IMPLEMENTING ASSET MANAGEMENT INSIDE INFRASTRUCTURE AGENCIES: THE CHALLENGE OF CONFLICTING LOGICS

DAAN SCHRAVEN

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SUMMARY

In many countries, the infrastructure sector is in transition towards changed practices of managing transport infrastructure assets. In particular, Asset Management (AM) has been emerged as a promising approach of connecting and aligning organizationally separated infrastructure management decisions. However, due to the integrative, fluid and dynamic character¹ of AM its implementation appears a difficult and lengthy exercise for many public infrastructure agencies, and makes the attainment of a consistent decision-making a challenging task. A deeper understanding of the reasons for the AM implementation difficulties would support transport infrastructure agencies in their effort to move towards an increased effectiveness and efficiency in their management of infrastructure assets.

This study focuses on the AM implementation challenge from an employee perspective. Viewpoints of employees can help to generate an understanding of the possible conflicts and discrepancies in the current AM decision-making process and to consider AM implementation as a continuous achievement contextually bound to the existing way of working at public infrastructure agencies. This distinguishes this study from previous research that has addressed AM implementation by assessing agencies' working practices for discrepancies on idealized AM visions and models.

The main question of this research is:

- What viewpoints are present on the management of infrastructure assets and how should these be addressed when implementing AM at public agencies?

Research approach and design

We argue that the challenges of implementing AM at public agencies stem from employees perceptions of decisions and roles in AM inducing an AM understanding of certain employees that may conflict with the views of other employees. We see this as a 'dominant logic' problem. The 'dominant logic' concept is prominent in the strategic management literature, and fits the AM implementation challenge at public agencies with their historically developed and separated viewpoints on how infrastructure should be managed. Similar viewpoints on how AM approach should be implemented can form dominant logics in an agency. If there are different views about the AM approach that needs to be implemented then this means there are conflicting logics and they will require particular attention when implementing AM.

In order to answer the main question the research is designed in four steps. The first two steps are explorative and descriptive, and include an investigation of how the management of infrastructure assets is understood in the academic literature and at a particular agency: the Dutch Public Works and Water Management Agency (RWS). The final two steps are of explanatory character and include

¹ We accommodate the richness of perspectives that researchers and practitioners can have of AM. To reflect this, we are mindful of some characteristics that contribute to the complexity of AM. With 'integrative' it is meant that several elements (decisions) are often connected in AM decision-making models. With 'fluid' it is meant that AM knows many versions depending on the perspective applied. With 'dynamic' it is meant that decisions can change decisions to be made or previously made.

the design and application of a method to reveal the dominance of existing and conflicting viewpoints at the same Dutch agency, and to determine their implications for the implementation of AM.

Table 1. Description of Knowledge Groups in PFNET Result²

Component Number - Knowledge Group Label	Shared Research Objectives
Highest Density Centre	
2 - Statistical Deterioration Models	– Improve deterioration prediction of large assets
17 - Bridge Management Systems	– Plan maintenance with Bridge management system
Life Cycle Decision Making and Organization Path	
3 - Life Cycle Approach for Bridges	– Introduce a reliability approach to managing bridges
6 - Maintenance Decision for Replacement and Rehabilitation	– Optimize long-term replacement and rehabilitation schedule
7 - Life Cycle and Preventive Maintenance for Pavements	– Model road roughness for long term and plan preventive action
8 - Resource Based View	– Harness human competence in organizations
9 - Maintenance Decision for Repair and Inspection	– Optimize repair and inspection policies
12 - MR&R Decisions with Genetic Algorithms	– Compare trade-off between maintenance or rehabilitation
18 - Condition Prediction for Concrete Bridges	– Improve deterioration prediction of concrete bridges
18 – Multicriteria Decision Making	– Simplify complex decision making issues
19 - Performance Measurement	– Balancing performance measurement criteria
Pavement Management Path	
4 - Network-level Management for Pavements	– Optimize interventions across homogeneous road sections
11 – Optimized Management of Pavement	– Predict pavement deterioration with Markov Process
13 – Traffic and Maintenance Effects	– Understand interaction between failure and environment
14 – Guidelines to Asset Management for Roads	– Inform on American Guidelines for Asset Management on Roads
Water and Utility Infrastructure Path	
1 – Information and Data Quality	– Determine quality of business information to achieve goals
5- Deterioration and Decision Modeling of Sewer Pipes	– Improve deterioration prediction of sewer systems
10 - Modeling Water-Main Breaks	– Optimize replacement time to prevent water main breaks
16 – International Guidelines for Asset Management	– Justify budgets to maintain deteriorating assets

Implementing Asset Management

In step 1, we explore whether the research community has a shared understanding of the management of infrastructure assets. This step is important because researchers discern a potential

² This table is reproduced and part of Chapter 2. The table is further explained and clarified there

for ‘scope creep’ in researching the management of infrastructure assets, and also worry that AM lacks a clear focus given the broad range of topics it addresses. We apply a systematic methodology called the ‘intellectual structure’ approach for collecting and analyzing publication data. This helps to understand how the conceptual understanding and scope of AM has developed based on the research that academics read and cite.

Our review shows that there is no shared understanding. Table 1 shows the knowledge groups we reveal from our analysis. Between 1996 and 2013, researchers mainly advance an object-oriented understanding of managing infrastructure assets. Yet, we also see that emerging research includes more life cycle decision-making and organizational aspects. This supports that AM is integrating different disciplines, and covering different assets and different life cycle phases of these assets. Nevertheless, the results indicate that organizational aspects are only weakly integrated with knowledge from object-oriented research, and that researchers tend not to use knowledge available on non-technical aspects in their various models and practical instruments. More specifically, it suggests that researchers find such integration difficult and that many studies adopt a specific perspective. This makes it difficult to identify a commonly shared view on AM in the research community and suggests that a common view is also missing in practice.

Step 2 focuses on investigating how an AM strategy is understood by employees and to which extent maturity models (a maturity test for AM) are able to support the implementation of an AM strategy. This is important since AM is more than a set of documents and instruments. AM adds a ‘strategic theory’, namely a set of systematic and coordinated activities and practices to achieve an organizations’ strategic plan (BSI, 2008a). By using Rumelt’s tests, developed by Richard Rumelt (1979), we study in-depth the views of employees who work together in AM to achieve the organizational strategic plan of the Dutch Public Works and Water Management Agency.

Table 2. Accounting Employee Experiences with Rumelt’s Tests and Maturity models³

Rumelt’s tests	Maturity model
– Focuses on challenges between understanding and action	– Focuses on challenges and good situations as defined by criteria
– Triggers remarks of great detail that describe the development of a problem	– Triggers remarks that describe the characteristics of a situation
– Cannot specify whether a detailed example from practice is generalizable	– Cannot specify how a generalized observation amounts in practice
– Offers direction for improvement by removing problems	– Offers a direction for improvement by defining the ideal situation
– Requires full transcriptions of interviews	– Requires comments to maturity level scores
– Selected employees need to have a work relationship	– Selected employees need to have experience with criteria

³ This table is reproduced and part of Chapter 3. The table is further explained and clarified there.

In the study we compare Rumelt's test results with results from a Maturity check, performed at the same organization and period. The comparison of the methods (see Table 2) shows employees' experiences are insufficiently addressed when using current tools and methods (such as the maturity check) which consequently fail to support AM implementation. Uncovering these experiences reveals, for example, how AM activities and decisions regarding the replacement of a traffic light or maintenance of a road along the top of an embankment are coordinated. The employees' collective accounts shows how the challenges they face makes them blinkered and focused on achieving a single goal⁴. In addition, the views articulated by employees' play a role in the outcome of a work process and the maturity check overlooks this interaction. Therefore, employees' views need to be considered in an AM implementation but current tools (such as maturity checks) fail to take these sufficiently into account.

In step 3 we develop an empirical method to detect, identify and discuss dominant asset management' logics of employees and where inconsistencies in AM decision-making are located. The method uses causal maps to detect individual views, performs statistical tests to identify the significantly shared views and applies graphs to show the connection between these views of AM.

Table 3. Overview of contradicting logics⁵

Contradiction	Opposing views	
1. Between 'Budgeting' and 'Risk Management' logic	• <i>Demand-based resource allocation*</i>	• <i>Supply-side resource allocation</i>
2. Within 'Budgeting' logic	• <i>Budgeting has no impact on other decisions*</i>	• <i>Budgeting has impact on other decisions</i>
3. Within 'Risk Management' logic	• <i>Managing risks impacts on other decisions*</i>	• <i>No impact of managing risk on other decisions</i>
4. Between minority 'Contractor Relations' logics	• <i>More responsibility to contractor*</i>	• <i>More control over contractor</i>
5. Between minority 'Policymaking' logics	• <i>Performance-driven policymaking*</i>	• <i>Problem-driven policymaking</i>
6. Between minority 'Knowledge Management' logics	• <i>Creating new knowledge base*</i>	• <i>Preserving old knowledge base</i>

* This viewpoint tolerates the agency logic

In step 4 the developed method is applied at the same agency as in step two. The study suggests it is quite possible that there is no dominant logic about AM supported by a majority of the employees. Rather, there may be multiple logics that employees recognize or reject in the context of their personal mandate. This implies that the official AM decision-making process potentially faces conflicts between different combinations of these logics. Table 3 shows the contradictions between multiple 'asset management' logics held by employees and the official AM decision-making process.

⁴ We use some concepts to describe observations in chapter 3. We describe that employees have a single goal when we observe employees focusing on one direction while addressing a challenge. We base employees' blindness on observations of employees who disregard other directions to address the same challenge.

⁵ This table is reproduced from and part of Chapter 5. The table is further explained and clarified there.

The most prominent contradiction we find is the one between the 'Budgeting' logic and the 'Risk Management' logic. Here one group of employees views resources to be allocated based on demand, whilst others view resource allocation to be based on supply. This shows that AM implementation needs to address personal mandates and the various expectations of different departments if it is to achieve a consistent decision-making process.

Workshop discussions confirm that employees are inclined to apply different perspectives on AM when filtering information. Firstly, we reveal the major differences between local department and project department personnel on the most important AM decisions and that the specific conflict between these departments is based on a fundamental difference in the mandates that each department proclaimed. Secondly, we encounter that some differences are unexpected, for example, upon showing differences between the regional and corporate department about determining policy goals the majority of the workshop participants seemed astonished that members of both departments made decisions that were expected of the other party. Finally, the workshops reveal that views on AM are mostly determined individually and do not necessarily pertain to departments where individuals work. For example, it became clear that interpretations about the word 'maintenance management system' was the basis for participants to form opinions on how AM should be implemented. This insight should be used to clarify to departments how AM is understood and which position departments take in a consistent decision-making process.

Conclusions and discussions

Regarding the first part of the main research question, neither in literature nor in practice there seems to be common understanding about AM. In current AM literature there are multiple research domains oriented on objects in which the integrative character of AM is not being well captured. In practice, our case study shows that employees were each focused on achieving goals that they themselves had in mind when preparing decisions collectively. Moreover, evidence from the final steps suggests there is no dominant logic by a majority of employees, instead multiple logics exist that employees recognize or reject based on their personal mandate. Furthermore, workshops reveal that semantics could explain the relationship between the varying availability of existing information to employees and their construction of different perspectives about AM.

Regarding the second part of the main research question, transport infrastructure agencies should address the conflicting viewpoints among employees. From a knowledge point of view, this can be achieved by focusing the different research domains on their shared research problems in AM as a discipline. In practical sense, agencies should make their decision-making process more consistent, by avoiding that employees pursue conflicting views. For this to happen an agency has to address employee's personal mandates and the semantics they apply in the AM decision-making process. They can do so by separating decision-making process where conflicting logics exist and integrate the decision-making where a dominant logic exist. Employees' mandates and semantics offer clues of the reason and background for separating or integrating parts of the AM process.

The study makes some scientific contributions. First, in terms of AM research, this study contributed the finding that employees play an important role in AM implementation as a link between strategy and realization. In addition, whereas previous research (with approaches such as maturity checks) has mainly focused on integration challenges, our study provides insights related to the coordination challenges in AM implementation. Second, turning to the dominant logic literature in general, the

main contribution made is the recognition that multiple dominant logics can coexist within a large organization. We have uncovered the reality that these logics are distinct in terms of both the held view as well as the line of reasoning regarding the task in hand. The approach we have developed covers both the apparency and the dominance of logics, whereas previous attempts to operationalize dominant logics have addressed either their apparency or their dominance, but not both.

In terms of practical relevance, this study has contributed knowledge that can be used by the Dutch Public Works and Water Management Agency and by other transport infrastructure agencies. First, for the Public Works and Water Management Agency, the main practical contribution of our research is that it shows that, in order for the agency to implement a consistent decision-making process, it needs to resolve the contradiction between employees' logics and the agency's logic (how AM should be). The contradictions can be used to discuss with departments what their position is in the official decision-making process. If a contradiction is due to different assumptions about meaning of terms used in practice (semantics) then the Dutch agency can enlist these words such that employees speak the same language and attach the same meaning to these terms. If a contradiction is because of personal mandates, then the decision-making process can be split to remove the conflicts out of this process. Other transport infrastructure agencies could also benefit from this research in meeting the coordination challenge in their AM implementation. The research identifies recurring coordination challenges both in the AM literature (for example, trade-offs) and in the Public Works and Water Management Agency case study (for example differences between mandates). Further, this study elaborates on methods that other agencies can use to analyze coordination challenges and contradicting logics in their own organizational context.

Some choices that we made in the design of this study need to be reflected critically. One limitation is that the empirical work focuses on a single organization. We recognize that collecting empirical evidence from a single organization makes it hardly possible to state propositions about the AM implementation generally applicable to transport infrastructure agencies. The empirical work points to contradictions between employees from a single agency, but these do not immediately say whether these are also contradictions for other agencies. Another limitation is that a single theoretical perspective was used. We have seen many instances that mark the complexity of the AM implementation, which illustrates the limitation of one theoretical perspective to understand it. More theoretical perspectives can look at more facets of the implementation challenge.

1 INTRODUCTION

In many countries, the infrastructure sector is in transition with the aim of better coping with a multitude of issues revolving around the management of transport infrastructure assets⁶. In particular, Asset Management (AM) has been seen as of strategic importance for transport infrastructure agencies in bringing managerial practices together such that decisions become better coordinated. However, AM implementation appears a difficult and lengthy exercise for many public agencies, and difficult to understand because of the many contexts in which these agencies are situated. Addressing the AM implementation problems facing transport infrastructure agencies is the main driver for this PhD dissertation. In this chapter, we introduce the background and the structure of the facets that make up this dissertation. To start with, some key reasons for implementing AM are discussed and the reasons for the implementation challenges in practice described in Section 1.1. Section 1.2 provides a description of the state of the art in studying the implementation challenge, and especially approaches such as the maturity check, benchmarking studies and assessing the attitudes of employees. The problem statement, objective, and main research question are then presented in Sections 1.3 and 1.4. The research design is laid out in Section 1.5, after which we close this chapter by outlining the structure of the dissertation.

1.1 The relevance of implementing asset management at transport infrastructure agencies

Infrastructure is of vital importance to an economy, and the sound management thereof becomes increasingly essential due to rising pressures, such as the growth in stakeholder needs and demands, an ageing infrastructure and climate change. Often, budget constraints have been a precursor to transport infrastructure agencies seeking new and other promising ways to deal with these pressures. Published standards related to asset management, such as PAS-55 (BSI, 2008a, 2008b), IIMM (IPWEA, 2006) and ISO-55001 (ISO, 2013a; 2013b; 2013c), further reinforce the relevance and attention in AM implementation of integrating, or bringing together, decisions regarding infrastructure assets. Some key reasons why transport infrastructure agencies implement AM, particularly in terms of external pressures, are described in Section 1.1.1, and in Section 1.1.2 we elaborate on the challenges within public infrastructure agencies when implementing AM. It is these challenges that form the context of this dissertation.

1.1.1 The need for change in managing transport infrastructure assets

Over the years, external pressures have created reasons for public agencies to change how they manage infrastructure assets. One reason why public infrastructure agencies need to change is the influence exerted by various stakeholders. Infrastructure agencies can have a very divergent array of

⁶ Please note that transport infrastructure assets (the main focus in this dissertation) are referred to using many interchangeable terms in the literature, such as public infrastructure assets, transportation assets, civil infrastructure assets, and infrastructure assets. In this dissertation, we also use these various terms at times rather than adopt a fixed expression. Firstly, this is to accommodate the various audiences and the journals in which some of this research has been published. Secondly, this is to avoid unnecessarily repetitive and tedious use of language.

stakeholders that have to be satisfied, including regulators, customers and users, or the public in general (Arthur et al., 2009; Popović, Vasić, Curović, 2010). Agencies are challenged to address such stakeholder needs and demands in the way they manage infrastructure. For example, regulators follow the public interest and impose increasingly strict standards, such as in establishing regulations on carbon emissions (De La Pena González, 2009). Further, public opinion can be formed in quite chaotic ways and can change rapidly (Ahonen et al., 2010; Tam and Tong, 2011). With this increasing stakeholder influence, transport infrastructure agencies need to be able to change their decision-making process such that it can deal with new issues arising within the organization.

In addition, public agencies see a need to change their approach to managing infrastructure assets because much of the existing infrastructure is ageing and falling foul of nature's influence. Today, a lot of the infrastructure in Western countries is requiring increased maintenance or replacement due to the fact that many such assets were constructed immediately after the Second World War and are now reaching the end of their expected life (Yang and Kumaraswamy, 2011). In many instances, it is difficult for public agencies to fully understand the lifecycle of an existing asset and to forecast or assess its condition (Yang and Kumaraswamy, 2011). Nature's influences include extreme weather events and climate change (Warren, 2010). This can mean that public agencies have to reprioritize their assets as a result of unexpected forces of nature (Lambert, et al., 2013; Bryce, Flintsch, and Hall, 2014).

Agencies also need to change their decision-making processes due to the increasingly tough budget constraints (Thurlby, 2013). Facing budget constraints, agencies have to better justify their expenditures (Salman and Salem, 2012). For example, the UK government applied the 'more for less' principle, in which the Highways Agency was required to re-examine its expenditures (Barker et al., 2012). Governments can impose various budgeting procedures on transport infrastructure agencies. For example, agencies may be allowed to use funds intended for future repairs for current major improvements, meaning that agencies need to weigh the consequences of short- and long- term interventions (Popović et al., 2010; Adey and Hajdin, 2011).

1.1.2 The implementation challenge facing transport infrastructure agencies

To deal with the external pressures on their management of infrastructure assets, agencies have started to implement an overarching concept known as Asset Management (AM) that has been introduced in the literature and is reflected in international manuals and guidelines such as FHWA (1999), BSI (2008a, 2008b), and ISO (2013a, 2013b). AM is described in many of these standards as a way to connect different organizational levels (strategic, tactical, and operational), disciplines (technical, financial, organizational), assets (single assets, multiple assets, networks), and time horizons (short- and long- terms). As such, AM seems to offer an attractive solution to agencies trying to respond to the growing external pressures. However, making all these connections and achieving consistency in AM decision-making is a challenging task, which we refer to as the 'implementation challenge'.

The integration challenge reflects one reason why implementing AM is so difficult. The aforementioned characteristics of asset management see it as a concept that integrates specific issues, such as disciplines and assets, involved in decision-making. This integrative character is very apparent in the many existing models of AM processes that often focus on a specific set of elements in the decision-making process. Several process models have been developed, including by Scarf and

Martin (2001), Vanier (2001), Howard (2001), Šelih et al., (2008), Gharaibeh et al., (2006), and Karydas and Gifun (2006). Not only is developing the model in itself a considerable task, how to subsequently understand and connect all the relevant dimensions is far less clear-cut. Managing infrastructure assets involves a multitude of interconnected decisions the impacts of which are not easily understood. Infrastructure networks are often complex, and their assets highly interdependent (Halfawy, 2010). Furthermore, this integration is also hampered by the fluid nature of AM. Here, evidence shows that AM implementations vary case by case (Cardoso et al., 2012). This underpins the point that implementations face different conceptual understandings and AM scopes. Depending on the perspective adopted, AM is given a different flavor, certain decisions are included and others left out, or certain decisions are given greater importance than others. As transport infrastructure agencies have been seeking to integrate their practices into a system, the challenge has very much been to find a consistent direction for the whole organization.

