leidraad instandhouding tunnels: Paragraaf 6.5		Paragraaf waarin eisen worden gesteld aan het inrichten van een OMS en BMS
7.6.1	Gedocumenteerde informatie Algemeen			2.5.0 leidraad instandhouding tunnels: Paragraaf 6.5		Paragraaf waarin eisen worden gesteld aan het inrichten van een OMS en BMS
7.6.2	Gedocumenteerde informatie Creëren en actualiseren			2.5.0 leidraad instandhouding tunnels: Paragraaf 6.5		Paragraaf waarin eisen worden gesteld aan het inrichten van een OMS en BMS
7.6.3	Gedocumenteerde informatie Beheer			2.5.0 leidraad instandhouding tunnels: Paragraaf 6.5		Paragraaf waarin eisen worden gesteld aan het inrichten van een OMS en BMS
8.1	Operationele planning en beheersing			2.7 operationele tunnelbeheerprocessen		Dit document beschrijft de beheer processen om een tunnel operationeel te houden
8.2	Management van wijzigingen			2.7 operationele tunnelbeheerprocessen : Hoofdstuk 6		Hoofdstuk gaat over hoe veranderingen doorgevoerd kunnen worden na signalering van problemen
8.3	Uitbesteden			2.7 operationele tunnelbeheerprocessen : Paragraaf 2.2 en 4.3		Het beheer wordt uitgevoerd door RWS, en het onderhoud door marktpartijen (de aannemer). Deze onderhoudsaannemer monitort actief op storingen en meld deze dan bij RWS
9.1	Monitoren, meten, analyseren en evalueren			2.7 operationele tunnelbeheerprocessen : Paragraaf 4.2 en 4.3		Paragraaf 4.2 en 4.3 beschrijven wat, en hoe er moet worden gemeten
9.2	Interne audit			2.7 operationele tunnelbeheerprocessen : Paragraaf 7.4		Er vinden periodiek en op verzoek audits plaats
9.3	Directie beoordeling			2.2 Leidraad kwaliteitsmanagementsysteem tunnels: Paragraaf 3.3		Er vinden periodiek tunnelbeheerderbeoordelingen en externe audits plaats
10.1	Afwijkingen en corrigerende maatregelen			2.7 operationele tunnelbeheerprocessen : Hoofdstuk 4,5 en 6.		Deze hoofdstukken gaan over het ITIL proces. Dit houdt in dat als er een incident is geweest, dit kan worden beoordeeld als probleem, en als dit probleem dan moet worden opgelost moet er een verandering worden doorgevoerd
10.2	Preventieve maatregelen			2.7 operationele tunnelbeheerprocessen : Bijlage D		Proactief beheer door de technisch beheerder

10.3	Continue verbetering			2.5.1 leidraad instandhouding tunnels: Paragraaf 4.1		Voor elk project wil RWS de PDCA cyclus volgen, hierbij wordt dus continue verbetering nagestreefd

APPENDIX D: CONFORMITY BETWEEN ISO 55001 AND THE ISO 9001

This appendix visualises the conformity between the ISO 55001 and the ISO 9001. The location were the relevant passage can be found is included in the table. The last column gives an explanation about each requirement and its correspondence. (Table D.2) Table D.1 shows the used colour scale.

Table D.1 Used colour scale

Green	Means that the ISO 55001 requirement is fully covered by one or multiple requirements in the source document.
Yellow	Means that the ISO 55001 requirement is partially covered by one or multiple requirements in the source document.
Red	Means that the ISO 55001 requirement is not covered by requirements in the source document.