Another reason why implementing AM is complicated has to do with the coordination challenge. Although many process models seem to see AM as a logical process with sequential steps that an agency can follow, AM is not in practice a static process. AM implementation therefore has to go beyond the integration of decision steps. For example, Famurewa et al., (2013) observed that efforts to integrate practices are complicated by the fact that some decisions have organizational consequences. For example, an outsourcing decision giving responsibilities to contractors, leads to a range of consequent actions and decisions to ensure that the required capacity is met (Famurewa et al., 2013). In that sense, as transport infrastructure agencies are implementing AM to cope with the dynamics of the sector's practice (Lownes et al., 2010), they need to understand the consequences of decisions already taken for decisions still to be made. In addition, the coordination challenge alludes to the very fact that implementation also means changing existing practices. Public agencies do not start managing infrastructure assets when they implement AM, rather they have to change the way they have been managing infrastructure assets up to the moment that AM implementation commences. For example, many transport infrastructure agencies have managed different types of assets in separate management systems, such as a bridge management system and a pavement management system (Flintsch and Chen, 2004). As such, the views on how infrastructure assets were managed before and during an implementation constitute a force that a public agency needs to address.

1.2 State-of-the-art in assessing asset management implementation

In this section, we discuss the approaches used elsewhere in investigating and assessing AM implementations. The current state of the art is reflected in studies using asset management maturity checks, benchmarking, or addressing the attitudes of employees low down the hierarchy.

1.2.1 Maturity checks and benchmark studies on asset management

Some researchers have investigated AM implementation issues by viewing AM as a prescription, and this approach, in effect, leaves many challenges unresolved. By 'prescription' we mean a range of registered and documented normative rules, or methods, on how AM should be carried out. These prescriptions do help in correctly implementing various practices in the decision-making process. One perspective which has been tried is to view the implementation challenge as overcoming discrepancies between an agency's top-down strategy (how AM should be) and the implemented result (how AM practice is). Several AM evaluation schemes have been developed to identify such discrepancies, such as maturity checks (Macgillivray et al., 2007; Volker et al., 2011; Laue et al., 2013)

and benchmark studies (Ozbek et al., 2012; Zeb et al., 2012). However, this perspective does little more than accept that discrepancies exist between a certain standard and the current practice, and then assume that the issues would be resolved if an agency adopted best practices. For example, Nastasie et al. (2013) claim that implementing AM involves relying on advanced computing technology and information systems to ensure the effective management of engineering assets. As such, they seem to imply that the cornerstone of AM is the integration of technologies, tools, and methods. As a result, they see the problem in implementing AM as the fact that standards (e.g. MIMOSA and ISO) are not being taken up as rapidly as expected. In reality, many AM implementations have been treated as serious and long-term challenges by agencies (Pantelias et al., 2008; Haider, 2013). In reality, the discrepancy perspective barely addresses the consistency or otherwise in the decision-making. That is, although it examines whether particular decisions are made or certain practices are in place, whether decisions and practices are coordinated is often neglected.

1.2.2 Addressing employees' viewpoints on asset management

A more recent perspective, which is still being developed, considers the role of employees during the implementation. A case study by Povey and Peach (2013) shows how a new AM strategy will have implications for the meaning attached to AM by the employees and by the organization. An Australian study similarly found that changing an AM strategy affects employees' attitudes toward the implementation (Xerri et al., 2014). Similarly, Ratnayake (2013) found that implementing AM is dependent on the ability of the human authority in an organizational hierarchy to maintain different asset operations in alignment with sustainable considerations. In particular, Ratnayake (2013) found that humans are critical in AM implementation as they are part of the organizational integrity of the eventual operating process. Another argument why the focus on employees is important builds on Park and Kim's (2013) finding that the techniques involved in decision-making processes are complicated and difficult to implement without a certain level of engineering experience and training. Focusing on employees can provide information on the fit of the organization with the intentions to change. Despite these arguments concerning the influence and role of employees, most studies have only considered how to change employees' attitudes to match how top management thinks AM should be. In practice, focusing on changing the attitudes of employees fails to take account of internal concerns within public agencies that are not readily visible but lead to implementation challenges, such as conflicts between departments, (Grubišić et al., 2008). Over time, such unresolved concerns can surface. As such, a critical bottom-up view that incorporates such internal concern as an explanation as to why employees' views make AM implementation difficult has not yet been offered. Essentially, the AM implementation challenge (achieving consistent decision-making) requires an understanding of the possible conflicts and discrepancies in the current AM decision-making process, and this argues for adopting an employee perspective.

1.3 Problem statement

In current studies that address AM implementation, there is a lack of understanding as to why transport infrastructure agencies find it difficult to implement AM in terms of their own employees' involvement.

First, this is because much of the emphasis in research has been on the difficulties that stem from the complexity of the AM concept itself. For example, AM tries to integrate multiple dimensions of the decision-making process involved in managing assets, and the changes made when introducing AM

decision-making can introduce fluid components (such as unclear and ambiguous goals) or add a dynamic component (feedback loops between subsequent decisions). However, as noted earlier, there is also the key fact that implementing AM means a change in existing practices. Before transport infrastructure agencies even considered AM as a new way to manage infrastructure assets, they already had a set of practices in place for this. It is important to deal with existing practices since these are part of the agency's historical context. These existing practices also mark the organization's starting point when they are used as a reference by the agency in seeking improvements in their practices as proposed in the AM concept.

Second, investigations into AM implementations have focused mainly on assessing the ideas behind the AM concept. For example, maturity checks are mainly used to identify discrepancies between an idealized vision of AM and how it is implemented in practice. However, regardless of the way in which AM is idealized by a transport infrastructure agency, the agency still needs to address the existing practices if it wishes to change. Therefore, we argue that the failure of current studies to address the role of existing practices in AM implementation is a weakness. It is quite possible that the existing practices have implications, and therefore warrant study. Rather than seeing the need as being to change employees' attitudes to match the idealized vision of AM, one should see employees as being able to provide a vital insight into the challenges to be addressed in AM implementation. As such, employees' views can be a fruitful basis for studying the implementation challenges that may arise from existing practices.

1.4 Research objective and central research question

The main objective of this research is to understand the challenges in AM implementation by taking into account that AM is an integrative, fluid and dynamic concept⁷ and that transport infrastructure agencies have an existing way of managing infrastructure before the change. In this respect, we pay particular attention to the perspectives of agency employees regarding AM and the consequences of these for the consistency in AM decision-making. As such, the main question of this research is:

- **What viewpoints are present on the management of infrastructure assets and how should these be addressed when implementing AM at public agencies?**

The following research questions guide the research towards answering the main question:

1. What research orientations are used in studying the management of infrastructure assets? (chapter 2)
2. What role do employees' viewpoints play in the implementation of AM at public agencies? (chapter 3)
3. How can employees' viewpoints about AM be analyzed on different layers of management within a public agency? (chapter 4)
4. Which implications do employees' viewpoints have for the implementation of AM inside a public agency? (chapter 5)

⁷ We accommodate the richness of perspectives that researchers and practitioners can have of AM. To reflect this, we are mindful of some characteristics that contribute to the complexity of AM. With 'integrative' it is meant that several elements (decisions) are often connected in AM decision-making models. With 'fluid' it is meant that AM knows many versions depending on the perspective applied. With 'dynamic' it is meant that decisions can change decisions to be made or previously made.

1.5 Research perspective and design

In this section, we discuss the research perspective and the steps taken in answering the main question.

1.5.1 Research perspective - the dominant logic theory

We argue that the challenges of implementing AM at public agencies stem from employees' role perceptions inducing an AM understanding that conflicts with the views of top management. We see this as a 'dominant logic' problem. The 'dominant logic' concept is prominent in the strategic management literature, and was first developed by Prahalad and Bettis (1986) as a potential theory to link patterns of corporate diversification (e.g. a portfolio of different business units) to organizational performance. This brought them to the important realization that two dissimilar technologies could be more simply managed using two tailored approaches than a single approach. As such, the dominant logic concept fits the AM implementation challenge facing public agencies with their historically developed and separated viewpoints on how infrastructure should be managed. The dominant logic concept suggests that the official top management view as to which AM approach should be implemented may conflict with the views held by employees inside the agency. If these viewpoints represent dominant logics regarding the AM decision-making process they will require particular attention when implementing AM.

1.5.2 Research design

In this section, we describe the research design adopted in this dissertation to address the main research question. In answering the main question we aim to collect and analyze the views that employees have in their work environment. The research design facilitates this by involving a systematic and uniform data collection process. In this way, the potential differences, similarities, and conflicts between views can be analyzed and explained within the organization's context and the AM approach being implemented. Based on this, the research design involves four steps. The first two steps are explorative and descriptive, and explore how the management of infrastructure assets is understood. We do so by reviewing the relevant literature (Step 1) and the agency's practical context (Step 2) regarding the management of infrastructure assets. The final two steps include the design and then application of a method to understand the implications of existing viewpoints, and how these should be addressed, within public agencies when implementing AM.

Step 1 – Chapter 2: Research orientations towards the 'management' of infrastructure assets: an intellectual structure approach

The first step helps to answer our research question: What research orientations are used in studying the management of infrastructure assets?

In Chapter 2, we explore whether the research community has a shared understanding of the management of infrastructure assets. This step is important because researchers have discerned a potential for 'scope creep' in researching the management of infrastructure assets, and also worry that the concept lacks a clear focus given the broad range of topics it addresses (Stapelberg, 2006, Lin et al., 2007). Further, the diverse definitions of AM found (e.g. BSI, 2008a, 2008b; FHWA, 1999) suggest a mushrooming of topics and issues covered. Moon et al. (2009) note that even the meaning of 'management' seems to be unclear to organizations that publish standards of 'asset management'.

Adopting the dominant logic perspective requires us to answer this research question with an objective and systematic research methodology. Here, bibliometric methods can be used to collect data about the sensemaking related to the concept being studied, asset management in our case, through existing publications. These data can help to understand how the conceptual understanding and scope of AM has developed by reviewing the research that academics have drawn upon and relied on with frequent citations.

Our review shows that there is no shared understanding. Applying a well-known and objective approach called the 'intellectual structure approach', we revealed and reviewed the structure of research on the management of infrastructure assets. This approach shows that infrastructure asset management is a fairly fluid, integrative and dynamic concept. It also appears that little attention is given to the implementing organization in the AM literature.

Step 2 – Chapter 3: When organizations and asset management meet: accounting for employee's experiences

The second step helps to answer our next research question: What role do employees' viewpoints play in the implementation of AM at public agencies?

Chapter 3 focuses on investigating the inconsistencies that potentially arise when managing infrastructure assets. This is done through a field exploration of the views of employees who work together in AM to achieve the organizational strategic plan of the Dutch Public Works and Water Management Agency. It is an important starting point because the first step in implementing AM is to establish a link between a comprehensive asset management system (the AM system) and the organization's strategy (Parida, 2012). An AM system is defined by the British Standards Institute (2008; the PAS-55), as documents and instruments that bind amongst others the organization's asset management policy, strategy, objectives and plans (BSI, 2008a). However, AM involves more than just the AM system. AM adds a 'strategic theory', i.e. systematic and coordinated activities and practices, that makes the AM system useable and help employees in achieving its organizational strategic plan (BSI, 2008a).

The dominant logic idea requires us to collect employees' views about the consistency of AM decision-making using a criteria-free approach. That is, the data collection should not direct the responses of employees by relating it to how AM 'should be'. An approach that has proven useful in such cases is a set of four questions developed by Richard Rumelt (1979). Rumelt created four tests, in the form of questions, that could be answered to check the consistency of a strategy and a fit, as well as an approach to study the role of employees and the consistency in decision-making. A benefit of this approach is that it is in line with the dominant logic concept of a neutrality in data collection. The four questions are open and cumulative and are designed to draw out examples that employees bring to mind in terms of AM decision-making and further probe employees' experiences of these events and situations to identify problems in realization.

The in-depth study is performed at the Dutch Public Works and Water Management Agency. We opted for a single organization because coordination challenges are best viewed through the interactions between employees. The focus is therefore on the in-depth collective accounts of decision-making activities and events, which are best collected within a single organization. The case results are compared to results from a different analysis of AM implementation, this time using the

results of a maturity check conducted by other researchers in the same agency. This comparison shows employees' experiences are insufficiently addressed when using current tools and methods (such as the maturity check) which consequently fail to support AM implementation.

Step 3 – Chapter 4: Resuming an unfinished tale: applying causal maps to analyze the dominant logics within an organization

The third step helps in answering our next research question: How can employees' viewpoints about AM be analyzed on different layers of management within a public agency?

Chapter 4 develops an analytical tool to detect the viewpoints of employees regarding AM and possible conflicts and discrepancies that lead to inconsistent AM decision-making. We found in the in-depth analysis that inconsistencies are present in the AM decision-making, and that the role of employees' views should be studied in the wider context of the organization in order to fully appreciate the impact on AM implementation. To achieve this, it is important to further improve the way we collect and analyze different and conflicting views from a large population that is representative of an organization.

The method we develop is based on the dominant logic theory and expands the current measurement of logics to include conflicting and differing logics that are empirically possible. This is relevant because researchers have called for more resourceful methods that more fully examine how to avoid tensions between practitioners possessing a multitude of dominant logics (Greenwood et al., 2011; Daudigeos et al., 2013). Von Krogh and Roos (1996) proposed two additional elements – self-reference and self-similarity – that more explicitly describe how dominant logics can be unique to individual employees and can also be found on different levels within an organization. The developed method is tested through a demonstration involving a small implementation team within a public agency.

Step 4 – Chapter 5: Implementing asset management in public transport infrastructure agencies: about the employees and their mandates

The fourth step contributes to answering our final research question: Which implications do employees' viewpoints have for the implementation of AM inside a public agency?

Chapter 5 applies the method developed in Chapter 3 to reveal the views on AM of employees in an agency and identifies where inconsistencies in AM decision-making are located. This is relevant for the implementation of AM since the decision-making process appears to have traditionally been organized along separated issues, such as the lifecycle of bridges or the network of pavements. The agency is now trying to integrate these in a decision-making process for the entire transportation system. Based on the findings using this method recommendations are made as to how public agencies should approach AM implementation.

The in-depth study was conducted at the same agency from step two, the Public Works and Water Management Agency in the Netherlands. This Dutch transport infrastructure agency was in the process of implementing AM as a component of managing their core business at the time of the study. We had full access to their employees in conducting a large number of interviews at a spread of management layers ranging from the local to the corporate levels. We focused on a single agency

because collecting views from within the same organization allow an in-depth analysis of potentially different and conflicting views on AM and the implications of this for the AM implementation.

1.6 Outline

The following chapters cover the various research steps described above. All but one of the main chapters have been published as papers in scientific journals, the other has been submitted. We note each chapter's publication status. Chapter 2 provides a literature review and bibliometric study of the body of knowledge regarding the management of infrastructure assets. Chapter 3 presents the results of a field study in which we investigated the decision-making issues that arise when employees together make decisions on infrastructure assets inside a Dutch agency. A method to overcome the challenges identified here is developed and demonstrated in Chapter 4. The method is applied within a large infrastructure agency in Chapter 5. The dissertation concludes with a discussion of the research and provides answers to the main question of the dissertation, presented as an overall conclusion to the main themes. Table 1 shows the outline of this dissertation.

Table 1. The research outline

2 RESEARCH ORIENTATIONS TOWARDS THE ‘MANAGEMENT’ OF INFRASTRUCTURE ASSETS: AN INTELLECTUAL STRUCTURE APPROACH⁸

Abstract:

In recent decades research on the management of infrastructure assets have increased steadily. However, there are concerns raised about the contribution of studies to a coherent body of knowledge. There is a call for a more structured understanding of the knowledge that is emerging around the management of infrastructure assets. This paper attempts to answer this call through an empirical study based on the reference lists of over 8,200 articles that present their study relevant to the management of infrastructure assets. In so doing, we apply recognized techniques from bibliometric and social network analysis to visualize and identify major and minor topics, where researchers have oriented and contributed. We find that managing infrastructure assets traditionally was object-oriented, like pavements, bridges, water and utility networks, and that attention is only now emerging on the life-cycle decision making and organizational aspects although the latter remains weakly linked with technical aspects. We conclude with shared research orientations in ‘managing’ infrastructure assets.

Keywords: Bibliometric analysis, Infrastructure Asset Management; Network Analysis, Intellectual Structure

2.1 Introduction

Research and development regarding managing infrastructural assets has grown rapidly since the late 1990s. Since then, an increasing number of studies have tried to integrate various disciplines and practices associated with the management of infrastructure objects such as civil engineering, finance, economics, and organizational science. The concept of infrastructure asset ‘management’ (IAM) has been introduced as a coherent and overarching framework for work on infrastructure assets and is viewed as an ‘emerging field’ (Pantelias et al., 2009; Lynch, 2007), a ‘new paradigm’ (Moon et al., 2009), and as an ‘emerging philosophy’ (AASHTO, 2002). Flintsch and Chen (2004) describe how, from the 1980s on, the topics and themes related to managing infrastructure assets have expanded from management systems for single object-types to a more strategic and broader orientation. However, researchers discern a potential for ‘scope creep’ in the research orientation of IAM, and worry that the concept lacks a clear focus given its broad range of topics (Stapelberg, 2006, Lin et al., 2007). Moreover, the diverse definitions of IAM found (e.g. BSI, 2004; 2008a; 2008b; FHWA, 1999) suggest a mushrooming of topics and issues included. Moon et al. (2009) notes that the meaning of ‘management’ is also unclear to organizations that publish standards of ‘asset management’. For example, the Federal Highways Administration (1999) “does not clearly differentiate between the integrated management of all assets and asset groups ... and the fragmented management of various asset groups separately” (p. 27). For the future enhancement of the body of knowledge around the

⁸ This chapter has been published as: Schraven, D., Hartmann, A. and Dewulf, G. (2015). Research orientations towards the ‘management’ of infrastructure assets: an intellectual structure approach. *Structure and Infrastructure Engineering*, 11(2), 73-96.

management of infrastructure assets it seems essential to develop a more consistent and coherent understanding of the concept (Spatari and Aktan, 2013).

With a growth in publications, it becomes increasingly valuable to analyze and graphically represent the existing body of knowledge that explicitly addresses research and contributes to the 'management' of infrastructure assets. Such an analysis can help to clearly distinguish emerging topics, their influence, and their linkages with each other. There are already some reviews done in the past, but they focus on either other sectors or specific issues. For example, reviews can be found about asset management in the electrical and utilities industry (Brint et al., 2009; Okamoto and Takahashi, 2007). Related to the civil engineering sector reviews are done on soft computing applications (Flintsch and Chen, 2004), wireless technologies for structural health monitoring (Lynch, 2007), available commercial IM software (Halfawy et al., 2006), water deterioration and failure rate prediction models (St. Clair and Sinha, 2012), inspection practices (Wakchaure and Jha, 2012), and deterministic and stochastic programming models (Ng et al., 2011). Frangopol et al. (2012) reviewed publications in the *Structure and Infrastructure Engineering* journal in the period from 2005 to 2011. They found that studies could be divided into many categories and belonged to more than one research area. Also, Hegazy et al. (2011) point to the diverse nature of the "management" of infrastructure assets. They consider the infrastructure domain to be one of the largest with a wide spread of research. These characterizations suggest that many different views exist among researchers as to what managing infrastructure assets actually means. To the best of our knowledge, there has been no attempt to analyze research on the management of infrastructure assets in a comprehensive manner.

Analyzing the references used in published articles has been suggested as a useful approach to understanding how important topics interact with one another (Small, 1973). Recent developments in this type of analysis could help in addressing the different orientations and scope in the research of managing infrastructure assets. In addition, Hegazy et al. (2011) show that researchers could gain a more realistic and simplified understanding of the IAM concept through using visualization tools, such as visual mapping, to analyze the literature. Elsewhere and related to other management topics, similar visualization techniques combined with bibliometric analysis have proven beneficial in this respect (e.g. Pilkington and Meredith, 2009; Lee and Chen, 2012). In this paper we aim to identify the intellectual structure of research on managing infrastructure asset by conducting a bibliometric study combined with graphical visualization. First, we investigate to what particular body of knowledge researchers orient themselves, when they intend to research on and contribute to the 'management' of infrastructure assets. Then, we aim to understand which studies and topics have been a frequent referent for the work of these authors; thus which knowledge is shared by several studies and authors. Based on that, we discuss the intellectual structure of the existing research on managing infrastructure assets and recommend avenues for further research in this area.

2.2 Intellectual Structure Approach

In library science, an intellectual structure is defined as a pattern and track-record how scientists, who contribute intellectually, consult the work of other scientists. By considering citations as evidence of such a consultation an intellectual structure approach analyzes the frequency, relation among citations to determine important themes, authors and concepts. In so doing, the analysis does not depend on the reviewers' knowledge and any subconscious literature preferences (Bricker, 1989). This makes it a suitable approach to analyze a concept with so many different views such as

managing infrastructure assets. Moreover, this approach is a well-accepted procedure in other bibliometric studies on management literature (White and Griffith, 1981), for example see Marsilio et al. (2007) on public-private partnerships. The approach consists of three steps.

The first step is the collection of articles that explicitly address the management of infrastructure assets. The intellectual structure approach assumes that authors cite publications as a testimony of their indebtedness and to reveal the previous contributions to their research orientation. As such, a compilation of reference lists can expose an inherited structure of these testimonies and contributions. In the further proceedings of this paper we will use 'Article' for the document that cites, and we will use 'Citation', for the document that was cited by an 'Article'.

The second step identifies knowledge groups as sets of two (or more) citations that both appear to have been cited by articles. Citation analysis and co-citation analysis have been well-established techniques in the intellectual structure approach since the 1970s. In citation analysis, a researcher uncovers the most frequent associated publications in a field by counting citations and ranking each unique publication. As a further refinement, a co-citation analysis is often used to find the relationship between the most cited studies by investigating the frequency at which two studies are cited together (i.e. co-cited) in reference lists. When two citations are both found in many reference lists, a co-citation analysis assumes that these have a strong intellectual relationship with one another. These relationships are then used to describe the structure of specialties (Small and Griffith, 1974) within a field, and allocate them to knowledge groups.

The final step analyzes if articles are also orientating on shared research problems, when they are citing similar citations and knowledge groups. Although knowledge groups indicate which topics are frequently cited, they do not help in understanding why influential citations are cited by many articles. The intellectual structure approach can point toward possible reasons why an article might refer to a citation belonging to a specific knowledge group. If two or more knowledge groups appear closely related, in the sense that they are both cited by the same articles, then this is an indication that these groups share a common disciplinary interest to solve a research problem (Wagner et al., 2011).

2.3 Articles related to Managing Infrastructure Assets

In order to create an intellectual structure of a domain, it is essential to have a representative set of articles. In selecting an appropriate set of articles, two aspects are important. First, is the question as to whether an article is relevant to the topic of study. Next, is the question as to whether the identified sample of articles is sufficiently substantial. In collecting appropriate articles, various approaches can be used. A common approach is to use a panel of experts who are asked to identify the prominent authors on a topic and their publications. Once these source documents are identified and retrieved, they become the subject of the bibliometric study. An improvement to this approach is seen as the selection of the publication record of field-specific journals (Pilkington and Meredith, 2009). A relevant journal provides a natural selection of appropriate articles given its review procedure results in the publication of only articles relevant to the topic of interest. Although this method perhaps raises the fewest questions, not every domain has journals with a long tradition of regular contributions. When researchers in a field publish in a range of more general journals, a third option is to select articles from a comprehensive and academic database using relevant search terms. We concluded that this was the best option for our study. Our study requires a good coverage of

engineering-related research and multiple disciplines. Scopus is an appropriate online database that meets this requirement.

In order to uncover the relevant articles for this study, we need to define the search query. An important feature of our article population should be that articles explicitly address and position their research efforts to the 'management' of 'infrastructure assets'. This means that as a minimal requirement, authors explicitly position their work to this topic by using these words in the title, abstract or keywords. Furthermore, to avoid articles that contain these words incidentally, we require that 'management' refers to 'infrastructure asset' explicitly.

Frequently used terms seem to refer to managing infrastructure assets in split forms: "asset management" and "infrastructure management". In addition, we noticed that many articles used different terminologies to refer to when applying a more-focused description of 'infrastructure asset' group or type, for example: "highway management" or "road management". In order to select such diverse terms in a reproducible, consistent, and acceptable way, we consulted the Transportation Research Thesaurus (TRT) to identify synonyms for infrastructure asset. We retrieved synonyms for objects belonging to these transport modes according to the relational and hierarchical structure of this web-based thesaurus (on 20 June 2013). We included a synonym in our search query when the word, combined with 'management' retrieved at least one article in the search result (see Figure 1).

Various units of analysis have been used in previous bibliometric studies. In the early debate on developing co-citation analysis in information science, authors were often proposed as the unit of analysis (McCain, 1990). Adopting this option, the raw count of citations of an individual who had authored or co-authored referenced documents was established. However, it was seen that 'authors' do not represent a very stable unit of analysis since they can move or evolve to other specialties or fields (Lee and Chen, 2012). Therefore, another option proposed was to count document citations themselves. If the set is limited to journal articles, this suggests a form of certified knowledge reviewed by peers (Ramos-Rodríguez and Ruíz-Navarro, 2004). Conference proceedings could also be of great value to citation data, provided that the asset management literature is covered to a large extent at conferences, like World Congress of Engineering Asset Management or the Conference on Bridge Maintenance Safety and Management. Given these arguments, we designed our search query to cover journal and conference articles.

Finally, we had to decide on the period of the analysis. Several studies that have reviewed the recent structure of their own particular domain have used 15 to 20 years of co-citation data (e.g. Durisin and Puzone, 2009; Locke and Perera, 2001). Our selected database, Scopus, only appeared useable for publications from 1996 on and therefore we decided to limit our search from this date to the most recent complete year. We also noticed that in March of 2013, Structure and Infrastructure Engineering published a special issue on 'Asset management in the Civil Sector' which we consider of high relevance to this study and decided to collect articles of 2013, provided the online appearance on the day of the search (20th of June 2013). As such, we found 8,201 articles, published between January 1996 and June 2013.

The relevant search results are illustrated in Figure 2 in terms of the frequency of publications per year. A clear trend is visible in the development of articles published. From 1996 to 2001, the number of published documents remained below 150 per year. Between 2002 and 2006, the number of IAM publications rose steeply and seems to reach a peak around 2008. This trend reflects the perception

that the interest to the management of infrastructure assets grew in the beginning of the last decade.

2.4 Frequently cited studies and knowledge groups among Citations

2.4.1 Citation Analysis

In bibliometrics, the results of a citation analysis provides indications about the influence of research efforts. However, counting and ranking citations does not provide a bias-free indicator of influence. In practice, authors can have various reasons for citing work (Smith, 1981). Garfield (1977) pointed out that negative citations and self-citations were not that uncommon. The former are citations that authors show as examples of poor practice in the field, whereas the latter are intended to promote one's own work. In our study, we found about 15,000 self-citations within a total of roughly 110,000 citations. We analyzed the citation data with and without these self-citations.

Figure 1. Design of the Empirical study

2.4.2 Frequent Citations

Sources that are cited the most indicate a strong influence in the sample. Noticeably, the most frequently cited sources are about pavement management. Table 1 lists the 10 most frequent citations. The five most cited works all concern pavement management with the most influential being Haas et al. (1994) – a textbook on pavement management. AASHTO (1993a) is ranked second and is therefore the most influential of the guidelines issued by an organization. As such, it provides a set of procedures that can be used for the design and rehabilitation of pavement structures. Golabi et al. (1982) is ranked fifth and is therefore deemed to be the most important study which was about the implementation of a pavement management system (for the state of Arizona) to integrate policy decisions, budgetary policies, and environmental and engineering decisions. Its popularity may be due to its use of a mathematical model to capture this rich range of decision aspects applied to pavement maintenance.

Table 1. Highest Ranking Citations

Citation	#	Title	Times Cited
Haas et al. (1994)	1	Modern Pavement Management	104
AASHTO (1993a)	2	Guide for design of pavement structures	80
Goldberg (1989)	3	Genetic Algorithms in Search, Optimization, and Machine Learning	60
FHWA (1999)	4	Asset Management Primer	59
Golabi et al. (1982)	5	A statewide pavement management system	59
IPWEA (2006)	6	International Infrastructure Management Manual	55
Shahin (1982)	7	Pavement Management for Airports, Roads, and Parking Lots	49
Madanat et al. (1995)	8	Estimation of infrastructure transition probabilities from condition rating data	47
Frangopol et al. (2001)	9	Reliability-based life-cycle management of highway bridges	44
Saaty (1980)	10	The Analytic Hierarchy Process	44

Figure 2. Frequency of Articles from begin January 1996 to end June 2013

2.4.3 Co-Citation Analysis

The second step in our study is to uncover the similarities between the most frequent citations. To this end, we applied co-citation analysis focusing on citations with the most frequent occurrence in reference-lists. A co-citation analysis assumes that authors recognize a relationship between citations when they are cited together. Figure 3 shows the way that co-citations are counted. Co-citation counts are stored in a matrix, where citations are represented by the vertices (rows and columns), and each record represents the co-citation count of the citations in the rows and columns. Following the commonly accepted approach to treat diagonal cells in the matrix (White and Griffith, 1981; 1990; Eom, 2001), we sum the three largest co-citation counts in a vertex and divide by 2 and store them in the diagonal cells.

Figure 3. Counting Co-Citations

A large frequency of co-citations reveals groups of citations with dependent patterns, and shows how such groups are interrelated (Small, 1973). Co-citation counts are often converted into a correlation matrix to measure the similarity between citations (McCain, 1990). Often the grouping of citations is based on having a high similarity, determined by multidimensional scaling (MDS) or principle component analysis (PCA). However, techniques recently found in social network analysis have also been used. Every method has different strengths in uncovering knowledge groups. Ultimately, co-citation analysis should derive and graphically represent relationships between documents or topics.

2.4.4 Principal Components on Citations

A Principle Components Analysis (PCA) is frequently applied in bibliometric studies (White and McCain, 1998) and is seen as having considerable benefits over MDS. This analysis performs data reduction by grouping citations into overarching components based on statistical significant patterns of variability. This way, PCA enables a researcher to obtain a higher dimensional understanding of the data structure and can include more citations (Leydesdorff and Vaughan, 2006). Consequently, using a PCA approach addresses a larger number of citations to be analyzed than when using MDS. Thus, of these two valid techniques, we decided to use PCA so that we could include more citations and thus cover a larger portion of the body of knowledge.

In order to properly generalize knowledge groups from the citations, a choice has to be made as to the appropriate number of citations to include. PCA is particularly useful in analyzing larger datasets

(between 100 and 200 of the most frequent citations). We compared the validity of the test results by varying the frequency of citations to include in the analysis from 11 or more to 12 or more. We found 198 citations reduced to 50 components with citations with 11 or higher frequency and explained 70 % of variance in the data. A Kaiser Meyer Olkin test of Sampling Adequacy measures the level of appropriateness for using PCA for a particular data set (where 0 is inappropriate and 1 is most appropriate). For the bandwidth of 11 times cited or more we obtained a good level of 0.880 (Dziuban and Shirkley, 1974). Bartlett's test of Sphericity (Bartlett, 1937) assesses whether the analysis of variance (PCA output) can lead to invalid statistically significant results, due to heteroskedasticity. We find an acceptable level of 0.0000 for Bartlett's test of Sphericity (in SPSS). We checked whether lowering the included citations to frequency of 12 or more citations would improve these test-results. We found 151 citations fitted on 43 components. However, test results for Kaiser-Meyer-Olkin's test and the variance explained appeared lower for this alternative. We performed the PCA with 198 citations overall.

In order to identify which citation belongs to which component (i.e. knowledge group), a PCA can apply various alternative rotation methods to change coordinates in the data table. We selected VARIMAX rotation as this tries to fit the maximum number of citations to the minimum number of components. The result of a VARIMAX is a rotated component matrix with factor loadings for every citation to a component (where 0 means no association and 1 means perfect match). A minimum accepted value for these factor loadings, for a citation to statistically belong to a component is 0,4 (Eom, 2001). Given the high average of values in our VARIMAX, we were able to fit 148 citations to the 50 components with a 0,6 factor loading value. Table 2 indicates the number citations loaded onto each component.

2.4.5 Knowledge Groups among Citations

Components can be made up of multiple variables or equate to an individual variable. Where three or more citations are frequently cited together in a single article, they are statistically fitted into a group. We call these 'knowledge groups' because the knowledge output is frequently co-cited in articles. The PCA revealed 21 knowledge groups ranging in size from 11 fitted sources down to 3. Such citations indicate the presence of an influential subtheme within the field. Within each knowledge group, documents shared a main topic that could be used to qualitatively characterize and label the focus of the group.

Table 2 reveals multiple issues, part of research contributions and academic enquiry, when managing infrastructure assets. Besides the complexity, we can see a rough distinction that the research community has made between attention to technical and non-technical issues of 'management'. On the technical side, it appears that many knowledge groups are particularly oriented to several asset types. Frequently researched objects include pavements, bridges and water piping. Managing the technical issues of these objects has interested researchers particularly by developing and applying life cycle analysis, information systems, deterioration models, decision techniques and guidelines on designing and inspecting assets.

Also managing more non-technical issues are of interest to researchers. Particularly, organizational and performance aspects receive research attention. Organizational aspects include the preservation of knowledge in the organization, measuring organizational performance and use of resources. This

distinction raises the question whether the non-technical issues that researchers have oriented and cited in studies have a relation to the technical and more object-oriented activities.

2.5 The Intellectual Structure

2.5.1 Pathfinder Network Scaling of Citations

Although citations can be strongly related based on identical co-citation patterns, this does not guarantee a strong one-to-one relationship with other group members. The correlation between citations loaded into the same knowledge group reflects the strength of the connection within a group. This connection within a group is weak if correlations between groups are higher than those within a group. Figure 4 shows the strongest relationships between citations as a PFNET graph drawn using Pajek© (Batagelj and Mrvar, 2011). This figure was generated with the pathfinder network algorithm in Network Workbench© (NWB Team, 2006). The algorithm delivers a network of the citations (nodes) and their relatedness based on their correlations (links) (Dearholt and Schwaneveldt, 1990; Schwaneveldt et al. 1990; White, 2003). We used the spring-embedded algorithm of Kamada and Kawai (1989) in creating the graph. This algorithm iteratively seeks to position stronger connected nodes in the center of the graph and alters the position of each node accordingly. A computed graph can help interpret relations between topics, see Lee and Chen (2012) The citations displayed in Figure 4 are listed in Table 2.

Table 2. PCA results for Citations Loaded to 21 Groups, 13 Pairs and 12 Single

Component	Main Topic of Loaded Citations	Citations Loaded with 0.6	Loads as	Eigen Values	% of Variance Explained	Citations with a Factor Loading larger than 0.6 on this Component
1	Information and Data Quality	11	Group	17,043	8,608	1-1 (Wang and Strong, 1996, 18 cits.); 1-2 (Woodhouse, 2001, 16 cits.); 1-3 (English, 1999, 15 cits.); 1-4 (Wang, 1998, 15 cits.); 1-5 (IPWEA, 2002, 23 cits.); 1-6 (Levin and Redman, 1998, 12 cits.); 1-7 (Wand and Wang, 1996, 13 cits.); 1-8 (Kahn et al. 2002, 12 cits.); 1-9 (Eerens, 2003, 11 cits.); 1-10 (Shanks and Darke, 1998, 11 cits.); 1-11 (Strong, 1997, 11 cits.);
2	Statistical Deterioration Models	11	Group	10,524	5,315	2-1 (Madanat and Mihalani, 1995, 47 cits.); 2-2 (Madanat and Ibrahim, 1995, 21 cits.); 2-6 (Mishalani and Madanat, 2002, 21 cits.); 2-7 (Thompson, 1994, 18 cits.); 2-8 (DeStefano and Grivas, 1998, 16 cits.); 2-9 (Lounis, 2003, 16 cits.); 2-10 (Kleiner, 2001, 15 cits.); 2-11 (Mauch and Madanat, 2001, 13 cits.);
3	Life Cycle Approach for Bridges	11	Group	9,989	5,045	3-1 (Frangopol, 2001, 44 cits.); 3-2 (Thompson, 1998, 43 cits.); 3-3 (Hawk and Smill, 1998, 32 cits.); 3-4 (Miyamoto et al. 2000, 23 cits.); 3-5 (Lu and Frangopol, 2004, 19 cits.); 3-6 (Kong and Frangopol, 2003, 17 cits.); 3-7 (Estes and Frangopol, 1999, 13 cits.); 3-8 (Frangopol and Das, 1999, 12 cits.); 3-9 (Aguil and Frangopol, 2003, 11 cits.); 3-10 (Deb, 2001, 11 cits.); 3-11 (Lu et al. 1997, 11 cits.);
4	Network-level Management of Pavements	8	Group	9,073	4,582	4-1 (Ferreira et al. 2002, 20 cits.); 4-2 (Abaza et al. 2004, 18 cits.); 4-3 (Fwa, 2000, 17 cits.); 4-4 (Mbwana and Turnquist, 1996, 17 cits.); 4-5 (Wang et al. 2003, 16 cits.); 4-6 (Madanat et al. 2006, 15 cits.); 4-7 (Abaza et al. 2001, 11 cits.); 4-8 (Kerati, 2000, 17 cits.);
5	Deterioration and Decision Modeling for Sewer Pipes	7	Group	6,364	3,214	5-1 (Ariaratnam et al. 2001, 19 cits.); 5-2 (Baik et al. 2006, 20 cits.); 5-3 (Micevski et al. 2002, 18 cits.); 5-4 (Wirahadikusumah et al. 2001, 18 cits.); 5-5 (WRC, 2000, 17 cits.); 5-6 (Davies et al. 2001, 16 cits.); 5-7 (Baur and Herz, 2002, 11 cits.);
6	Maintenance Decisions for Replacement and Rehabilitation	6	Group	5,812	2,935	6-1 (Lu and Madanat, 2002, 18 cits.); 6-2 (Chan et al. 1994, 13 cits.); 6-3 (Friesz and Fernandez, 1979, 13 cits.); 6-4 (Ouyang and Madanat, 2004, 12 cits.); 6-5 (Tsunokawa and Schofer, 1994, 12 cits.); 6-6 (Ouyang and Madanat, 2006, 11 cits.);
7	Life Cycle and Preventive Maintenance for Pavements	6	Group	5,681	2,869	7-1 (Walls, 1998, 28 cits.); 7-2 (NCHRP, 2006, 15 cits.); 7-3 (Peshkin et al. 2004, 13 cits.); 7-4 (Peterson, 1985, 12 cits.); 7-5 (Smith et al. 1993, 12 cits.); 7-6 (Sinha and Labi, 2007, 11 cits.);
8	Resource Based View	7	Group	4,719	2,383	8-1 (Barney, 1991, 25 cits.); 8-2 (Pranadad and Hamel, 1990, 15 cits.); 8-3 (Reece et al. 1997, 15 cits.); 8-4 (Porter, 1985, 13 cits.); 8-5 (Wernerfelt, 1984, 13 cits.); 8-6 (Arnt and Schoemaker, 1993, 11 cits.); 8-7 (Dierckx and Cool, 1989, 11 cits.);
9	Maintenance Decisions for Repair and Inspection	4	Group	3,72	1,879	9-1 (Carnahan et al. 1987, 27 cits.); 9-2 (Madanat and Ben-Akiva, 1994, 23 cits.); 9-3 (Smilowitz and Madanat, 2000, 22 cits.); 9-4 (Madanat, 1993, 18 cits.);
10	Modeling Water-Main Breaks	5	Group	3,342	1,688	10-1 (Kleiner and Rajani, 2001, 26 cits.); 10-2 (Rajani and Kleiner, 2001, 18 cits.); 10-3 (Shamir and Howard, 1979, 19 cits.); 10-4 (Rajani and Makar, 2000, 12 cits.); 10-5 (Kleiner and Balvant, 1999, 11 cits.);
11	Optimized Management of Pavements	3	Group	3,183	1,608	11-1 (Grivas et al. 1993, 16 cits.); 11-2 (Shahin et al. 1987, 14 cits.); 11-3 (Abaza and Ashur, 1999, 12 cits.);
12	MR&R Decisions with Genetic Algorithms	4	Group	2,82	1,424	12-1 (Goldberg, 1989, 60 cits.); 12-2 (Holland, 1975, 32 cits.); 12-3 (Lu et al. 1997, 21 cits.); 12-4 (Hegazy et al. 2004, 12 cits.);
13	Traffic and Maintenance Effects	4	Group	2,64	1,333	13-1 (Paterson, 1986, 31 cits.); 13-2 (AASHTO, 1962, 26 cits.); 13-3 (Prozzi and Madanat, 2000, 12 cits.);
14	Guidelines to Asset Management for Roads	3	Group	2,311	1,167	14-1 (FHWA 1999, 59 cits.); 14-2 (GASB, 1999, 25 cits.); 14-3 (FHWA, 1996, 17 cits.);
15	Reliability Evaluation for Utilities	2	Pair	2,303	1,163	15-1 (Berling, 2005, 16 cits.); 15-2 (Kostic, 2003, 15 cits.);
16	Official Guidelines for Asset Management	3	Group	2,142	1,082	16-1 (IPWEA, 2006, 55 cits.); 16-2 (EPA, 2002, 21 cits.); 16-3 (AWWA, 2001, 15 cits.);
17	Bridge Management Systems	3	Group	2,026	1,023	17-1 (AASHTO, 1993b, 23 cits.); 17-2 (Hudson et al. 1987, 12 cits.); 17-3 (Golabi, 1993, 11 cits.);
18	Multicriteria Decision Making	3	Group	1,943	0,981	18-1 (Saaty, 1980, 44 cits.); 18-2 (Keeney and Raiffa, 1993, 12 cits.); 18-3 (Saaty, 1977, 11 cits.);
19	Performance Measurement	3	Group	1,896	0,957	19-1 (Sveiby, 1997, 17 cits.); 19-2 (Kaplan and Norton, 1992, 16 cits.); 19-3 (Edvinsson and Malone, 1997, 12 cits.);
20	Condition Prediction for Concrete Bridges	3	Group	1,84	0,929	20-1 (Aktan and Farhey, 1996, 15 cits.); 20-2 (AASHTO, 1994, 12 cits.); 20-3 (Enright and Frangopol, 1999, 12 cits.);