Table D.1 Conformity between the ISO 55001 and the ISO 9001

ISO 55000 paragraaf	Onderwerp	ISO 9000	Toelichting
4.1	Inzicht in de organisatie en haar context		Over context worden geen eisen gesteld
4.2	Inzicht in de behoeftes en verwachtingen van de stakeholders	5.2 & 7.2.1	in Paragraaf 5.2 staat alleen de eis dat er rekening moet worden gehouden met de klant als stakeholder. In Paragraaf 7.2.1 worden producteisen opgesteld rekening houdende met de klant en de organisatie
4.3	Vaststellen van het toepassingsgebied van het assetmanagementsysteem	4.2.2	De organisatie moet een handboek opzetten waarin het toepassingsgebied van het kwaliteitssysteem duidelijk word, het gaat hier dus niet om het toepassingsgebied van een AM systeem
4.4	Assetmanagement systeem		Document gaat over het opzetten van een kwaliteitsmanagement systeem, de onderliggende onderwerpen zijn in veel gevallen toepasbaar op beide systemen
5.1	Leiderschap en betrokkenheid	5.1	De directie moet betrokkenheid tonen, er wordt niet gesproken over leiderschap
5.2	Beleid	5.3	De eisen die gesteld worden aan het beleid komen overeen met de ISO 55000, maar het opgestelde beleid is kwaliteitsbeleid, en geen AM beleid
5.3	Rollen, verantwoordelijkheden en bevoegdheden binnen de organisatie	5.4	Paragraaf 5.4 bevat eisen die overeenkomen met de eisen in de ISO 55000, maar de eisen gaan specifiek over kwaliteit en niet over AM
6.1	Maatregelen om risico's en kansen vast te stellen voor het assetmanagementsysteem	0.4	In Paragraaf 0.4 staat dat er in deze norm geen eisen zijn opgenomen die specifiek betrekking hebben op andere systemen, hier wordt ook risico management bij genoemd

6.2.1	Assetmanagementdoelstellingen	4.2.1, 5.1 & 5.4.1	In Paragraaf 4.2.1 staat de eis dat er doelstellingen moeten worden opgesteld. In 5.1 wordt duidelijk dat de directie hiervoor verantwoordelijk is. In 5.4.1 staat nogmaals dat de directie moet zorgen voor doelstellingen. Het gaat hier over kwaliteitsdoelstellingen en dus geen AM doelstellingen
6.2.2	Planning voor het bereiken van de assetmanagementdoelstellingen	5.4.2	In Paragraaf 5.4.2 staat de eis dat er een planning moet worden gemaakt en uitgevoerd om te voldoen aan de kwaliteitsdoelstellingen. Er wordt hier niet gesproken over afstemming met andere plannen en er worden geen eisen voor deze planning opgesteld
7.1	Mensen en middelen	6.1, 6.3 & 6.4	In Paragraaf 6.1, 6.3 & 6.4 worden eisen gesteld die overeenkomen met de eisen in ISO 55000, het gaat hier echter om kwaliteit en niet om AM
7.2	Competentie	6.2	In Paragraaf 6.2 worden eisen gesteld die overeenkomen met de eisen in ISO 55000, het gaat hier echter om kwaliteit en niet om AM
7.3	Bewustzijn	6.2	In Paragraaf 6.2 worden eisen gesteld die overeenkomen met de eisen in ISO 55000, het gaat hier echter om kwaliteit en niet om AM
7.4	Communicatie	5.5.3	In Paragraaf 5.5.3 wordt de eis voor interne communicatie gesteld, geen externe
7.5	Eisen aan informatie	5.6.2, 7.2.3, 7.3.2, 7.3.3, 7.5.1 & 8.2.1	In Paragraaf 5.6.2, 7.2.3, 7.3.2, 7.3.3, 7.5.1 & 8.2.1 worden eisen gesteld aan benodigde informatie. Deze eisen staan niet geordend in het document en er worden niet consequent eisen gesteld aan de kwaliteit en de manier van uitwisselen van deze informatie
7.6.1	Gedocumenteerde informatie Algemeen	4.2	Paragraaf 4.2 gaat over documentatie-eisen, deze komt globaal overeen met de eisen in de ISO 55001
7.6.2	Gedocumenteerde informatie Creëren en actualiseren	4.2	Paragraaf 4.2 gaat over documentatie-eisen, deze komt globaal overeen met de eisen in de ISO 55001
7.6.3	Gedocumenteerde informatie Beheer	4.2	Paragraaf 4.2 gaat over documentatie-eisen, deze komt globaal overeen met de eisen in de ISO 55001
8.1	Operationele planning en beheersing	7.1	In Paragraaf 7.2 worden eisen gesteld die overeenkomen met de eisen in ISO 55000, het gaat hier echter om kwaliteit en niet om AM
8.2	Management van wijzigingen	7.3.7	In Paragraaf 7.3.7 worden eisen gesteld die overeenkomen met de eisen in ISO 55000, het gaat hier echter om wijzigingen in ontwerp en ontwikkeling en niet om AM
8.3	Uitbesteden	4.1	In paragraaf 4.1 wordt de eis gesteld dat uitbestede processen moeten worden beheerst