21	In-field failure measurements for Utilities	2	Pair	1.8	0.909	21	21-1 (Billinton and Allan, 1996, 18 cits.); 21-2 (Brown and McKim, 2002, 16 cits.);
22	Pavement Design	2	Pair	1,764	0.891	22	22-1 (Huang, 1993, 27 cits.); 22-2 (Yoder and Witzak, 1975, 15 cits.);
23	None	1	Single	1,693	0.855	23	23-1 (AASHTO, 1986, 20 cits.);
24	None	1	Single	1,624	0.82	24	24-1 (FHWA, 1995, 45 cits.);
25	Reliability & Maintenance Standards	2	Pair	1,547	0.781	25	25-1 (Jardine and Banjevic, 2006, 16 cits.); 25-2 (Lee, 2006, 11 cits.);
26	Probability Concepts	2	Pair	1,524	0.77	26	26-1 (Czepliel, 1995, 12 cits.); 26-2 (Cesare et al, 1992, 12 cits.);
27	Knowledge in Organizations	2	Pair	1,497	0.756	27	27-1 (Nonaka and Takeuchi, 1995, 18 cits.); 27-2 (Davenport and Prusak, 1997, 16 cits.);
28	None	1	Single	1,477	0.746	28	28-1 (Wang, 2000, 11 cits.);
29	Portfolio Selection	2	Pair	1,451	0.733	29	29-1 (Markowitz, 1952, 42 cits.); 29-2 (Markowitz, 1959, 13 cits.);
30	Investment and Pricing Uncertainty	3	Group	1,381	0.697	30	30-1 (Sharpe, 1964, 24 cits.); 30-2 (Black and Scholes, 1973, 18 cits.); 30-3 (Kahneman and Amos, 1979, 15 cits.);
31	Structure Inventory Appraisal	2	Pair	1,351	0.682	31	31-1 (Shepard and Johnson, 2001, 12 cits.); 31-2 (AASHTO, 1997, 11 cits.);
32	None	1	Single	1,322	0.668	32	32-1 (AASHTO, 2002, 11 cits.);
33	Highway Management Systems	2	Pair	1,312	0.663	33	33-1 (Watanatada et al, 1987, 23 cits.); 33-2 (Robinson, 1998, 12 cits.);
34	Road & Surface Roughness	2	Pair	1,296	0.654	34	34-1 (Sayer et al, 1986a, 16 cits.); 34-2 (Sayers et al, 1986b, 13 cits.);
35	None	1	Single	1,257	0.635	35	35-1 (FHWA, 2003, 17 cits.);
36	Official Guidelines for PAM	2	Pair	1,251	0.632	36	36-1 (Brown and Humphrey, 2005, 25 cits.); 36-2 (Cavallini et al, 2003, 11 cits.);
37	None	0	None	1,244	0.628	37	
38	Sustainability and Infrastructure Scores	2	Pair	1,199	0.606	38	38-1 (ASCE, 2009, 31 cits.); 38-2 (AASHTO, 2001, 13 cits.);
39	Maintenance Optimization	1	Single	1,173	0.592	39	39-1 (Dekker, 1996, 13 cits.);
40	None	1	Single	1,157	0.584	40	40-1 (SHRP, 1993, 14 cits.);
41	None	0	None	1,147	0.579	41	
42	None	1	Single	1,122	0.567	42	42-1 (Eisenhardt, 1989, 15 cits.);
43	None	1	Single	1,1	0.556	43	43-1 (Deb, 2002, 11 cits.);
44	None	1	Single	1.08	0.545	44	44-1 (McKay et al, 1999, 13 cits.);
45	None	1	Single	1,072	0.541	45	45-1 (Kolodner, 1993, 11 cits.);
46	Intelligent Agent Systems	2	Pair	1.05	0.53	46	46-1 (Woodridge, 2002, 11 cits.); 46-2 (Woodridge et al, 1995, 11 cits.);
47	None	1	Single	1,034	0.522	47	47-1 (Brundtland, 1987, 22 cits.);
48	None	1	Single	1,024	0.517	48	48-1 (Jensen and Meckling, 1976, 12 cits.);
49	None	1	Single	1,015	0.513	49	49-1 (Campbell, 1995, 14 cits.);
Highest Factor Loading below 0.6	None	50	Single			50	0-1 (Haas et al, 1994, 104 cits.); 0-2 (AASHTO, 1993a, 80 cits.); 0-3 (Golabi et al, 1982, 59 cits.); 0-4 (BSI, 2004, 43 cits.); 0-5 (Shahin, 1994, 49 cits.); 0-6 (BSI, 2008a, 41 cits.); 0-7 (Butt et al, 1987, 38 cits.); 0-8 (Haas et al, 1997, 39 cits.); 0-9 (Moubray, 1997, 25 cits.); 0-10 (AASHTO, 2001, 21 cits.); 0-11 (Kaplan, 1996, 21 cits.); 0-12 (Vanier, 2001, 21 cits.); 0-13 (Yin, 2003, 21 cits.); 0-14 (Scherer and Giagola, 1994, 21 cits.); 0-15 (Zadeh, 1965, 20 cits.); 0-16 (NCHRP, 2004, 24 cits.); 0-17 (Frangopol et al, 1997, 17 cits.); 0-18 (Morcous, 2002, 17 cits.); 0-19 (Ang and Tang, 1984, 16 cits.); 0-20 (Berling, 2002, 15 cits.); 0-21 (Fwa et al, 1996, 15 cits.); 0-22 (Pilson et al, 2000, 16 cits.); 0-23 (Endrenyi, 1998, 14 cits.); 0-24 (FHWA, 1988, 14 cits.); 0-25 (Jacobs, 1992, 14 cits.); 0-26 (Liu et al, 2005, 13 cits.); 0-27 (Thoft-Christensen, 1995, 14 cits.); 0-28 (AASHTO, 1990, 13 cits.); 0-29 (Dresner and Stone, 2008, 14 cits.); 0-30 (Endrenyi, 2001, 13 cits.); 0-31 (Feighan et al, 1987, 13 cits.); 0-32 (ASCE, 2005, 13 cits.); 0-33 (Ben-Akiva and Gopinath, 1995, 12 cits.); 0-34 (Charnes et al, 1976, 12 cits.); 0-35 (Cigre, 2000, 14 cits.); 0-36 (McGhee, 2003, 17 cits.); 0-37 (Neves and Frangopol, 2005, 12 cits.); 0-38 (Porter, 1980, 12 cits.); 0-39 (Chavler and Ellison, 1997, 11 cits.); 0-40 (Haas and Hudson, 1978, 12 cits.); 0-41 (Jelinek, 1981, 11 cits.); 0-42 (Keeney and Raliffa, 1976, 11 cits.); 0-43 (Li and Haas, 1996, 14 cits.); 0-44 (Lytton, 1987, 11 cits.); 0-45 (Miyamoto et al, 2001, 11 cits.); 0-46 (Patidar et al, 2007, 11 cits.); 0-47 (Poff et al, 1997, 11 cits.); 0-48 (Saegrov, 2005, 11 cits.); 0-49 (Wang et al, 1994, 11 cits.); 0-50 (TAC, 1997, 12 cits.);

Figure 4. PFNET scaling of the 198 citations from begin-January1996 to end-June 2013

2.5.2 Relatedness and Emergence of Topics among Citations

Our results confirm that there are many knowledge groups that focus on different research topics. Moreover, we could observe in Figure 4 that each of these topics can be structured by their extent of relation between other topics about managing infrastructure assets. In that respect, our study provides greater insight into the observation, made by some researchers (e.g. Moon et al., 2009; Hegazy et al., 2011), that IAM-oriented studies have mushroomed to cover a wide range of topics. In addition to this, the changes in levels of cite frequency between 1996 and 2013 enable us to indicate relatedness and emergence of topics concerning the ‘management’ of infrastructure assets. Here, we note that weaker connected and emerging topics form parts of different paths in specialization. Our empirical study, particularly the PCA in combination with PFNET, has highlighted a set of clearly distinguishable paths along which the articles focusing on managing infrastructure have developed. Based on these insights, our study suggests that IAM-oriented research appears to cover a wide range of topics but that the citation patterns point to some shared research orientations.

In Figure 4, citations are presented by nodes, and their frequency is presented by their size. We circled the knowledge groups, found through the PCA, and show their inherent structure by reducing the links to the most essential relationships between knowledge groups (found by using PFNET scaling). The PFNET illustrates the constellation of subfields. It is apparent that group 1 – Statistical Deterioration Models – appears as a strong anchor at the center, with other thematic knowledge groups strongly connected to it. As such, the graph indicates that group 2 has a strong presence in

articles that focus on managing infrastructure assets. This topic is devoted to modeling the deterioration of large assets, especially bridges and focuses on improving predictive accuracy through the use of statistical and econometrical techniques (see Table 3). A technique frequently debated within these citations is the use of the Markov decision process technique.

We can also observe how the strongest connection between citations form 3 paths beginning from 2 – Statistical Deterioration Models. Each of these paths connects related topics and established contributions. The path that connects the most citations in departure of 2- Statistical Deterioration Models, is connected between citation code 2-4 (Golabi and Shepard, 1997) and 9-3 (Smilowitz and Madanat, 2000). The connected knowledge groups appear thematically related with main interests in Life-Cycle Decision Making and Organization. Life Cycle Decision Making include the long-term management of bridges and pavement and introduce the development of trade-offs between long-term quantifiable parameters. Some knowledge groups constitute various well-cited approaches to the quantification and development of clear trade-offs. A clear trade-off can be found between repair and inspection policies when deterioration rates are uncertain for infrastructure (see 9-4: Madanat, 1993;). Another clear trade-off can be found between the replacement and rehabilitation of pavements and bridges when the appropriate intervention timing is uncertain (see 6-4: Ouyang and Madanat, 2004; 6-6: Ouyang and Madanat, 2006). Various knowledge groups, pairs or single studies that are closely related to these trade-offs seem to address different techniques or methods to model the uncertain aspects and help decide. For example, the uncertain deterioration rate be modeled by: Genetic Algorithms (see 12-1: Goldberg, 1989), management systems (see 17-1: AASHTO, 1993b); 17-2: Hudson et al. 1987). The appropriate intervention time can be computed by portfolio selection techniques (27-1: Markowitz 1952), multi-criteria decision-making (see 19-1: Saaty, 1980; 19-2: Keeney and Raiffa, 1993), and investment pricing (see 31-1: Black and Scholes, 1973). A final element we can observe to develop clear trade-offs are the development of parameters of important criteria for maintenance. The international roughness index is an important parameter for expressing the life-cycle trends of pavement (see 33-1: Sayers et al. 1986; and 33-2: Sayers, 1986). In the case of bridges, structural reliability analysis is a way to express life-cycle trends (see 17-3: Golabi et al. 1993).

Knowledge groups further into the Life Cycle Decision Making and Organization include the more strategic and holistic topics of managing infrastructure assets on the question how to make decisions operational. For example, some citations in this path capitalize on a balanced measurement and reflect how well organizations perform both financially and operationally (see 20-2: Kaplan and Norton, 1992; 20-3: Edvinsson and Malone, 1997). In extension, 8 - Resource Based View contributes to the strategic suggestion that an organization can perform more effective when core competent individuals perform operations (see 8-2: Prahalad and Hamel, 1990). Other citations in this area include the use of tacit knowledge, or accumulated experience of the individual (see 27-1: Nonaka and Takeuchi, 1995; 27-2: Davenport and Prusak, 1998), and evaluating research.

A second path departs from coded citation 2-3 (Jiang et al. 1987) to 0-7 (Butt et al., 1987). This path appears to orient around citations specifically devoted to Pavement Management. Among the citations on this path, a knowledge groups involves the 11 – Optimized Management of Pavements by means of a Markovian prediction model (see 11-3: Abaza and Ashur, 1999) or other econometrical techniques (see 11-2: Shahin et al. 1987). Contributions are particularly made in terms of the accuracy of measuring pavement deteriorations transitioning state and curve. Also the 4 - Network-

level management of pavements is an frequently recurring topic in this path. Citations here focus on predicting and measuring pavement performance for use in Pavement Management Systems. They attempt to optimize pavement conditions within budgetary constraints and aim to simplify the optimization problem by analyzing the road network in sections, with each section having its own set of uniform homogeneous pavement characteristics (see 4-1: Ferreira et al. 2002; 4-4: Mbwana and Turnquist, 1996;). Other citations in this path attempt to standardize and classify pavement construction (see 23-1: Huang, 1993; 23-2: Yoder and Witzak, 1975), process failure data (see 22-1: AASHTO, 1986; 0-36: McGhee, 2003), and understand the causes and effects of failure (see 13-1: Paterson, 1987; 13-2: AASHTO, 1962).

Table 3. Description of Knowledge Groups in PFNET Result

Component Number - Knowledge Group Label	Shared Research Objectives
Highest Density Centre	
2 - Statistical Deterioration Models	– <i>Improve deterioration prediction of large assets</i>
17 - Bridge Management Systems	– <i>Plan maintenance with Bridge management system</i>
Life Cycle Decision Making and Organization Path	
3 - Life Cycle Approach for Bridges	– <i>Introduce a reliability approach to managing bridges</i>
6 - Maintenance Decision for Replacement and Rehabilitation	– <i>Optimize long-term replacement and rehabilitation schedule</i>
7 - Life Cycle and Preventive Maintenance for Pavements	– <i>Model road roughness for long term and plan preventive action</i>
8 - Resource Based View	– <i>Harness human competence in organizations</i>
9 - Maintenance Decision for Repair and Inspection	– <i>Optimize repair and inspection policies</i>
12 - MR&R Decisions with Genetic Algorithms	– <i>Compare trade-off between maintenance or rehabilitation</i>
18 - Condition Prediction for Concrete Bridges	– <i>Improve deterioration prediction of concrete bridges</i>
18 – Multicriteria Decision Making	– <i>Simplify complex decision making issues</i>
19 - Performance Measurement	– <i>Balancing performance measurement criteria</i>
Pavement Management Path	
4 - Network-level Management for Pavements	– <i>Optimize interventions across homogeneous road sections</i>
11 – Optimized Management of Pavement	– <i>Predict pavement deterioration with Markov Process</i>
13 – Traffic and Maintenance Effects	– <i>Understand interaction between failure and environment</i>
14 – Guidelines to Asset Management for Roads	– <i>Inform on American Guidelines for Asset Management on Roads</i>
Water and Utility Infrastructure Path	
1 – Information and Data Quality	– <i>Determine quality of business information to achieve goals</i>
5- Deterioration and Decision Modeling of Sewer Pipes	– <i>Improve deterioration prediction of sewer systems</i>
10 - Modeling Water-Main Breaks	– <i>Optimize replacement time to prevent water main breaks</i>
16 – International Guidelines for Asset Management	– <i>Justify budgets to maintain deteriorating assets</i>

A final path departs from 2-1 (Madanat and Mishalani, 1995) to 5-4 (Wirahadikusumah et al. 2001). This path covers the development of asset management in the Water and Utility Infrastructure environment. Most of the topics from citations in this path have adapted statistical deterioration

models to the context of water and utility infrastructure, mainly regarding sewer pipes (see 5-3: Micevski et al. 2002; 5-4 Wirahadikusumah et al. 2001) and water main breaks (see 10-2: Rajani and Kleiner, 2001). Specific adaptations include answering the need for long-term and one-off investment decisions with a focus on the more functional criteria: safety, reliability, and sustainability (see 5-1: Ariaratnam et al. 2001; 10-1: Kleiner and Rajani, 1999; 49-1: Brundtland, 1987) and the overall 1 – Information and Data Quality to necessary to achieve them (see 1-3: English, 1999; 1-8: Kahn et al. 2002; 1-10: Shanks and Darke, 1998). Also international asset management standards have been cited a lot in combination with water and utility infrastructure, for example the International Infrastructure Management Manual, 16-1: IPWEA (2002; 2006) or the PAS-55, 0-6: (see BSI, 2008a).

Figure 5. Emerging Research Orientation of Articles about the ‘management’ of infrastructure assets

From our results, we note that the various paths have each emerged at a different pace. Figure 5 shows that each path saw growths and fallings off in articles that cited between 1996 and 2012. The Life Cycle Decision Making and Organization Path surged tremendously from the start-year of our study until 2012. The increase in this path is mainly due to the growth in citations to five knowledge groups: 3, 7, 8, 9 and 12. 3 – Life Cycle Approach for Bridges covers an explicit shift that was made towards a reliability-based approach to bridges intended to balance life cycle costs and lifetime reliability with quantifiable risks, costs and benefits. The second knowledge group is called 7 - Life Cycle and Preventive Maintenance for Pavements which is about modeling pavement life cycle by means of roughness index. The other three knowledge groups that contributed to the surge are 9 – Maintenance Decisions for Repair and Inspection, 8 – Resource Based View and 12 – MR&R Decisions with Genetic Algorithms. Overall, our finding is that Life Cycle Decision Making and Organization citations have increased to become more able and informed to formulate and weigh well-defined trade-offs.

Other paths have also emerged steadily. For example the Water and Utility Infrastructure Path has driven by 1 - Information and Data Quality, 5 - Deterioration Modelling of Sewer Pipes and 10 - Modeling Water-Main Breaks. The latter group reflects the exceptional impact that a break in a water main can have on a community, and the group focus on predicting water-main breaks to

determine optimal replacement times. We concluded that the Water and Utility Infrastructure path has grown because of the relevant agencies' need to justify their budgets with good information quality for investing and maintaining water and utility infrastructure. The final path on Pavement Management has also received emerging attention and had a peak in 2009.

The intellectual structure shows that the 8,200 articles, we found to explicitly address the 'management' of infrastructure assets, are still predominantly focused on object-specific research into pavements, bridges, water and utility infrastructure. However, other, more strategic, human and organizational aspects of asset management are increasingly being recognized and associated as a relevant research as having the potential to address the more practical issues that infrastructure agencies face in their operating environment.

2.5.3 Research Orientations Among Retrieved Articles

To produce a clear research agenda, a focus on the research problems is an important issue. Our findings regarding the central knowledge group and paths reveal that some articles recognize the recurrence of certain topics among citations. However, for such a path to receive a disciplinary orientation, articles require a central problem with aspects, that are considered to be relevant to that problem, and with explanations, theories, and goals that are related to the problem (Darden and Maull, 1977; Porter et al., 2006; Wagner et al., 2011). As such, whether we can call literature about managing infrastructure assets established a disciplinary domain will depend on the attention that researchers pay to the linkage of different topics and link of these topics to the problem. In this respect, some authors have criticized IAM-oriented articles for lacking such a focus (e.g. Stapelberg, 2006; Lin et al., 2008). Our analysis adds insight into the topics that are linked (through co-citation) and for which research problems they are linked. These links are to be found within paths, identified by looking at knowledge groups that have been co-cited many times (see illustration in Figure 3). As such, articles that have recently linked (i.e. co-cited) knowledge groups within each path can inform us on how the research orientation is created and why these linkages are on the research agenda. We found that articles citing 1 – Statistical Deterioration Models and each of the paths in Figure 4 share research orientations. We discuss some of these research orientations here. In the discussion we particularly address examples we find in the specific paths to disclose some reasons why articles have shared these orientations.

One research problem surfacing with frequent examples in the data set is the inaccuracy of deterioration models in other words the uncertainties that undermine the reliability of predicting performance. One uncertainty that is slowly gaining attention with articles citing the core of Figure 4 (1 – Statistical Deterioration Models) is the relation between deterioration and maintenance expenditure, geographical locations and climate (Anastasopoulos et al., 2012; Lee et al., 2012; Lee et al., 2013). Beside contextual uncertainties, Articles in the Pavement Management path many technical difficulties remain unresolved in the models themselves such as 'autocorrelation bias' (Li et al., 2010) or interpretive bias (Hong and Prozzi, 2010; Farran and Zayed, 2012) and demonstrate the importance of reliable models (Tsai et al., 2012). Similarly, articles that cite from the Water and Utility Infrastructure path argue that using standard asset lifetimes to predict performance is biased (Burn et al., 2010) due to often differing ages (Ugarelli and Di Federico, 2010). Finally, also some retrieved articles, citing from Life Cycle Decision Making and Organization, raise the little progress has been made in estimating the remaining service life of bridges (Dissanayake and Karunanda, 2008;

Frangopol and Liu, 2006) and perhaps can be addressed by fuzzy logic and analytical hierarchy process techniques (Sasmal and Ramanjaneyulu, 2008).

Another example research problem that receives attention across several paths could be themed determinism in decision-making. Many asset management decision-models assume that the final solution of an optimization process will be the best option, and subsequently will form the implemented decision outcome. However, the articles, citing in the Life-Cycle Decision Making and Organization path recognize that, in practice, decision models merely have a support function for the decision-maker and require a tailoring of preferences like a genetic algorithm (Bian et al., 2008; Golroo and Tighe, 2012; Yeo et al., 2013) , an evolutionary groups process (Bian et al., 2009) or applying simulation data (Irfan et al., 2012). Some other financial articles, addressing the determinism in decision-making, focus on the decision-makers' behaviors side and suggest that more accurate forecasts will lead them to more often base their choices on the forecasted values (Takahashi, 2010a).

Also the justification of budget plans as related to infrastructure conditions has been a recurring example. Articles citing from the Water and Utility Infrastructure path emphasize that agencies have an urgent need to justify higher budgets (Wood and Lence, 2006) given the poor water infrastructure conditions and potential severe effect on the community (Ana Bouwens, 2010) in a period of shrinking public finances and problems to collect data for proper justification (Unsworth, et al. 2011; Molina et al. 2013) Similarly, articles, citing the Life Cycle Decision Making and Organization path propose to justify budgets when dealing with investment needs with an accounting system (Kobayashi et al., 2008), a model to estimate the intervention threshold for a given budget and plan (Khurshid et al. 2010; Younis and Knight, 2010) or the identification of immediate risks (Salman and Salem, 2012). One article, citing from the Pavement Management path, recognizes that both justifying and anticipating budgets become more imminent, because funding uncertainty can otherwise lead to suboptimal maintenance plans (see Gao et al. 2013).

A different example of a research problem that we see recurring in several paths is the fitness of decision-making in agencies. Articles, citing in the Pavement Management path, focus on ways of tailoring decision-making and support tools such that they are fit-for-use in agencies, like tailoring prediction models (Kim et al., 2010) and tailoring models to the preferences of an agency (Ferreira et al., 2011; Jorge and Ferreira, 2012). Some articles that cite citations in the Water and Utility Infrastructure path often indicate the issue that asset management tools appear unfit for the practices of water infrastructure agencies, with agencies feeling that tools are too sophisticated for practical use (Alegre, 2010; Frenette et al. 2010) or too expensive for their size (Osman et al., 2012). In reality, asset management decision-making still extensively relies on organizational knowledge held by an agency and anecdotal insights into past failures (Hampapur et al., 2011). Finally a set of articles, actively citing in the Life Cycle Decision Making and Organization path, notes that decision models in this area require simplification for practical use in agencies (Sathaye and Madanat, 2011; 2012; De la Garza et al., 2011; Yehia et al., 2012).

A final example we like to point out is the challenge of redefining the roles of public and private actors in asset management. Articles that have cited citations in the Life Cycle Decision Making and Organization path encourage the trend that construction companies transform their maintenance divisions into service providers (Ahonen et al., 2010) and yet observe that they merely create

temporary business units to win project contracts and avoid changing their overall business model (Leiringer et al., 2009). Some other articles mention that public agencies particularly struggle with using their internal organizational knowledge in asset management operations through their management capabilities (Too, 2012; Chua and Goh, 2008; Nyström and Söderholm, 2010) or implementation of information systems (Haider, 2013), and yet recognizes that knowledge management plays an important role in realizing objectives (Massa and Testa, 2009; Teece, 2011; Gibbons et al. 2012).

These examples of recent raised research issues indicate that the research on the 'management' of infrastructure assets is re-orienting to understanding and addressing the practical consequences and complex challenges of managing infrastructure assets for agencies and the environment. We have found articles in our set with solutions in various ways: tailoring existing knowledge, making more accurate mathematical models, addressing the non-technical issues of interpretive bias in the data analysis and developing the identification of the most prominent decision dilemma's for practitioners.

2.6 Summary and Conclusions

This study has analyzed empirical data, consisting of publication citations, in order to find the most frequent recurring citations and topics for articles that explicitly address the 'management' of infrastructure assets between 1996 and June 2013. Our analysis was guided by the question: to what particular knowledge do researchers orient themselves, when they intend to study and contribute to the 'management' of infrastructure assets? A first finding was the confirmation that knowledge groups remain somewhat object-oriented, however research in life cycle decision making and organization is shifting to more multiple object-orientations. For example, we see that knowledge groups in the life-cycle decision making and organization path are focused on the application of specific techniques and methods to assist in life-cycle costing. By another example decision-making is assisted by clearly identified time-based trade-offs regarding the repair versus inspection and rehabilitation versus replacement of infrastructure assets.

Secondly, our results show that articles from organizational focused knowledge groups of 8 – Resource Based View and 20 – Performance Measurement are sporadically cited with the other knowledge groups in the life-cycle decision making and organization, water and utility infrastructure and pavement management paths. This weak consultation might be explained by a remark, made by Moon et al. (2009), that the integrated management of assets and fragmented management of all asset groups separately remain unclearly differentiated. 8- Resources Based View and 20 – Performance Measurement accommodate knowledge on dealing with non-technical aspects that could help a clear differentiation where tasks are pertained to the management of "all assets" and where tasks are pertained to the management of "separate asset groups". This observation concludes that researchers do not, yet, orient themselves to use knowledge available about non-technical aspects with implementing various available models and instruments in practice.

Thirdly, we found similar examples in many paths where articles address similar research problems. For example, both the justification of budget plans and the fitness for decision-making in agencies, are addressed in all three paths. When a research problem is shared by multiple paths, then the articles confined to one path could meaningfully contribute insights to other paths. As a third

conclusion we see that researchers orient themselves in different paths of knowledge, but deal with similar types of problems.

Addressing these conclusions, we can say this paper has shown that authors, related to the “management” of infrastructure assets have gradually disciplined themselves towards some shared research problems. With regards to future research we argue that integrating knowledge from different paths can serve as a clear research agenda.

2.6.1 Limitations

There are limitations of this study. Some of the drawbacks are due to the research design; others are a direct consequence of the bibliometric methodology. We would agree with White and McCain (1998) that the intellectual structure approach cannot replace, but merely complement, extensive reading and fine-grained content analysis.

Inevitably, search queries in these kinds of analysis can always receive questions with regards to the coverage (Pilkington and Meredith, 2009; Lee and Chen, 2012). Therefore we have focused our central question of this research to articles, where authors explicitly associate their work to the “management” of infrastructure assets. This decision might result in a smaller scope of collected journal articles than some researchers would expect when thinking of infrastructure asset management. Yet, it is this ambiguous understanding and unclear conceptualization of the ‘management’ of infrastructure assets, which was the driving factor for conducting our study. We believe that we have approached the concept in a more objective way, rather than restricting our study to one definition or perspective.

Commonly, a bibliometric analysis uses citations as an indicator of influence and co-citations as an indicator of structure. It is based on the premise, that the more frequent a publication is cited the more times it has had a role and possible impact on other research. Provided that our empirical study addresses a domain with several arguable perspectives about the scope of data, we recognize the limitations of our data set and acknowledge that conclusions on citations and co-citations require a critical approach on their generalizability as matters of influence or structure of the Infrastructure asset management domain. Nonetheless, the exact measurements of citations and co-citations remain representative of the 8,200 of journal and conference articles and can describe frequent recurring topics, the relation between topics and possible orientations that can help integrate less related topics within that reproducible set. Therefore, we emphasize on the descriptions of the (co-)citations that we have measured rather than resorting to the common bibliometric labels of influence and structure.

2.6.2 Future Research and Recommendations

We have found the intellectual structure approach a useful tool for understanding the underlying complexity of large research domains such as the ‘management’ of infrastructure assets. Therefore, we would encourage future studies to try this approach in related fields. Uncovering the intellectual structure of specialized domains can provide deeper insight into the competences of advanced techniques and their suitability for specific infrastructure assets. A similar study to this one in ten years time could help in understanding the evolution and changes in the use of infrastructure asset management between the last decade and the next. With regards to research in the management of infrastructure assets we recommend attention to the gap between the development of asset management tools and the organizational aspects of ‘management’. Based on our empirical study,

we see a potential for research that integrates the pavement management, water and utility infrastructure and life-cycle decision making and organization paths. Despite we have not found an inclusive list of recommendations, at least we see some merit in five examples where we believe this could be achieved.

As a first example, inaccuracies in deterioration models can have serious consequences for a decision-maker's behavior. Takahashi (2010a; 2010b), citing in the life-cycle decision making and organization path, has shown that investors tend to focus on one value, if the forecasting accuracy of that value improves, and discard other criteria with less accurate measures. In such circumstances, accurate values become goals in themselves for an investor. We observed a similar response by researchers who define preventive maintenance strategies solely based on roughness index measures in the pavement management path. Future research could study if this 'focus and disregard' theory holds for infrastructure asset management decisions.

A second example covers the determinism in decision-making. Research in the life cycle decision making and organization path has shown that many decision models assume that the final solution in an optimization process will be the best option, although critical, and yet, hardly quantifiable measures are not accounted. Research by Kaplan and Norton (1992) (a citation from the life cycle decision making and organization path) showed that realizing organizational objectives is not only measured in terms of financial performance, but also by non-financial and less-quantifiable measures. For such a balanced performance measurement, objective and subjective measures can usefully be captured in decision tools. Recently, this has been realized by some authors, including Sasmal and Ramanjaneyulu (2008), allowing a more balanced collection of information. However, there remains a need for research on how to capture subjective judgments to support decision-making.

A third example involves justification of budget plans. We can see in the pavement management and water and utility infrastructure paths that governments have started to demand more convincing arguments before dispatching infrastructure funds. The justification thus becomes a major issue for management practitioners in infrastructure asset decision-making. Future research could consult citations from the organizational and performance aspects path to link tacit knowledge about the need for funds to organizational objectives and performance targets, for example Nonaka and Takeuchi (1995) and Davenport and Prusak (1998). In addition, future research could improve fund evaluations schemes by government to consult citations from 2- Statistical Deterioration Models.

A fourth example concerns the fitness of decision-making in agencies. Articles which have actively cited in the water and utility infrastructure, pavement management and life-cycle decision making paths have shown that decision-making instruments are not a one-size-fits-all. Future research could borrow studies from 1 – Information and Data Quality and 20 – Performance Measurement to help define information and rules to tailor instruments to individual agencies.

Our final suggestion for a potential research example involves redefining the public and private role in asset management. This research orientation is mainly covered by the life cycle decision making and organizational path. On this issue we discussed that individual managers use their own preferences to realize objectives. Future research would have great potential to borrow the insights from the life-cycle decision making path to gain a clear understanding of trade-off dilemma's in asset management learn whether private or public actors are best suited to decide on them.

3 WHEN ASSET MANAGEMENT AND ORGANIZATIONS MEET: ACCOUNTING FOR EMPLOYEE EXPERIENCES⁹

Abstract

For some time, organizations have encountered challenges when implementing asset management, particularly when closing the gap between how the asset management is understood by employees and how they support it in practice. Maturity models, common applied evaluations for implementing asset management, have so far only addressed the extent to which implemented asset management matches prescriptive standards. In this paper, we argue that, beside the value of maturity evaluations, shortcomings of maturity models remain in accounting for employee experiences with specific operational characteristics that challenge implementation. We then offer a criteria-free, employee-based approach to complement maturity models known as Rumelt's tests. By applying this approach to the case of a Dutch transportation agency, we show how employees understand the organization's strategy behind asset management and how they coordinate asset management activities in practice.

Keywords: Organization, Asset management, Rumelt's tests, Maturity model

3.1 Introduction

Over the last decades asset management (AM) has emerged as an approach of "systematic and coordinated activities and practices through which an organization optimally and sustainably manages its assets and asset systems, their associated performance, risks and expenditures over their life cycles for the purpose of achieving its organizational strategic plan" (BSI, 2008a). One of the main characteristics of AM is seen in the interconnection of "the organization's asset management policy, asset management strategy, asset management objectives, asset management plan(s) and the activities, processes and organizational structures necessary for their development, implementation and continual improvement" (BSI, 2008a). Although many organizations have started implementing formal AM systems and followed the prerequisites laid down in standards or manuals, they frequently encounter problems during the implementation. For example, Pantelias et al. (2008) found that AM implementation in the United States has been a very lengthy endeavour with many hurdles, e.g. to integrate and coordinate different activities and practices. In their survey, 24 out of 40 State Departments of Transportation had already been eight years in the planning phase of implementing an AM system following the publication of the AM primer (see FHWA, 1999). Also, in the industrial asset sector, Parida (2012) found that it has been hard to put a proper AM strategy in place, even though many conceptual developments (e.g. reliability-centred maintenance) were already well-researched and available. Especially small and medium industrial enterprises (SMEs) (see Winter and Fabry, 2012), but also municipalities (see Halfawy, 2008), miss guidance on the effective implementation of AM because their ambitions do not correspond to the available prescribed implementation options. Such problems are not surprising. Before organizations have started to widely implement AM standards, guidelines and tools (e.g. APCC, 2001; FHWA, 1999;

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OECD, 2002; TAC, 1999; NAMS and IPWEA, 2006; BSI, 2008a; 2008b), they mainly relied on fragmented systems and strategies to manage distinct objects (Chen and Flintsch, 2004). The challenges in implementing AM many organizations face emerge from the comprehensiveness with which AM affects and interlinks different organizational layers and units. The implementation success strongly depends on how an organization's AM strategy is understood by the organization's employees and ultimately coordinated in practice (Ratnayake, 2013; Van der Velde et al. 2013; El-Akruti et al. 2013).

In order to evaluate the progress of AM implementation and to identify areas for improvement, organizations often use evaluation techniques such as benchmarking (see Ozbek et al., 2012; Zeb et al., 2012) and more specifically maturity models (see Macgillivray et al., 2007; Volker et al., 2011; Laue et al. 2012). Maturity models evaluate the progress in implementing predefined standards along a desired path of discrete stages describing an organizations capability to comply with these standards (see Baldasarre et al. 2009). A prerequisite for applying maturity models is having criteria that constitute the desired stages of implementation. Typically, maturity models for evaluating AM implementation use specific criteria representing the strategic perspective of an organization on AM. Although such a view can provide insights in how an organization develops such standards, it remains limited in its ability to identify whether employees understand the organization's strategy behind AM and how they coordinate AM activities in practice. A criteria-free perspective for evaluating the presence of discrepancies between an employees' understanding of the organizations' AM strategy and their activities of it would be advantageous to complement maturity models (see Henderson and Venkatraman, 1993).

The objective of this study is to propose an employee-focused, criteria-free evaluation approach that identifies discrepancies between the way in which employees understand the organization's AM strategy and coordinate their activities to achieve it. We argue that such an approach can fruitfully complement AM maturity models and we demonstrate that a set of four tests, as proposed by the strategic management scholar Rumelt (1979), are sufficient to establish the approach. Rumelt's tests provide four open questions for practitioners aimed at drawing out experiences (i.e. particular concerns or issues) and identifying recurring patterns in them (i.e. finding emphasis). This open-ended, and hence criteria-free, evaluation helps to identify and specify challenges in employees' contribution to the AM ambitions of an organization and the coordination of AM activities and decisions within an organization..

3.2 Challenges with implementing asset management

Several challenges during AM implementation have been reported in the literature which can be characterized as integration and coordination challenges.

3.2.1 Integration challenges

Integration of organizational systems is prescribed in many AM standards (e.g. BSI, 2008; 2008b; FHWA, 1999) and failing to integrate systems is recognized as an implementation challenge. Organizations may fail to integrate several systems (among others information, decision support or business process systems) when they implement separate systems at different times, each with its own characteristics (e.g. López Campos et al. 2013) or maintained by different areas within the organization (e.g. Sitzabee et al. 2009). Another challenge occurs if an integrated set of systems cannot be redesigned or updated quickly (López-Campos and Crespo Márquez, 2010). Today, AM

standards recommend dynamic updates or process redesigns of AM systems. However, it is only recently that organizations have been moving away from inflexible maintenance applications and towards adaptively designing and updating AM practices (López-Campos and Crespo-Márquez, 2010). A danger in implementing inflexible AM systems is that sunken costs remain when a hasty implementation results in suboptimal system designs, such as ones lacking appropriate lifecycle planning, being deployed (Sturtevant et al. 2012). Finally, some researchers have reported that implementation can be negatively affected if AM is not properly linked to the organizational strategic plan, a link which many AM standards view as essential. El-Akruti et al. (2013) argue that current AM systems focus on the lifecycle of engineered systems and that too little is done to link them to the organizational strategy. The link between the organizational strategic plan and an AM system is often made explicit through an asset performance assessment (Parida, 2012). A weak link is likely to result in a failure to integrate various stakeholders and changing requirements when assessing strategic asset performance and this remains a challenge in many industries (Parida, 2012).

3.2.2 Coordination challenges

Another view has been offered more recently, explaining that challenges may also arise by the way in which employees conceive AM and coordinate their activities to achieve the specific vision that the organization has defined for their AM strategy (Ratnayake, 2013; Van der Velde et al. 2013; El-Akruti et al. 2013). For example, a framework (i.e. vision of the organization) might not supply employees with the know-how to translate organization's AM strategy to their individual and operational activities. Such a discrepancy could arise from the complexity of the framework, and, as a consequence, implementation might fail when employees are not able to understand the framework (Al-Najjar, 2012) or when the framework may have an infeasible ambition (Winter and Fabry, 2012) or infeasible business horizon (see Bai et al. 2012) for the organization. Besides, the implementation of the AM strategy can also be negatively affected when employees evaluate and make decisions on more measurable risks and exclude these actions from evaluating and making decisions on less measurable risks. Catrinu and Nordgård (2011) show that experts at an electricity distribution companies, in their AM, address risks and allocate resources that are quantifiable in financial terms and exclude decisions from less quantifiable risks such as personnel safety or environmental damage. When employees are excluding decisions and evaluations with dissimilar risk visibility and measurability, then critical, less visible risks might not be coordinated altogether, see the example on geotechnical risks as addressed by Sanford Bernhardt et al. (2003). Finally, in uncertain and dynamic times, employees may attach several meanings to AM and lose focus on what an organization's AM strategy means for their work (Davies et al. 2011). When goals of implementation are still being developed, this creates a possibility for organizations or forums to influence the development of these standards (Davies et al. 2011). Conceptual misinterpretation and lack of overview can lead to coordination problems which undermine implementation efforts and AM strategies (Parida, 2012).

The described challenges raises the question: by which means can these challenges be properly identified and analysed? To answer this question we review maturity models frequently applied to evaluate AM implementation.

3.3 Maturity models

Scholars, who have studied integration challenges during AM implementation are quite clear on the merits of applying maturity models (e.g. Närman et al. 2012; Woodall et al. 2013). Maturity models support AM implementation for several reasons. Firstly, maturity models measure the extent to

which management practices comply with a certain standard, providing evidence of an organization having achieved compliance (Baldasarre et al. 2009; Dhaliwal et al. 2011) on multiple levels (Hefner, 2003). For this reason, maturity models incorporate a set of criteria that describe a desired practice (e.g. a standard or procedure) and measure the compliance of current practical processes along those criteria (De Haes and Van Grembergen; 2005; Becker, 2009). Volker et al. (2011) and Van der Lei et al. (2011) specifically used maturity models to empirically evaluate the compliance of public organizations in the Netherlands with the AM PAS-55 standard. Hence, AM maturity models can provide a normative description of good practices (Volker et al., 2011), and help to evaluate compliance with other standards that contribute to AM performance (Van der Lei et al., 2011).

Another merit of applying maturity models is that, when criteria are clearly defined they provide an agenda for change. For example, Närman et al. (2012) find maturity models helpful in identifying which industrial maintenance management tools are most often used in an organization and why that is. Woodall et al. (2013) mention that maturity models help to guide organizations in properly collecting and ensuring asset information quality.

Maturity models are also beneficial to tailor to the specific criteria that matter (Baldasarre et al. 2009; Peng et al. 2011) and further tailor the implementation's steps of growth that define progress for an organization. The flexibility in tailoring criteria has made maturity models widely applicable, including to project management and people management (Peppard and Ward, 1999; Batenburg et al. 2005). This wide potential application makes maturity models relevant when designing an evaluation for multiple standards (see Baldasarre et al. (2009), while also instilling a need to argue and defend the chosen coverage of criteria (Ravichendran and Lertwongsatien, 2005; Becker, 2009). The flexibility in tailoring growth steps means that maturity models are able to take sequential snapshots during the management of change (Becker, 2009). These snapshots make maturity models relevant when wanting to define a clear upward development path for organizations (e.g. Batenburg et al. 2005).

Despite these benefits of maturity models, criteria used are often sketchy and poorly justified by researchers (Becker, 2009). A good start would be to clearly provide an extensive account of the criteria development. However, even a well-motivated maturity model does not necessarily ensure a focus on direct employee elicitation. Criteria can be politically set (Grembergen and de Haes, 2005) or based on commercial interests (Becker, 2009), for example to benefit particular stakeholders or executives. It is also hard to know in advance how comprehensive (required for successful implementation) the criteria selection has been (Ravichandran and Lertwongsatien, 2005), and this eventually forces some subjective assessment on the criteria (Zhou and Cai, 2011) and on the maturity levels (Versendaal et al. 2013).