9.1	Monitoren, meten, analyseren en evalueren	8.2	In Paragraaf 8.2 worden eisen gesteld die overeenkomen met de eisen in ISO 55000, het gaat hier echter om kwaliteit en niet om AM
9.2	Interne audit	8.2.2	In Paragraaf 8.2.2 worden eisen gesteld die overeenkomen met de eisen in ISO 55000, het gaat hier echter om kwaliteit en niet om AM
9.3	Directie beoordeling	5.6	Paragraaf 5.6 beschrijft exact wat een directiebeoordeling moet inhouden. Het gaat hier wel over kwaliteit en niet over AM
10.1	Afwijkingen en corrigerende maatregelen	8.2.2, 8.3 & 8.5.2	In Paragraaf 8.2.2 wordt geëist dat als er bij een audit afwijkingen worden gevonden, deze zo snel mogelijk moeten worden opgelost. In Paragraaf 8.3 staat wat er moet gebeuren bij afwijkingen en 8.5.2 bevat eisen over corrigerende maatregelen
10.2	Preventieve maatregelen	5.6.2 & 8.5.3	In Paragraaf 5.6.2 staat de eis dat preventieve maatregelen moeten worden besproken tijdens de directiebeoordeling. In Paragraaf 8.5.3 staat dat er een procedure moet komen voor preventieve maatregelen
10.3	Continue verbetering	0.2, 8.1 & 8.4	In Paragraaf 8.1 wordt genoemd dat de doeltreffendheid van het systeem continu verbeterd moet worden, Ook wordt in Paragraaf 0.2 gezegd dat de Demming cirkel met de Plan-Do-Check-Act methodologie toegepast kan worden op alle processen. Paragraaf 8.4 eist dat er gegevens worden geanalyseerd waarop continue verbetering kan worden gebaseerd.

APPENDIX E: CONFORMITY BETWEEN ISO 55001 AND THE REQUIREMENTS SPECIFICATION OF THE M-M TUNNEL

This appendix visualises the conformity between the ISO 55001 and the examined Requirements Specification for the prolonged maintenance of the Markt-Maastunnel. The location were the relevant passage can be found is included in the table. The last column gives an explanation about each requirement and its correspondence. (Table E. 2) Table E.1 shows the used colour scale.

Table E.1 Used colour scale

Green	Means that the ISO 55001 requirement is fully covered by one or multiple requirements in the source document.
Yellow	Means that the ISO 55001 requirement is partially covered by one or multiple requirements in the source document.
Red	Means that the ISO 55001 requirement is not covered by requirements in the source document.

Table E.1 Conformity between the ISO 55001 and the Requirements specification of the long term maintenance of the Markt-Maastunnel