In addition, the ideal circumstances, that criteria are intended to represent may, make the maturity model a vulnerable approach to evaluate AM implementation. For example, separate criteria may be described as separate ideal circumstances. An evaluation then overlooks possible conflictive relationships between the optimum state of one criterion and the optimum of another (Mettler, 2011). Criteria are also not necessarily equally applicable to all industries' aspirations or nature of business (Grembergen and de Haes, 2005) and may trigger incomparable assessment from employees in different industries.

The assessment of criteria of a maturity model might be also influenced by the evaluator's opinion about the most mature description of the ideal situation. An employees' opinion may well be a critical aspect to account for, since employees may have different perceptions of what is ideal asset management (Nyström and Söderholm 2010). And as such, employees might have different opinions or different approaches to evaluate the maturity level of their AM, if asked. Ravichandran and Lertwongsatien (2005) estimate that it takes at least four years to develop a widely supported and accepted maturity model of what is an ideal description of criteria in the model. They found that when organizations tried to base their implementation on a maturity model they often failed to systematically develop and invest into the ideal descriptions. In essence, when the implementation of asset management has just begun it is hard to know whether an idealized criterion is going to stand the test of time (see Pantelias et al. 2008; Parida, 2012; Ratnayake, 2013; Winter and Fabry, 2012).

Despite their clear and well-accepted benefits, maturity models fall short when it specifically comes to the evaluation of systems and practices where employees from different organizational layers and units are involved, as is the case with AM. Ratnayake (2013), for example, argues that organizations reliant on industrial assets depend on the ability of human authority to realize the forthcoming demands of their stakeholders and to exploit assets to their maximum ability and achieve a balanced and sustainable asset performance. Van der Velde et al. (2012) explain that employees are invaluable because they can interpret data and convey an understanding of failure causes and severity of the failure to senior management positions in the organization. To address the aforementioned shortcomings of maturity models, we are seeking to develop an employee-focused, criteria-free evaluation approach.

3.4 A criterion-free approach for eliciting employee experiences

In order to objectively address criteria-free comments, we propose that a systematic way helps to understand AM conceptualisations by employees. When AM is not at all clear within an organization this may be due to different perceptions among employees, or various ambitions within the organization (Vamanu et al., 2010). Consequently, rather than collecting data on discrepancies between how employees understand AM and coordinate it in practice, we need to compare how the understandings and actions concerning asset management correspond between employees. In essence, we are seeking an approach that helps us to follow an employees' AM conceptualisation of a strategy and its coordination. For such studies, Rumelt (1979) offered an approach to test how thorough a conceptualization has been thought through. Rumelt (1979) noticed that any strategy can prove conceptually weak if the theory behind it cannot provide solutions to four possible reasons as to why the strategy might fail in practice. To assist, the author developed four possible tests to assess the possible discrepancies between the conceptualization of a strategy and the strategy-in-practice. In other words, Rumelt's tests help identifying a conceptually effective strategy by uncovering the parts that can make the strategy ineffective in practice. We believe this approach could enable employees to determine detailed areas of improvement.

The tests that Rumelt (1979) proposed are focused on thoroughly answering four strategic analytical questions and then evaluating how well thought out a strategy appears to be. First, the goal consistency test seeks to specify the primary goals and to avoid inherently conflicting objectives. Second, the frame test seeks to distinguish important from unimportant factors and to define the critical sub-problems that must be resolved. Thirdly, the competence test seeks ways to use

organizational skills, resources and competences to resolve critical issues. Finally, the workability test aims to provide a reasonable expectation that the desired results can be achieved if the strategy is appropriately applied. These tests suffice as a criteria-free approach, provided that these tests do not focus on the content of what is conceptualized, but on how thorough that conceptualization has been,

Lengnick-Hall and Wolff (1999) further elaborated on the application of these tests by formulating the questions more precisely. They demonstrated that this application of Rumelt's tests was able to identify similarities and contradictions between multiple theories in strategic management. Following from that, Rumelt's test can be used to evaluate the multiple conceptualizations that exist between employees, and locate their opinions on similar subjects. For that reason, we followed the questions proposed by Lengnick-Hall and Wolff (1999) and adjusted them slightly to draw out employee-focused experiences.

Table 1. Rumelt's four tests for evaluating strategies

No.	Test	Question
1	Goal Consistency test	What are the primary aims of your work?
2	Frame test	What are the most critical sub-problems and critical issues that have to be addressed within the domain of your work?
3	Competence test	What feasible solutions to solvable sub-problems can you suggest?
4	Workability test	How are your actions linked with results? Which issues influence the results? What are examples of success?

3.5 Case study

To apply our approach we focus on an organization where a vision for asset management has just been formulated and is in the beginning stage of being implemented, and where employees within the organization might not yet have a clear understanding of its asset management. Such an organization is still searching to explicate the criteria that they find important for the longer term (Ravichandran and Lertwongsatien, 2005).

A suitable case that matched this situation concerned the Dutch transportation agency in the Netherlands, who just formulated a vision to asset management in 2008 and was at the start of their implementation efforts in 2011. This agency manages the main part of the Dutch transportation infrastructure. We were granted the opportunity to interview key AM employees in the beginning of 2011 to uncover possible discrepancies between their understanding of AM and their coordination of activities.

We have to stress that these discrepancies mark a snapshot of the agency's implementation challenges pertained to 2011. This agency also supplied us with secondary data from a first maturity model evaluation (which also occurred in early 2011) to properly compare the identification of challenges that originate during AM implementation with both our employee-focused, criteria-free approach and maturity models.

3.5.1 Unit of analysis

The unit of analysis refers to the aggregation level of the data collected. To objectively analyse potential challenges we have to account for the role of each employee. In so doing, we regard the

working relationships between employees as our unit of analysis, because employees work together and through them assets are managed. We started with interviewing three process experts from the organization which helped us to select relevant employees. The experts were asked to point us towards job occupations which they thought would cover in the relevant functions for AM in the organization from top to bottom. Using such informants, we were able to study the developments in activities and events as they occur through the links between job occupations that cover the organizational structure. In sum, our unit of analysis involves the work relationships between a set individual job occupations, relevant to AM, from which we compare their conceptualizations about AM.

3.5.2 Sample selection

A necessary step in identifying the employees' role in organizational challenges was to select a sample of employees who corresponded to the identified job occupations. We required proficient employees who were able to think and analyse AM based on their experience in the organization. Further we needed to select employees who were directly connected when participating in AM-related activities and events. In operational terms, we would then be able to find possible discrepancies between the understanding and coordinating activities of employees because we were not limiting ourselves to specific predetermined criteria and were open to hearing experiences from employees on issues from their overall work environment. This helps in contrasting their views related to the same issues.

Figure 1. Selected AM-related employees and their work relationships

We identified fifteen employees from a regional office of the Dutch transportation agency and a member of senior management who was responsible for AM and finally crosschecked our intended sample with the three experts. The interviewees' functions are shown in Figure 1 and we carried out interviews over a period of two months in 2011. The data retrieved are also reflective of that period.

3.5.3 Data collection and analysis

It is important that we remain sensitive, during data collection, to any issue that employees regard as relevant. The interview data, therefore, describes a discrepancy between employees' understanding of AM and their coordination, providing us a good description of the problems during AM implementation. We adopted, as our main interview questions, the four tests of Rumelt (see Table 1). In this way we were able to collect issues arising in the form of discrepancies between the AM understanding of individual employees and their coordination of AM activities at the agency. When documenting interview data it is important to determine in which way the data capture discrepancies. To ensure this, we applied a range of techniques to draw out examples of discrepancies. First, during each interview, we noted the responses that we understood as primary answers and crosschecked them with the interviewee before moving on to the next question. To reduce the possibility of respondents not answering the Rumelt-test questions, we asked the questions in the 'what' or 'which' form shown in Table 1. We also asked them to provide examples and clarify how events and activities marked their experiences. We followed the suggestion of Zappavigna and Patrick (2010) by asking 'how' and 'who' questions to learn more about the context and preceding and succeeding events and activities. Zappavigna and Patrick (2010) explain that capturing tacit knowledge by actively asking for clarification about an interviewee's grammar-in-use enables the interviewer to access a more subconscious level. Furthermore, we recorded and transcribed the interviews to ensure nothing was missed.

We expect that the interviews with connected employees and managers reveal a rich account of situations where multiple employees were involved. Therefore, we operationalized individual remarks at the collective level by coding similar examples addressed by two or more employees when answering Rumelt's tests questions. When colleagues refer to the same situations, we can contrast them and identify the resultant challenges between their understandings and actions. This way we could reconstruct individual stories into a sequence of events that tells a story in detail with multiple actors who were constantly tested with unexpected developments or issues. The employees that we interviewed gave clear clues to these developments. The interviews were conducted within a short timeframe of two months, to ensure that employees' responses to the open-ended questions would reflect a fairly consistent work situation. A catalogue of these details could constitute an agenda for organizational challenges that could help remove barriers to achieving the organizational strategic plan.

We used the reconstructed stories of multiple employees to discuss differences with a maturity model evaluation, which was conducted at the agency. We collected secondary data from this evaluation which was conducted in the identical period and at the same regional department where we conducted our Rumelt's tests. We were cleared to use two interview reports from this maturity model evaluation . These were one-hour conversations performed by two interviewers and 2 interviewees each. During the conversations interviewees were asked to evaluate 7 criteria along a 5 categorical scale of maturity .

3.6 Results with Rumelt's tests

To illustrate the context from which the interviewed employees interact, we first describe the background of our case. Particularly we describe how each individual employee sees his or her goal in asset management and their work relationship with other interviewed colleagues in asset management. We then provide examples where their individual positions require them to interact

with other employees. We selected 3 examples that related to comments that were provided on several maturity model criteria at the agency from 2011 (for a summary see Table 2).

3.6.1 Background of employees' work relationships

As of the operating year, 2011, senior management of the agency initiates and prepares a business plan for achieving the agreed service levels with the higher authorities (i.e. the asset owner) for a four-year period. To ensure that the business plan is met, the agency's senior management team meets once a year with the Regional Managers to formulate a strategy for each region and agree on priorities, milestones and available resources.

Once these managers have agreed on the decisions that have to be taken to achieve the business plan, they sign a service level contract that applies for one operational year. After it has been signed, a Regional Manager is responsible for the overall costs of his or her region and delegates most primary responsibilities relating to infrastructure services to its water and road divisions. The Middle Manager manages the road division and acts as the internal client for project teams who tender the construction and maintenance work and formulate requests for proposals to contractors. The Middle Manager receives information to define maintenance and construction work from the heads of every infrastructure zone in the regional department. When the infrastructure zone heads inform the Middle Manager, they also advocate an intervention plan that their maintenance planning department has optimized for the district.

The infrastructure Zone Managers are likely to provide the Middle Manager with plans that are optimized for their own district. Consequently, a traffic advisor and the Asset Quality Advisor advise the Middle Manager on a broader network plan for maintenance and construction work across the districts, and they advise on the best moment to intervene on the regional roads. In particular, they inform the Middle Manager how particular plans will impact on the traffic and road quality.

A project planning department groups the activities to provide a compilation of the required maintenance work to the Middle Manager. This department is staffed by a senior project planner and several project planning advisors. To arrive at a sound plan, the project planning department tests whether projects can be realistically initiated based on the personnel capacity that they can allocate to project teams. Once the Middle Manager allows a project to proceed to the preparatory phase, a project team is manned with a intervention project leader, a specialist for project risks, a specialist for operations, a specialist for tender and an specialist for environment. Each of these team-members acts as a specialist with a main area of focus during the entire development of the project.

Table 2. Comparing examples with Rumelt's tests and Maturity model Details from 2011

Rumelt's tests example	Details identified by Rumelt's tests that describe the example	Noted by which employee(s)	Details identified by Maturity model Evaluation that relate to the same example	Noted at which criteria
Replacing a Traffic Light	<ul style="list-style-type: none"> –An accident occurred with failing traffic light –The accident caused commotion –Municipality proposed a roundabout as safer alternative for traffic light –Trade-off between roundabout or traffic light –Regional department advocated roundabout –Corporate planning department would not cover the roundabout –Roundabout required multiple funds 	<ul style="list-style-type: none"> –Zone Manager –Asset Quality Advisor –Zone Planning Advisor –Middle Manager 	<ul style="list-style-type: none"> – Coordination between regional and corporate department operates well – Regional department needs to report improvements as new facts to corporate planning department – Risks are systematically identified and qualitatively justified – Technical solutions are often provided – Alternatives are weighed – Regional department takes lead managing risk with municipalities – Budgetary problems prevent a high maturity 	<ul style="list-style-type: none"> – Internal coordination – Market approach – Risk management – External coordination
Addressing Frost Damage	<ul style="list-style-type: none"> – Winter causes much frost damage – Frost damage is deferred maintenance – Money was reserved for other conditions – Roughness had no worse impact than frost damage – Preventive measures for roughness could be postponed for frost damage – Scenarios are possible to weigh between frost damage and other failures – Frost damage may occur with very open asphalt concrete roads – It is politically motivated to correcting frost damage over preventing roughness 	<ul style="list-style-type: none"> – Zone Planning Advisor – Zone Manager – Senior Zone Planner – Asset Quality Advisor 	<ul style="list-style-type: none"> – Quantitative data is not complete in systems – Regional department gives attention to environment management – Performance indicators (failure frequency or downtime) not applied to assets – Risks are systematically identified and qualitatively justified – Technical solutions are often provided – Alternatives are weighed 	<ul style="list-style-type: none"> – Information management – Risk management – External coordination – Market approach
Maintaining a Road along the top of an Embankment	<ul style="list-style-type: none"> – Embankment controls the water flow – Embankment attracts tourism – Road runs along the top of the embankment – The road has severe maintenance requirements – Traffic Advisor finds maintenance not a road divisions' mandate – He requested action by a colleague at water division – Colleague found embankments' function to control the water flow was not affected – Traffic Advisor amplified that road deterioration meant loss of reputation – Road was not described as function of the embankment 	<ul style="list-style-type: none"> – Traffic Advisor – Specialist for Project Risks 	<ul style="list-style-type: none"> – Data is widely distributed in organization – Some questions exist for jurisdiction between divisions – Regional department gives attention to environment management – The embankment has a level 4 maturity – Job scope and definitions are not always clear 	<ul style="list-style-type: none"> – Information management – Internal coordination – External coordination – Risk management – Processes and roles

3.6.2 Rumelt's tests example 1: replacing a traffic light

The Zone Manager views the occurrence of a single accident as a critical issue because it can lead to the organization receiving a lot of political and public attention. On this issue, he remarked that "Last year there was an accident at a crossing with a defective traffic light. ... There was a lot of commotion and political attention to this accident" (Zone Manager, identifying critical issues).

As a consequence of this attention, the organization was triggered to bring forward a decision to replace the defective traffic light. While the traffic light was due to be replaced the next year, a municipality proposed that the agency co-invest in a roundabout as a safer alternative. The municipality would cover half the costs. The Zone Manager was eager to consider this initiative: "This is a nice decision, what is the better option - a roundabout or a traffic light? What would be the lifecycle costs of each option?" (Zone Manager, identifying a solution). The Zone Planning Advisor was inclined to analyse these options "A roundabout could be more expensive to construct but the reduced need for maintenance could pay back the investment" (Zone Planning Advisor, identifying critical issues).

The discussions between the municipality and the infrastructure zone led to the preparation of a few decision alternatives to weigh costs and benefits for replacing the traffic light. Firstly, the trade-off would require changing existing plans and cost more than the funds available: "We calculated the payback period, and the roundabout turned out more expensive" (Zone Planning Advisor, identifying a solution). For this reason, the corporate planning department was not willing to consider the options and "warned us that they would only cover our costs if we opted for the traffic light" (Zone Planning Advisor, identifying an action linked to results).

Despite the warning by the corporate planning department, the Zone Manager offered the alternatives to the Middle Manager and her advisors: "What would you like - a roundabout or a high quality traffic light?" (Zone Manager, identifying a solution). The Middle Manager was inclined to favour a roundabout, but she found it a challenging question since the corporate planning department had warned of the withdrawal of funds: "It meant that we had to find money through other subsidies, an internal programme and a municipality. It is quite complicated to fund projects in this way." (Middle Manager, identifying critical issues). Her Asset Quality Advisor was unenthusiastic towards the roundabout given its higher investment: "A roundabout would offer greater traffic safety but would require a higher investment. However, frankly, we have not received a budget to replace that traffic light with a roundabout." (Asset Quality Advisor, identifying critical issues). His response as a solution was frank: "I approached it purely from my perspective: and the answer was no" (Asset Quality Advisor, identifying a solution).

In the end, funding was sought from the corporate department for a roundabout: "We presented a financial plan complete with RAMSSHEEP criteria, and demonstrated the cost-effectiveness of the roundabout option. However, our own organization then proved unable to make that decision." (Zone Manager, identifying an action linked to results). Both the Zone Manager and the Zone Planning Advisor felt this hampered their ability to deliver increased traffic safety.

Despite the rejection by the corporate department, the Middle Manager decided to look for other sources to fund the roundabout: "we raised money from the traffic systems budget, another little fund for maintenance and a contribution from the municipality" (Middle Manager, identifying a solution).

The experience of seeking other subsidies, raised second thoughts about whether it was all worthwhile. When they had almost raised the required funds, “the citizens from the municipality started a court hearing and objected to the construction ... and due to that delay one of the subsidy programmes expired” (Middle Manager, identifying a solution). The Zone Planning Advisor showed signs of regretting this whole journey in trying to replace the traffic light: “the traffic light needs replacing soon, and we already have a fund to replace it with a traffic light. ... the risk of more problems is increasing ... formally we are not allowed to replace the traffic light with a roundabout.” (Zone Planning Advisor, identifying an action linked to results).

This example shows the persistence of both the infrastructure zone and the corporate planning department in proceeding to coordinate their actions in line with their own understandings. The corporate planning department did not recognize and act on the persistence shown by the infrastructure zone for a safer alternative. Conversely, the infrastructure zone did not see and act on the insistence of the corporate planning department to upgrade the traffic light. This example illustrates the consequences of these discrepancies. The endless pursuit of alternative subsidies confronted the Zone Manager and Middle Manager with a complexity of problems that they later would regret having attacked.

3.6.2.1 Discussing related maturity model details for example 1

At first glance, the details provided by the maturity model confirm remarks when replacing the traffic lights. For example, the maturity model evaluation describes that the agency takes the lead in managing risks that are affected by them and municipalities. In extension Rumelt’s tests example illustrates that particularly the infrastructure zone has taken the lead to find funds for the safer alternative, although it was proposed by a municipality. The maturity model evaluation generically describes that alternative solutions are oftentimes technically elaborated and weighed. The Rumelt’s tests detail this endeavour where the regional department prepared a trade-off between an already planned traffic light replacement and the roundabout.

Rumelt’s four tests also revealed a detail contradicting to some justifications for a maturity level on the internal coordination criteria. The maturity score for internal coordination at this regional department was evaluated by employees close to 4 out of 5. According to the model this level 4 represents a department coordinates all infrastructure problems within budgetary requirements and jointly communicates bottlenecks. One interview that was conducted for this maturity evaluation motivated this score with the remark that “communication and coordination, among other departments, the corporate planning department, was good”. Another interview that was conducted for this evaluation remarked that “we communicate and coordinate our planning and eventual problems intensively with the corporate planning”. Yet, the remarks made by employees regarding the same work relationship detailed the persistence by both departments standing their ground on their solution to replace the traffic light. The maturity model evaluation does not overlook this detail per se, since a general remark was made that budgetary problems prevent the agency from reaching a higher level of maturity. However, it did not specify that the complexity of gathering multiple funds may serve as the underlying explanation. This detail complements the maturity model evaluation.

3.6.3 Rumelt’s tests example 2: addressing frost damage

Frost damage is known to occur as a result of hard winters and sometimes repair budgets do not seem to be available. In the winter of 2011, the Zone Planning Advisor of the infrastructure zone

studied commented that they “encountered a lot of frost damage to the roads, but actually this was more a consequence of deferred maintenance” that they “did not have enough money to cover” (Zone Planning Advisor, identifying critical issues). This existing annual budget was “intended for measurable conditions (unacceptable roughness and deep ruts) and already allocated. However, we also had to do something about the frost damage” (Zone Planning Advisor, identifying critical issues).