ISO 55000 paragraaf	Onderwerp	Vraagspecificatie	Toelichting
4.1	Inzicht in de organisatie en haar context	Vraagspecificatie 1-1.5	Hier wordt genoemd dat de twee bovenliggende doelen zijn: de maximale doorstroming en veiligheid van het tunnelverkeer
4.2	Inzicht in de behoeftes en verwachtingen van de stakeholders	Vraagspecificatie 1-5 en Vraagspecificatie 2-4.2	In 1-5 worden aspecteisen en raakvlakeisen genoemd. Dit zijn in feite de vertalingen van de stakeholdereisen. In 2-4.2 worden eisen gesteld aan de communicatie met derden, waaronder gebruikers
4.3	Vaststellen van het toepassingsgebied van het assetmanagementsysteem	Vraagspecificatie 1-1.5, H2 en H3	Hier wordt genoemd dat het specifiek om het onderhoud, en zo nodig verbeteren van de TTI gaat. H2 bevat de omschrijving van het TTI meer in detail, en H3 beschrijft de scope van opdracht inclusief punten die buiten de opdracht vallen. Er is geen duidelijke link met de eisen en stakeholders
4.4	Assetmanagement systeem	Vraagspecificatie 2-1.6	Nakomen van alle eisen van de vraagspecificatie is zo ongeveer het inrichten, implementeren, onderhouden en continu verbeteren van een AM systeem
5.1	Leiderschap en betrokkenheid	Vraagspecificatie 2-3	Er worden geëist dat de ON zijn PMP klaar heeft en aan de hand daarvan zelfstandig dit project leidt. ON zal betrokken moeten zijn en anders te maken krijgen met boeteclausules
5.2	Beleid	Vraagspecificatie 2-3	In het PMP zal ON beleid moeten uitstippelen

5.3	Rollen, verantwoordelijkheden en bevoegdheden binnen de organisatie	Vraagspecificatie 2-3.1.4	Hier wordt geëist dat er een beschrijving komt van de taken, verantwoordelijkheden en bevoegdheden van de leidinggevende functies en de sleutelfuncties.
6.1	Maatregelen om risico's en kansen vast te stellen voor het assetmanagementsysteem	Vraagspecificatie 2-3.1.4, 8.1	In 2-3.1.4 wordt geëist dat er een beschrijving van de planning komt met de bijbehorende verificatie-, review-, keurings- en testplannen. In 8.1 worden eisen gesteld om risico's te beheersen en identificeren
6.2.1	Assetmanagementdoelstellingen	Vraagspecificatie 1-1.5 en Vraagspecificatie 2-Bijlage 1	in 1-1.5 wordt genoemd dat de twee bovenliggende doelen zijn: de maximale doorstroming en veiligheid van het tunnelverkeer. In 2-Bijlage 1 worden KPI's uitgewerkt, deze kunnen gezien worden als doelstellingen
6.2.2	Planning voor het bereiken van de assetmanagementdoelstellingen	Vraagspecificatie 1-1.5	Er moet gebruik worden gemaakt van een RAMS benadering waarbij risico- en kansen gestuurde keuzes worden gemaakt voor het beheer en onderhoud
7.1	Mensen en middelen	Vraagspecificatie 2-9.3.3.1 en 9.3.4.1	Hier worden eisen gesteld over het opstellen van functieprofielen en het vervullen daarvan, geen eisen over middelen
7.2	Competentie	Vraagspecificatie 2-9.3.3.1 en 9.3.4.1	Hier worden eisen gesteld over het opstellen van functieprofielen en het vervullen daarvan. Voldoen aan het profiel zou bekwaamheid moeten aantonen
7.3	Bewustzijn		Er worden geen eisen gesteld aangaande het bewustzijn van de mensen
7.4	Communicatie	Vraagspecificatie 2-3.1.4 en 4.2	Hier worden eisen gesteld over de overlegstructuur en de informatieoverdracht. 4.2 gaat over communicatie met derden
7.5	Eisen aan informatie	Vraagspecificatie 2-5.4.4.4	Complete beschrijving OMS
7.6.1	Gedocumenteerde informatie Algemeen	Vraagspecificatie 2-9.4	Hier worden eisen gesteld over de uniformiteit, traceerbaarheid en beschikbaarheid van de documenten.
7.6.2	Gedocumenteerde informatie Creëren en actualiseren	Vraagspecificatie 2-9.4	Hier worden eisen gesteld over de uniformiteit, traceerbaarheid en beschikbaarheid van de documenten
7.6.3	Gedocumenteerde informatie Beheer	Vraagspecificatie 2-9.4 en 5.4.4	Hier worden eisen gesteld over de uniformiteit, traceerbaarheid en beschikbaarheid van de documenten. 5.4.4 stelt eisen aan het beheer en onderhoud van gegevens. Inclusief een complete beschrijving van het OMS