To solve the problem of budget constraints, they decided to weigh the risks associated with frost damage and with unacceptable roughness and rutting. They found arguments in favour of repairing frost damage at the expense of meeting roughness criteria: “We looked at the performance indicators and tried to determine how the damage impacted on the organizational objectives. ... Roughness concerns could be resolved by placing warning signs along the road to inform road users. With the remaining budget, we could then address much of the frost damage.” (Zone Planning Advisor, identifying a solution). Also, the Senior Zone Planner welcomed this solution: “we believe that an accident occurring as a result of frost damage is more risky than a roughness problem on a minor road” (Senior Zone Planner, identifying a solution).

On reflection, employees do not seem to agree on this approach to frost damage. The Zone Manager commented: “we constantly get away with saying that we have damage as a result of hard winters but, strictly, it is not that, it is bad preventive maintenance” (Zone Manager, identifying critical issues). The Asset Quality Advisor substantiated the view that frost damage could be avoided by replacing the road surface: “you just know that frost damage occurs most frequently with Very Open Asphalt Concrete roads. When the asphalt reaches the end of its lifecycle, this is inevitable” (Asset Quality Advisor, identifying critical issues). However, this preventative approach was stopped due to budget limitations: “even if you know that you need to replace the top layer of a road you have to postpone this plan if the available budget is used up” ... “However, this postponement has occurred three years in a row” (Asset Quality Advisor, identifying critical issues). As such, employees seem to agree that addressing frost damage by switching budgets from roughness repairs to frost damage repairs is a fire-fighting intervention and a poor example of preventive maintenance.

The experience of employees mainly revolves around the need to make clear choices based on realistic expectations of failure types with different materials. The Zone Manager believes that making clear choices starts with outlining what you know: “If we consciously allocate less money to preventive maintenance and more money to corrective maintenance, then this is what happens ... however, in that case, you shouldn’t call it frost damage but see it as a corrective measure” (Zone Manager, identifying a solution). The Asset Quality Advisor adds to this by saying that causes of failure need to be openly labelled: “the Very Open Asphalt Concrete could be completely replaced. In the media, our organization calls this frost damage but strictly it is just Very Open Asphalt Concrete that is at the end of its life (Asset Quality Advisor, identifying critical issues).

This argument regarding preventive maintenance perhaps shows that having a public-orientation and favouring preventive maintenance could be conflicting approaches to road maintenance. The Asset Quality Advisor explained: “many political things are at work. We score with public opinion by repairing frost damage. We are alert. We repair the roads very quickly ... We have everything under control.” (Asset Quality Advisor, identifying an action linked to a result). Effectively, this employee’s experiences indicate that there are reasons why less quantifiable and more quantifiable failure types

could be decoupled in allocating budget, and why corrective action could have a greater impact on public opinion than preventive action.

3.6.3.1 Discussing Related Maturity model Details for Example 2

Comparing this example with related remarks from the maturity model evaluation further reveals the rich elaboration provided by Rumelt's tests over maturity models. For example, some remarks have been made during the maturity model evaluation that quantitative data is not yet completed in information systems and that performance indicators are not yet applied to assets. Rumelt's tests detail in the case of frost damage that less measureable risks are renounced from systematic risk evaluations and receive budget that has been ring-fenced from already budgeted measures, e.g. roughness measures were postponed for addressing frost damage.

Remarks from the maturity model evaluation particularly relate to the example of frost damage when used to justify the maturity level of the risk management criteria. The maturity score for risk management at this regional department was evaluated by employees close to a 4 out of 5. According to the model this level 4 represents a department that prioritizes all risks for objects systematically. One interview that was conducted for this maturity evaluation motivated this score with the remark that "risks are systematically identified and labelled and different scenarios are weighed in decisions". Another interview that was conducted for this maturity evaluation remarked that "we have the proper knowledge to reach the highest maturity, however budgetary limitations make that a challenge". Rumelt's tests results have extended the explanation as to why the budget may limit a high maturity level, i.e. because of quick and positive visible action.

3.6.4 Rumelt's tests example 3: maintaining a road along the top of an embankment

The poor quality of a road running along the top of an embankment illustrates the consequences of separate jurisdictions and limited specifications concerning the functionality of an asset. The issue arose when the Traffic Advisor was confronted with the poor quality of a road. He learnt that this road was a physical part of an embankment and therefore maintained and managed by the water division since "primarily its function relates to control the water flow" (Traffic Advisor, identifying critical issues). Further, the Traffic Advisor noted that "the embankment sees a lot of attention linked to tourism" (Traffic Advisor, identifying critical issues).

The Traffic Advisor had appealed to a colleague from the water division and was surprised by the response of his colleague who said that "the function of the embankment in relation to control the water flow is not endangered by the quality of this road" (Traffic Advisor, identifying critical issues). This moved the Traffic Advisor to a challenge the single functionality of the embankment. The Specialist for Project Risks had previously been employed by the water division and knew the details of the embankment. When identifying critical issues, he recalled that "the Traffic Advisor from the road division had emphasized the road's deterioration as a problem and pointed to the potential loss of reputation" (Specialist for Project Risks, identifying critical issues). He questioned whether the appeal by the Traffic Advisor was fair: "I understand what he means, but do you have to accept another function for this embankment?" (Specialist for Project Risks, identifying critical issues).

In effect, this example shows that workers from different divisions appear to follow their own division's mandate in determining priorities. Concerning mandates, the Traffic Advisor said that "this road (on the embankment and the water division's responsibility) is not my business, given that I am responsible for the road division" (Traffic Advisor, identifying critical issues). Nevertheless, he was

surprised that his colleague from the water division similarly reasoned when asked to respond to the need to repair the road. Although the Specialist for Project Risks no longer worked for the water division, he retained a water division view when saying “In my view this was just an object with a single function related to control the water flow” (Specialist for Project Risks, identifying critical issues).

3.6.4.1 Discussing related maturity model details for example 3

Some remarks made during the maturity model evaluation confirm some details of this example. On one instance, maturity model remarks point to the general view that some questions exist over the jurisdiction of both the road and water division at the regional department. Rumelt’s tests affirm that the Traffic Advisor and his colleague both had another view of the jurisdiction of their division to maintain a road along the top of an embankment. Further, Rumelt’s tests extend this affirmation by adding that the function of the embankment was interpreted differently by both employees.

In addition, the same test results on different views regarding the jurisdiction revealed a detail contradicting to some justifications for a maturity level on the processes and roles criteria. The maturity score for processes and roles at this regional department was evaluated by employees close to a 2 out of 5. According to the model this level 2 represents that employees within a department share a common view of processes and roles, yet are not completely anchored into job descriptions. One interview that was conducted for this maturity evaluation motivated this score with the remark that “roles for each employee are known, however the processes are not documented”. Another interview that was conducted for this maturity evaluation remarked that “asset management is not yet strongly determined in the process descriptions, however for certain objects we would score a high maturity”. Rumelt’s tests result detail an ambiguity between employees’ view who should maintain a road along the top of an embankment where a maturity level was determined at and a common view of roles.

3.7 Accounting for employee experiences

In our empirical study we compared the experiences of the employees as they have been drawn out by both approaches. Our data points to several differences on the focus of the Rumelt’s tests and the maturity model evaluations (see Table 3 for an overview). Firstly, Rumelt’s tests focus more on challenges as they emerge through examples, where maturity models are expected to show more deliberated comments about a situation. For example in Rumelt’s tests, a Zone Planning Advisor highlighted the disapproval of the corporate planning department to him considering the replacement of a traffic light by a roundabout, despite him informing them that it could be a possibly safer and cheaper alternative. In the same example, the maturity model comments focused on the criteria of internal coordination and assessed that the coordination between the regional department and corporate planning department was good and indicated that a maturity level 4 out of 5. This level indicates that a regional department coordinates all infrastructure problems within budgetary requirements and jointly communicates bottlenecks.

Second, a maturity model is suitable to receive remarks that assess a criterion on a higher level than Rumelt’s tests could, whereas Rumelt’s tests could reconstruct human interactions as a problem develops. We noted with Rumelt’s tests that some descriptions disclosed that employees focused on a certain goal and thereby disregarded other goals. We saw in example 1 that, despite the discouragement from the corporate planning department, the Zone Planning Advisor and the Zone

Manager continued to investigate alternatives to replacing the traffic light. Conversely, the corporate planning department remained blind to alternatives, and eventually the regional department started another process to find financial support elsewhere. Also, in example 2, we observed how the frost damage initiated a new approach to weigh the risks associated with rough road surfaces against the risks linked to frost damage, and eventually prioritizing frost damage. In both examples, a maturity model assessed whether from a risk management criteria view alternative decisions were commonly weighed.

A third difference may mark their complementary value. Despite we encountered great detailed examples, we could not conclude from Rumelt's tests whether these examples carry significance at an organizational level. We saw in example 3, the Traffic Advisor encountered an inflexible colleague in the water division when it came to maintaining the quality of a road along an embankment. The same situation was verified by the Specialist for Project Risks, but he offered a different view on the situation, in which he argued that roads did not belong to the water division. With this data we can summarize the different perspectives, but we cannot abstract a more organizational observation from it. We needed the maturity model data to support a more generalized remark on this case where employees commented that some questions exist for jurisdiction between divisions (see Table 2). In absence of either approach, the case material cannot link observations from afar to observations that are more close-up and personal.

A fourth difference may mark the added value if both approaches would be combined for a multi-method snapshot. For example, we were surprised to see in example 1, that the Zone Planning Advisor and the Middle Manager eventually conceded the roundabout option, but only after a variously subsidized project became stranded. The Zone Planning Advisor even admitted that "formally, we are not allowed to replace the traffic light by a roundabout." In essence, this example narrates that employees seem to notice a challenge, but seem to be blinkered as to when they can make a choice. To that extent, Rumelt's tests offer a direction for improvement by removing these detailed problems. When employees verify multiple of these detailed problems, then this could very well justify relevant criteria for a maturity model for offering the higher-level goal to improve similar situations, where Rumelt's tests then have helped to specify the involved management layers and units.

Although Rumelt's tests carry clear benefits in accounting for employees' experiences, it also requires considerable time and a large number of interviews to conduct it. In our case, we interviewed 15 individuals varying between 45 minutes to 2 hours. Rumelt's tests help to uncover clear examples, but require complete transcriptions, because the interviewer may not know the significance of every remark that has been made until the first reconstructions. Rumelt's tests also rely on the cooperation of every single individual link in the relationships between organizational layers and units. This is needed since multiple employees can describe the challenges with up-close and personal examples.

Table 3. Accounting Employee Experiences with Rumelt's Tests and Maturity models

Rumelt's tests	Maturity model
– Focuses on challenges between understanding and action	– Focuses on challenges and good situations as defined by criteria
– Triggers remarks of great detail that describe the development of a problem	– Triggers remarks that describe the characteristics of a situation
– Cannot specify whether a detailed example from practice is generalizable	– Cannot specify how a generalized observation amounts in practice
– Offers direction for improvement by removing problems	– Offers a direction for improvement by defining the ideal situation
– Requires full transcriptions of interviews	– Requires comments to maturity level scores
– Selected employees need to have a work relationship	– Selected employees need to have experience with criteria

3.8 Concluding remarks

In this paper, we identified three concerns with current maturity models' ability to deliver advice on implementing asset management. We have reviewed advantages and disadvantages when applying maturity models. We have attempted to relate these advantages and disadvantages to the task of evaluating asset management implementation. The first concern is that maturity models contain criteria and maturity level measurements that are crudely designed and poorly motivated (Becker, 2009), and hence require justification. From the literature we found that implementation challenges can involve integration challenges with implementing standards on the one hand and on the other hand coordination challenges. Empirically we found that accounting for the latter type would reveal more high-level information with a criteria-specific approach and more up-close and personal information with a criteria-free approach.

A second issue when accounting for employees experiences is that criteria applied to a maturity model can be a vulnerable approach to evaluate the implementation of asset management. Particularly, we found in literature that a maturity model would make the approach vulnerable to justify the criteria as ideal and an entire range of criteria incomparable across different contexts. From our empirical study we found that a criteria free evaluation can account for details that describe the background of generic statements triggered in a maturity model evaluation. This could be both beneficial to set criteria for a given context preceding a maturity model evaluation or to study the comparability of contexts succeeding an evaluation.

A final issue when accounting for employees' experiences is to consider that maturity models rely on evaluators' ambiguous assessments being a reflection of the truth. Empirically, we have seen how employees can become blinkered and believe that a certain way of solving problems or conducting work is the only way forward. Rumelt's tests enable us to account experiences as unique for an employee, an example and as response to one of the tests. This way we could deliver an employees' understanding of an example by looking at the moment of commentary and finding the similarity or difference of their understanding of a particular example with other colleagues. This way we hope to have provided a revealing new perspective to explore organizational challenges, which we have

attempted to demonstrate on the specific context of an organization assigned to implement asset management.

3.8.1 Limitations

Despite the benefits, the Rumelt's tests also have limitations. A first limitation is the shortcoming of generalizability when analysing data. Rumelt's tests draw out up close and personal examples of challenges. When an organization wishes to follow-up on suggestions to improve their work, then Rumelt's test results are not enough and require more information on the extent that these examples amount to more generic challenges in the organization. A second limitation is that Rumelt's tests require considerable amount of time and a large number of interviews. In order to evaluate the different organizational layers and units a considerable number of employees, connected with work relationships is needed. Therefore, a researcher or practitioner who considers using Rumelt's tests are advised to focus on a clear work relationships that are not covered by less costly and less-consuming methods, like maturity models. With a dedicated goal to explore or validate challenges, we believe Rumelt's tests can add significant value to other recently developed benchmarking techniques, like maturity models.

4 RESUMING AN UNFINISHED TALE: APPLYING CAUSAL MAPS TO ANALYZE THE DOMINANT LOGICS WITHIN AN ORGANIZATION¹⁰

Abstract

In aiming to understand how structures, such as rules, norms, and routines, establish inside organizations, scholars now focus their explanation on practitioners who enact a multitude of behavioral logics. Studies adopting this institutional logic perspective apply assumptions about the apperency and dominance of logics and, consequently, cannot adequately explain, with empirical evidence, how logics coexist or compete for dominance among practitioners. To fill this gap, we open these concepts up to recent academic enquiry as to the dominant logics that practitioners enact. In so doing, we address the still unanswered call by Von Krogh and Roos (1996) to collect empirical evidence on dominant logics by operationalizing two concepts: self-reference and self-similarity. We introduce a methodology that involves causal mapping enhanced with statistical tests and graphical approaches. Through an empirical investigation, we show how this method provides the enacted patterns of multiple logics, validates their dominance, and detects internal contradictions and inconsistencies. These findings highlight that, if one defines dominant logics in terms of self-reference and self-similarity, causal mapping then generates competing and coexisting logics that practitioners enact.

Keywords: Dominant Logic, Self-Reference, Self-Similarity, Organizational Research, Managerial Cognition

4.1 Introduction

In order to develop competitive advantage, organizations need to continuously adapt to dynamic outside pressure. For this reason, much attention has been paid in organizations on the institutional approach as a way of explaining how managers can effectively establish structures such as rules, strategies, and norms to direct practitioner's behavior (Scott, 2004). Recently, scholars like Thornton, Ocasio and Lounsbury (2012) have advanced the view that, in order to influence the organizational practices, managers must give attention to the structures as institutional logics that practitioners 'enact', i.e. the acts through which practitioners arrange where the logic becomes apparent in practices (Lindberg, 2014), which we refer to as apperency . Furthermore, researchers have shown that multiple logics might not only coexist but also might compete for dominance (Marquis and Lounsbury, 2007). This creates a need to understand clashes among multiple logics inside an organization if managers are to influence practitioners' thinking and acting (Tracey, Phillips and Jarvis, 2011; Besharov and Smith, 2013; Hills, Voronev and Hinings, 2013; Gawer and Phillips, 2013; Daudigeos, Boutinot and Jaumier, 2013). Such clashes might occur between particular groups, for example when public sector employees pursue a social mission while their management focuses on a business-like strategy (Sanders and McClellan, 2014). Therefore, researchers call for more resourceful methods in order to more fully examine how to avoid tensions between practitioners with a multitude of dominant logics (Greenwood et al., 2011; Daudigeos et al., 2013).

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Despite significant attention having been given to studying dominant logics within organizations, there is still the ‘burden of evidence’ required to explain their apperency and dominance. The work of Bettis and Prahalad (1995) who describe dominant logic as an ‘information filter’, i.e. a prior mindset through which an organization interprets business practices is often cited in the institutional logics perspective. However empirical studies based on their concepts are lacking. Phillips, Sewell, and Jaynes (2008, p. 777) note that there is only a “small amount of empirical work that has taken up Prahalad and Bettis’s challenge to operationalize dominant logics”. These include Lampel and Shamsie (2000) and Obloj, Obloj, and Pratt (2010) who proposed measuring logics by observing behavior. Dominant logic is also often theorized as a mental construct that needs to be measured as a scheme of cognition (Walsh, 1995; Narayanan, Kemmerer, and Zane, 2011; Kaplan, 2012). Although constructing maps often involves collecting data on cognition, cognitive mappers have yet to address the challenge of operationalizing the dominant logic, possibly due to the difficulties in quantifying it for large organizations (Van Rekom, Van Riel, and Wieringa, 2006). Clearly, there is a difficulty with measuring where the dominant logics become apparent in practice in a way that translates to the organizational level.

To take a step toward filling this gap, we develop a method to analyze dominant logics inside organizations. Von Krogh and Roos (1996) proposed two additional elements – self-reference and self-similarity – that more explicitly describe how dominant logics can have a unique presence and can also be found on different levels within an organization. However, these ideas of Von Krogh and Roos have not yet been methodologically incorporated in a transparent way. In this article, we extend the examination of multiple logics by enhancing causal maps with statistical tests and graphs, and providing self-reference and self-similarity as methodological choices to be made in setting theoretical boundaries. Next, we present this as a stepwise approach that enables researchers to determine whether causal mapping is a viable method for their own investigation, and therewith develop, measure, and analyze the dominant logic construct. Finally, we show how exciting new avenues for research in dominant logics are opened up at practitioners-level by applying this method in a case study.

The principal finding from our empirical case study is that our extensions to causal mapping help organizations and managers understand and then influence the way that people within the organization predominantly approach strategic change. The case demonstrated to those team members responsible for implementing a new strategy that two pairs of team members held different dominant viewpoints on this strategy. The team leader pairing had a strong interest in establishing uniformity through the change, whereas two other members shared a strong interest in their own roles and contributions to the change. These insights allowed the team leader to realize that the physical distance between offices and the specialties of his team made them think and act differently on the task in hand.

4.2 Dominant Logics

Prahalad and Bettis (1986) first developed dominant logic as a prospective theory that linked patterns of corporate diversification (e.g. a portfolio of various business units) to organizational performance. For example, they showed that two dissimilar technologies were simpler to manage using two tailored approaches than with a single approach. Here, the dominant logic was conceptualized as the key factor that managers could influence to avoid an inability to manage a diverse portfolio, such as by ensuring that an appropriate dominant logic was used to manage a

technology. Prahalad and Bettis (1986) defined top management as the dominating constituent, i.e. the most significant influence, in managing a diverse portfolio. This top management arranged their logic in schemas, e.g. encompassing a set of elicited management processes, in forms such as procedures and decision instruments. These operational definitions were key in explaining how tensions were presumably resolved between different management logics. In essence, Prahalad and Bettis (1986) emphasized that the apparency of a logic and the dominance it exerts are key pieces of evidence that are required to understand how to resolve tensions.

Nine years later, Bettis and Prahalad (1995) revisited dominant logics and recognized that they, by then, applied to a wider domain of managerial problems. By the mid-1990s, they had observed, with the greater use of information systems, organizations were being flooded with information but lacked the intelligence to interpret it. Many organizations found it hard to change and many appeared unable to react to changes in their environment. Therefore, Bettis and Prahalad (1995) redefined dominant logic as an information filter that constrains organizational attention. They illustrated how managers only focus on the data that are deemed 'relevant' by the analytic procedures they use. To address this problem, they advocated improving an organization's ability to learn. In essence, they argued that the dominant logic is a filter that prevents an organization from reacting to environmental changes.

Despite Bettis and Prahalad (1995) extending dominant logics to a larger domain of problems, they did not reconsider their assumptions regarding the apparency and the dominance of logics. Von Krogh and Roos (1996) argued that Bettis and Prahalad's 1986 position on the apparency and dominance of logics was obsolete once they adopted, in 1995, contrary assumptions regarding cognition. The 1986 paper assumed that the world was pre-given and predefined for a manager. Managers then had the task of accurately representing this world in their minds while performing at work. In order to do this, a manager needed to acquire information from files to develop a 'truthful' representation of a given world. This view supports the idea that these representations can be stored and retrieved from a managers' knowledge structure. Contrary to this view, the 1995 article held that cognition is neither a pre-given nor predefined: rather cognition creates a subjective world. In essence, this definition implies that each individual can have a unique perception of a problem. This 1995 view made the operationalization of a dominant logic much harder as evidence gleaned from cognition was a lot less apparent and less generalizable.