8.1	Operationele planning en beheersing	Vraagspecificatie 2-3.1.3	Hier worden eisen gesteld aan hoe werkpakketten worden opgesteld
8.2	Management van wijzigingen	Vraagspecificatie 2-9.4.4.3	Hier worden eisen gesteld over verzoeken tot wijziging, inclusief het aangeven van de hiermee gepaard gaande risico's
8.3	Uitbesteden	Vraagspecificatie 2-7.3.1	Hier wordt alleen geëist dat er toestemming moet worden gevraagd bij hoge bedragen
9.1	Monitoren, meten, analyseren en evalueren	Vraagspecificatie 2-5.4	Stelt eisen aan periodieke inspecties en hoe om te gaan met storingen
9.2	Interne audit	Vraagspecificatie 2-9.1.3.3	Hier worden eisen gesteld over het plannen, uitvoeren en registreren van audits
9.3	Directie beoordeling	Vraagspecificatie 2-9.1.3.2	Er moet meegewerkt worden aan toetsen van de OG, dit is geen interne directiebeoordeling
10.1	Afwijkingen en corrigerende maatregelen	Vraagspecificatie 2-9.1.3.4 en 9.1.3.5	Hier worden eisen gesteld over het identificeren en vastleggen van afwijkingen en het doorvoeren van verbeteringen
10.2	Preventieve maatregelen	Vraagspecificatie 2-9.1.3.3 en 9.1.4.2	Hier worden eisen gesteld over preventieve maatregelen
10.3	Continue verbetering	Vraagspecificatie 1-1.5	De organisatie moet de kwaliteit van de werkprocessen continu verbeteren door invulling te geven aan een lerende organisatie

APPENDIX F: CONFORMITY BETWEEN ISO 55001 AND THE LEIDRAAD RISICOGESTUURD BEHEER EN ONDERHOUD

This appendix visualises the conformity between the ISO 55001 and the Leidraad Risicogestuurd Beheer en Onderhoud. The location were the relevant passage can be found is included in the table. The last column gives an explanation about each requirement and its correspondence. (Table F. 2) Table F.1 shows the used colour scale.

Table F.1 Used colour scale

Green	Means that the ISO 55001 requirement is fully covered by one or multiple requirements in the source document.
Yellow	Means that the ISO 55001 requirement is partially covered by one or multiple requirements in the source document.
Red	Means that the ISO 55001 requirement is not covered by requirements in the source document.

Table F.1 Conformity between the ISO 55001 and the 'Leidraad Risicogestuurd Beheer en Onderhoud'

ISO 55000 paragraaf	Onderwerp	Leidraad Risicogestuurd Beheer en Onderhoud	Toelichting
4.1	Inzicht in de organisatie en haar context		Er worden geen eisen gesteld over het analyseren van de organisatie en haar context
4.2	Inzicht in de behoeftes en verwachtingen van de stakeholders	4.3.1	Omgevingsfactoren moeten worden beschreven, niet gekoppeld aan doelstellingen
4.3	Vaststellen van het toepassingsgebied van het assetmanagementsysteem		Er worden geen eisen gesteld over het vaststellen van kaders of iets dergelijks
4.4	Assetmanagement systeem	6.2, 6.3	De ProBO-processen, operationele processen, managementproces en ondersteunende proces zijn beschreven in het gehanteerde kwaliteitssysteem
5.1	Leiderschap en betrokkenheid	5.3.2	5.3.2 Er wordt benoemd dat de rol van het management heel belangrijk is, er wordt niet gekoppeld aan beleid, doelstellingen of strategie. 5.4.1 de directie moet betrokken zijn bij een innovatie totdat deze is geconsolideerd
5.2	Beleid	2.3.1	Het huidige beleid moet beschreven worden, deze wordt niet gekoppeld aan de doelstellingen
5.3	Rollen, verantwoordelijkheden en bevoegdheden binnen de organisatie	4.3.1	Rollen, taken en verantwoordelijkheden moeten worden beschreven, niet gekoppeld aan doelstellingen

6.1	Maatregelen om risico's en kansen vast te stellen voor het assetmanagementsysteem	6.3.1	Er bestaat een risicoanalyse met bijpassend B&O plan voor kritieke, en niet-kritieke delen, plus de bijbehorende organisatorische aspecten, de aannames voor de risicoanalyse worden periodiek heroverwogen en indien nodig aangepast
6.2.1	Assetmanagementdoelstellingen	6.3.1	Er komt een B&O-plan voort uit de risico analyse, de taakstellende eisen hieruit zijn expliciet en traceerbaar verwerkt in contractdocumenten, deze zijn niet gekoppeld aan de organisatiedoelstellingen of aan het beleid
6.2.2	Planning voor het bereiken van de assetmanagementdoelstellingen	6.3.1	B&O wordt uitgevoerd conform het B&O-plan.
7.1	Mensen en middelen	2.3.3, 3.2	2.3.3 De benodigde mensen en kennis moet op peil worden gehouden. 3.2 De benodigde middelen moeten worden vastgesteld
7.2	Competentie	2.3.2	De benodigde competenties moeten worden vastgelegd en er moet worden bepaald hoe deze te bereiken
7.3	Bewustzijn		Er worden geen eisen gesteld over bewustzijn van het AM systeem
7.4	Communicatie	6.2	Er is een communicatieplan ten aanzien van interne en externe communicatie met alle betrokkenen en belanghebbenden
7.5	Eisen aan informatie	6.3.1	Er moet informatie over de te beheren objecten worden opgeslagen in een OMS of BMS
7.6.1	Gedocumenteerde informatie Algemeen	2.2.3 / 6.3.2	2.2.3 De risicoanalyse moet worden vastgelegd in een rapportage. 6.3.2 bevat eisen over bedieningsinformatie
7.6.2	Gedocumenteerde informatie Creëren en actualiseren	2.2.3	Er worden eisen gesteld over revisiebeheer van de verschillende risicoanalyse documentaties
7.6.3	Gedocumenteerde informatie Beheer	2.2.3	Er worden eisen gesteld over revisiebeheer van de verschillende risicoanalyse documentaties
8.1	Operationele planning en beheersing	6.3.1	Het verstrekken van opdrachten en de afhandeling van opdrachten vindt plaats door gebruik te maken van een gevalideerd BMS of OMS, hier zijn niet alle processen vastgelegd
8.2	Management van wijzigingen	2.2.4	Om in te schatten wat de effecten van een systeemwijziging zijn, is aanpassing nodig van de risicoanalyse op de nieuwe objectarchitectuur.
8.3	Uitbesteden	2.4	Bij uitbesteden moet het gedachtengoed van ProBO goed worden overgebracht, en de juiste eisen moeten worden gesteld.

9.1	Monitoren, meten, analyseren en evalueren	3.4 / 5.4.2/6.2/6.3	3.4 stelt eisen over wat er gemonitord moet worden. 5.4.2 en 6.2 stellen dat de managementprocessen en ondersteunende processen worden als geheel periodiek geëvalueerd, er staat niet bij hoe en wanneer. In 6.3 staat dat deze periodiek, aantoonbaar en transparant moeten plaatsvinden
9.2	Interne audit	3.4	De afgesproken procedures en werkwijzen die in werkinstructies zijn vastgelegd, kunnen tijdens uitvoering worden ge-audit
9.3	Directie beoordeling		Er worden geen eisen gesteld voor een directiebeoordeling
10.1	Afwijkingen en corrigerende maatregelen	6.3.1	Wijzigingen en afwijkingen van eisen en prestaties, kennen een vertaling naar concrete vervolgacties, en afwijkingen en trends met betrekking tot storingen worden geanalyseerd en opgeslagen in OMS of BMS
10.2	Preventieve maatregelen	5.4.2/6.2	De organisatie moet in staat zijn om proactief te reageren op externe ontwikkelingen
10.3	Continue verbetering	2.2.3 / 2.2.5 / 3	Door het toepassen van de PDCA-cyclus wordt er altijd continue verbetering nagestreefd