Clearly, the ability to gather evidence of dominant logics is more problematic with Bettis and Prahalad's (1995) revision. Interestingly, studies adopting the institutional logic perspective have used Bettis and Prahalad's (1995) 'information filter' as a precursor (Thornton, Ocasio, and Lounsbury, 2012). Developing a method for gathering evidence requires a consideration of how researchers have framed various operational definitions as they set out to answer: (1) what data can make a logic apparent in a problem; and (2) whose logic dominates in a problem. In the next section, we discuss diverse nature of dominant logics as an 'information filter' and how Von Krogh and Roos's (1996) concepts of self-reference and self-similarity clarify the gathering of evidence.

4.2.1 What makes a logic apparent?

The theoretical developments since 1995 have led to diffuse views on what makes a logic visible. One view argues that the dominant logic becomes apparent in business plans or decision-making heuristics (Zyglidopoulos, 1999; Chinnis and White, 1999; Sabatier, Craig-Kennard and Mangematin,

2012) where elicited management processes are stored (Tansey, Neal, and Carroll, 2005). Researchers tend to assume that the content of a logic appears in such tangible sources, for example in explicit statements on how an organization plans to make a profit. Since, this approach presupposes that a logic will be apparent in written material, it fails to define the time when practitioners first enact this logic.

Researchers have also concluded that logics can become explicit as a socially constructed consensus through discourse (Ocasio and Joseph, 2005; Philips et al., 2008). That is, when a logic is articulated in a group, it constitutes a social dialogue that eventually results in a definitive constructed logic. This approach assumes that a logic becomes apparent in the words of group members participating in a dialogue, as for example when participants make agreements. As such, if participating individuals do not offer their opinions, the assumptions contained in this approach imply that logics will not be defined at the time of the discourse (see Ambrosini and Bowman, 2005).

Another group of researchers follow the implicit nature of logics espoused by Bettis and Prahalad (1995), and postulate that it is a filter that is used to emphasize a strong preference for specific solutions to a decision-making problem (Lane and Lubatkin, 1998) or for sources from which managers commonly seek information (Lampel and Shamsie, 2000; Novicevic and Harvey, 2001; Garg, Walters, and Priem, 2003). If this is valid, the content of a logic can become apparent through actions in real-time, such as when obtaining resources. Since real-time behavior does not explicitly describe a logic's content, a researcher has to rely on assumptions made regarding each observed action.

Each of these approaches confounds the collection of data on when practitioners enact logics in practice. However, Von Krogh and Roos (1996) introduced a concept addressing how managers think that potentially remedies this situation. As they expressed it: "Dominant logic, we argue, assumes self-reference. Each of us has a unique set of experiences that makes us see and react to things differently. ... what you see depends on who you are" (Von Krogh and Roos, 1996, p. 733). In other words, when a manager relates new information to previous information, this amounts to referring to self (Von Krogh, Roos, and Slocum, 1994). With this concept, they were articulating the idea that individuals rely on their own filters in developing thoughts about the world. From this, we argue that self-reference amounts to a theoretical boundary of time in accepting that, at any given moment, multiple logics can appear in an organization, each reflecting an individual employing a logic that appears unique to them.

As such, it is argued that the effort involved in collecting data about how practitioners make logics apparent in practice can be greatly reduced if one can carefully define the time when the action is observed. Here, Boisot and Li (2005) argue that people have different framing habits. In essence, this makes each individual the source of a logic: "Where managers constitute an organization's dominant coalition, their codification and abstraction choices will shape its epistemic practices, its goals, its rules, its routines, and through all these, its dominant logic" (Boisot and Li, 2005, p. 328). Similarly, when people frame their worlds without the help of some mechanism, e.g. rules, a dominant logic evolves and survives on its own. Here, researchers assume that, when individuals reason on their own, dominant logics will become apparent. This has led us to refine Bettis and Prahalad's (1995) initial schematic representation and include multiple funnels (Figure 1). In essence, this operational refinement accepts that multiple, potentially unique, logics can become evident in a response.

Figure 1. Self-reference and self-similarity by Von Krogh and Roos (1996) added to the scheme of Bettis and Prahalad (1995, p. 7)

4.2.2 Whose logic dominates?

Another important issue in the operationalization of dominant logics is whose logic can dominate within an organization. In an initial argument, Prahalad and Bettis (1986) stated that the perceptions of top corporate-level managers were key in establishing an organization's view. Since Prahalad and Bettis (1986) were focusing on a corporate-level problem, little thought was given to the various interpretations of the word 'dominance'. Top management was unquestionably recognized as the dominating constituent as it was the single highest office within an organization that determined the decision-making schemas (Ginsberg, 1990).

Another view that has become increasingly prominent in recent studies relates the dominant constituent to the type of problem. The corporate-level has remained the focus of many, for example by identifying the entrepreneur or founder (Campos, de la Parra, and Parellada, 2012) or the top management team (Lumpkin and Brigham, 2011; Guidice and Mero, 2007; D'Aveni, Ravenscraft, and Anderson, 2004) as the dominant constituent, but some now determine it by the influence it has on the problem. For example, Valliere and Peterson (2007) described the event of an entrepreneur selecting a venture capitalist to develop business opportunities. They found that the development of a 'dominant' selection criterion, i.e. experience gained from 'successful' former decisions and actions by entrepreneurs, impacts on how the venture performs. From this standpoint, it follows that the dominance of a logic is not dependent on an office, while still assuming that the dominance relies on a single role.

Some studies have shown that members outside of top management also have a substantial influence on the logic of the entire organization (Dijksterhuis et al., 1999). For instance, Watson and Wooldridge (2005) found that middle managers have greater influence in decisions made by the company board if they report directly to top management. Here, a logic is not necessarily dependent on the expected role of influence, but on the dominant influence that one person can have in their social relationship with another. This complicates academic investigations that use static definitions of a dominant constituent if it is accepted that dominance originates from multiple sources through conversation.

Each of these approaches complicates the collection of data on dominant logics inside the organization. However, a potential remedy, addressed by Von Krogh and Roos (1996), is to use self-similarity. Self-similarity reflects the idea that not only top managers can define a dominant logic,

and that these can appear on different levels within an organization (e.g. individuals, groups). More specifically, Von Krogh and Roos (1996) argue that a dominant logic not only occurs on different levels, but can also involve any combination of individuals: “We suggest that dominant logic can be self-similar. The way managers conceptualize and manage technologies, product development, distribution, advertising or people can be similar (but not identical) throughout the company” (Von Krogh and Roos, 1996, p. 735). An example of such self-similarity would be a situation where the thoughts of group members are similar despite different occupations or departments. Hence, we argue that self-similarity amounts to a theoretical boundary of space, implying that logics are not discrete. That is, their dominance (in any combination of individuals) is shown by the extent they share similar, but not identical, thoughts.

As such, the effort involved in collecting data about the dominant logics inside the organization can be greatly reduced with an approach that considers the dominance of a logic to be based on a group of individuals who are expected to share similar ways of working. In recent years, such a view on dominance has gained ground as organizations have become increasingly non-hierarchical and hybrid (Pache and Santos, 2013). Research has shown that communities of professionals, such as hospital employees (Vardaman, Cornell, Gondo, Amis, Townsend-Gervis, and Thetford, 2012), teachers (Chong, 2005), product designers (Magnusson, 2009), and rugby union players (O’Brien and Slack, 2004) are able to portray a dominating view. In this way, large communities of professionals can have a significant effect on the way in which information is filtered. This view fits with the idea that measuring the dominance of common ways of working can involve any combination of individuals. This has led us to refine the schema (Figure 1) as a snapshot in which the variance in filtered information is evidence of multiple logics and their respective dominance.

To summarize, the various operational definitions highlight that the apparency and the dominance of logics can either be defined as part of the problem description, as by Prahalad and Bettis in 1986, or be left unclear prior to investigation, as in their 1995 approach. When either, or both, the apparency and the dominance are operationally unclear, collecting evidence becomes problematic. In the next section, we discuss the methodological role of self-reference and self-similarity as theoretical boundaries to simplify these matters.

4.3 Measuring the apparency and dominance of logics

In this section, we raise critical questions in order to develop a method that can be used to investigate the apparency and dominance of logics. First, we look at how one can gather evidence about dominant logics. Then we focus on the technical adequacy of applying causal maps when the logic’s apparency and dominance are unclear.

4.3.1 When to collect data on the apparency and dominance of logics

An unclear operational definition first raises the question whether researchers should address the apparency and the dominance of logics prior to or after data collection. That is, should an investigation specify where a logic becomes apparent after evidence has been collected, or should it determine its apparency from among a range of expected sources? Further, a researcher might assume a specific source will be dominant, or determine which of multiple sources is the most dominant.

Various ways have been used to measure a dominant logic. One approach is to collect the explicit content of assumed dominant sources as evidence of the logic, for example by interpreting formal

documents. In this approach, a researcher has already made assumptions, both on where the dominant logics becomes apparent and why these logics are dominant, and is more interested in obtaining descriptions of those logics as evidence.

Another proposal is to collect data on dominant logics through observing behavior. This approach infers implicitly held logics by observing similar behaviors to provide evidence that the logic precedes the behavior, e.g. by interviews over a long period (Chow and Luo, 2007) or by retrospectively collecting observations of behavior (Côte, Langley, and Pasquero, 1999). A drawback of the observation approach is that while a pattern of repetitive behavior will become apparent, no understanding of the possible origins of the pattern is obtained.

A more direct way to collect data is discourse analysis. It focuses on the 'text' (verbal or written) to elicit articulated cognitions and trace them back to constructed final logics (Phillips et al., 2008). Discourse analysis is a powerful approach when researchers want to collect data on the dominance of explicit cognitions that compete through arguments in conversation or writings. Despite this apparent advantage, it is unclear how one could capture more tacitly held logics that are not verbalized in conversation or discussion (see Ambrosini and Bowman, 2005), such as when individuals remain silent in a group. For that reason, discourse analysis seems unconvincing in investigations where assumptions are not made regarding the explicit apparency of a logic or the origin of the dominance.

Recently, Crilly and Sloan (2012) have considered cognitive mapping as a way to elicit dominant logics in enterprises. Cognitive mapping is able to measure implicitly held logics from multiple sources. Causal mapping is one of many modeling techniques developed to address cognitive data in order to represent a person's ideas, values, beliefs, and attitudes, plus their relationships, in a way that is tractable for both study and analysis. This involves a procedure to identify an individual's or a group's judgment on patterns of influence among relevant concepts (Langan-Fox, Code, and Langfield-Smith, 2000). Once a person discloses their perceptions, a causal map then provides a graphical representation of an individual, or a collective, view of concepts in motion, i.e. developments or events. This makes causal mapping a relevant candidate when seeking to clarify the apparency and dominance of logics.

In summary, Table 1 reflects these approaches as choices, suggesting that, if the apparency of a logic is unclear in an investigation, the researcher should determine from which source(s) the logic becomes apparent. Similarly, if it is unclear which of multiple sources is dominant in an investigation, the researcher should include data collected on the dominance of sources.

Table 1. Choices in collecting Evidence of the Apparency and Dominance of Logics

Apparency of logics is	Implicit	Collect where logics become apparent and define the origin of dominance, <i>e.g. observations of behavior</i>	Collect where logics become apparent and the extent of their dominance, <i>e.g. cognitive mapping</i>
	Explicit	Define the sources of logics and the origin of dominance, <i>e.g. content analysis</i>	Define the sources of logics and collect the extent of their dominance, <i>e.g. discourse analysis</i>
		Single Origin	Competing Origins
Dominance is assumed to have			

4.3.2 Technical adequacy of causal maps for uncovering dominant logics

A second issue concerns what a specific data collection implies in terms of the adequacy of a causal map for eliciting evidence. A causal mapping procedure captures and builds a mental model of causal relationships among labeled factors that are unique to a person or entity (Langfield-Smith, 1992). Some authors have acknowledged that causal maps are useful for measuring dominant logics (e.g. Klimecki and Lassleben, 1998; Gnyawali and Stewart, 2003; Matthyssens, Vandenbempt, and Berghman, 2006; Kunc and Morecroft, 2008).

Some authors utilize maps for their quality of being able to represent a cognitive structure (see Walsh, 1988) in order to describe the drivers of action and behavior. With this type of focus, causal mapping is regarded as appropriate and meaningful because it reflects the predispositions of an individual's logic. As such, it harnesses the technical quality of a causal map to analyze a logic on several levels of process detail. When researchers use causal maps to represent a cognitive structure, they generally presume that a known individual is decisive to the problem and thus that his or her logic forms the dominant cognitive structure used in reaching a solution. Here, top management is often regarded as the decisive owner of problems pertaining to organizational action (Lyles and Schwenk, 1992; Nadkarni and Narayanan, 2007; Nadkarni and Perez, 2007; Nadkarni and Barr, 2008). In essence, with the aim of representing a cognitive structure, one only measures the apparency of logics.

Other authors utilize maps to reflect socio-cognitive patterns of interaction among members of a collective. This objective can be achieved by constructing a causal map within a group to uncover the extent of differences and similarities among respondents. As such, it harnesses the technical quality of a causal map in order to identify differences in cognition. In this endeavor, researchers argue that a causal map reflects dominant logics since it identifies views shared among individuals who own a decision problem (Allard-Poesi, 1998; Ginsberg, 1990). Researchers justify this application by arguing that a shared view impacts on individual views. For instance, interactions are expected to cause individual views to become similar over time (Hodgkinson, 1997). However, this assumes that an individual's view will automatically align with a collective shared view. As such, socio-cognitive patterns only measure the dominance of logics that may survive dialogue, and not thoughts.

In this discussion, we see that all the reasons advanced for measuring dominant logics focus on either a logic's apparency or its dominance. On the one hand, applying causal maps through cognitive structuration entails determining, through measurement, who owns a logic, while making

assumptions as to how dominant that logic is. On the other hand, applying causal maps to reflect socio-cognition patterns allows one to determine which logic dominates in a population, while assuming that participants automatically conform to a shared logic. Measuring only one element inevitably leaves a gap when gathering evidence of a dominant logic concept as this requires evidence on both. Hence, a process that elicits individual maps in a comparable form would be most appropriate for gathering evidence on both the apparency and dominance of a logic. By introducing two methodological choices, imposed by self-reference and self-similarity, we add this step to causal mapping.

4.3.3 Applying self-reference and self-similarity in causal maps

A third question is which elements of a causal map should one elicit. A causal map can analyze a logic on several levels of detail about the perceptions of a process. It can uncover whether elements are included in a process and, in more detail, whether these have a causal relationship. One in-depth detail is called the polarity of change, which reflects the nature of the relationship between two factors. A further detail is called the strength, often indicated using an ordinal scale ranging from number 1 (weak), through 2 (moderate), to 3 (strong). Although many causal maps aim to capture all of these levels, this is a methodological choice that can be tailored to a specific investigation (Clarkson and Hodgkinson, 2005).

A fourth issue is the elicitation procedure to be adopted for collecting the evidence of logics. Various protocols are available that probe into the cognition of respondents. At one end of the range, procedures have been proposed to collect cognitions based on a free monologue, where a person draws or talks about a work process (see Bougon, 1983), and elicitation procedures have also been proposed where people are asked to respond to a fixed input (Hodgkinson, Maule and Bown, 2002). Hybrid forms also exist that have the advantage of offering individual elicitations and generalizable analysis. Here, fixed questions can be raised to focus on a particular construct (Ambrosini and Bowman, 2001), and text-based data can also be collected (Axelrod, 1976). Data can be collected not only by asking directed questions but also by providing a fixed set of answers (Markóczy and Goldberg, 1995). As evidenced by the challenge from Bettis and Prahalad (1995) to operationalize dominant logics, an elicitation is technically adequate when it is individually elicited and in a comparable form. Determining which procedure should be followed rests with the researcher and should depend on the context of the investigation.

A fifth issue concerns how to compare data from causal maps. Causal maps are commonly analyzed using distance ratios (Langfield-Smith and Wirth, 1992; Markóczy and Goldberg, 1995). A distance ratio is a single indicator that sums all the individual differences between two maps and divides this total by the greatest possible difference between the maps, generating a number between 0 (similar) and 1 (dissimilar). Schaffernicht and Groesser (2011) found that many researchers have adapted the distance ratio, e.g. Fokkinga et al. (2009), Plate (2010), and Gary and Wood (2011), but that many had failed to account for differences on the detailed levels, such as in nodes or arcs. This is understandable in that, even with current software capabilities, comparing and aggregating causal maps remains problematic (Bougon, 1992, Langfield-Wirth and Smith, 1992) because a collective view does not necessarily reflect an individual's view and software such as Cognizer TM still relies on the specification of groups of origins (Clarkson and Hodgkinson, 2005). As such, current techniques cannot meet the theoretical boundaries of self-reference and self-similarity.

To simulate a self-referencing filter, we propose conditioning the elicitation procedure with probability theory. In this way, a filtering activity can be defined as a sequence of unique events. In this situation, a person develops and constructs an individual causal map through a sequence of responses, such as with a procedure similar to Markóczy and Goldberg (1995), i.e. with causal map details about nodes, linked nodes, causal relationships, polarities, and strengths. Such a procedure invites people to respond to accumulating multiple-choice questions without being influenced by others, effectively amounting to individual self-reference (see Figure 2). The responses could be the focus in analyzing whether people react differently or similarly when facing identical questions. In this way, one can compare employees' perceptions in responding to an identical enquiry.

Figure 2. Data Collection and Analysis with the new Proposed Scheme

To identify both dominant and less dominant logics, we propose excluding individual responses that statistically test as random phenomena. In this sense, probability theory addresses random phenomena, which we hold to be the opposite of a dominant constituent. Probability theory argues that selecting a causal map detail (such as a polarity) is a random process. That is, when a person is given a multiple-choice question, probability theory expects the person to respond randomly at any given time. Such responses can be excluded with a significance test. When an infinite number of people answer the same closed question, a significance test determines whether the responses are non-random, i.e. multiple people reasoned a logical response. Further, probability theory also assumes that random responses are mutually independent. A test for independence can determine

whether a response is likely to have followed from a dominant constituent. Here, a test for independence determines whether responses structurally depend on each other. The proposition below can be used to develop such tests:

Proposition 1 (about the Dominance of Logics): If a response to details of a work process is randomly filtered and independent of every other response, then that response was not caused by a dominant logic.

To identify those individuals that share dominant logics within an organization, we propose excluding those causal maps that only sporadically share responses. In expressing a clear expectation, self-similarity assumes that any combination of individuals can share a set of partial responses. If we detect similar responses from two or more individuals, we can say that these responses are self-similar among those individuals. We try to convey this point more powerfully in Figure 2. This figure represents the causal map of three people, symbolized by circles. Areas where two circles overlap signify the sections of both causal maps (containing nodes, causal links, etc.) that are self-similar. We can identify the exact set of shared responses using significance tests. If producing the causal maps of persons A and B involved them answering two questions, each with two alternative answers, then the individual probability of a specific combination of answers would be calculated as: $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$. That is, the probability that they both share a certain combination of answers would be $\frac{1}{4}$. If significance tests covering an entire organization show no particular combination of individuals rejecting this expectation, we can say that there is no dominant logic in the organization. A proposition to guide a feasible test protocol on this is formulated below:

Proposition 2 (about the Dominant Logics of an Organization): If all the responses concerning a work process, based on a representative sample of the organization, in a causal map are randomly filtered and independent from every response in other causal maps, then the organization's responses are not caused by a dominant logic of that process.

A sixth issue arises in preparing the various hypothesis formulations, before carrying out tests. Essentially, we formulate hypothesis to express the test whether the 'number of responses' is a significant and dependent metric of dominant logic. For example, in analyzing Proposition 1, we formulate that we want to know whether the 'number of nodes selected' occurred (a) random or non-random and whether these are (b) dependent or independent from other nodes. It is worth noting that hypotheses are also formulated for causal links, polarities, or the causal strength. Again in Proposition 2, we formulate hypotheses on whether causal maps are (a) random or non-random (b) and dependent or independent.

Hypotheses are also formulated with a certain probability distribution. Here, the way that multiple-choice questions are answered determines the expected distribution. For example, when we test the 'frequency of a node selected' with replacing them, then the expected distribution for that metric is a binomial one. On the contrary, when test the 'frequency of two nodes linked' without replacement, then we assume a hyper-geometrical distribution.

4.3.4 Graphs

A seventh issue is how to make the empirical test results accessible. Once we know which responses are metrics of a dominant logic, we can structure and present them graphically (Clarkson and Hodgkinson, 2005). A graph can depict a causal map, or a social network of people (Borgatti and

Foster, 2003). One option involves non-directional connections between nodes (or arcs, or edges), signifying that these are linked, but saying nothing about the direction of the links. Further, a graph can be (bi)directional, consisting of links that relate to one or two-way relationships between nodes. Graphs can be useful for detecting logics by revealing both the pattern of elements in causal maps, through a directional graph, and the patterns of similarities between people in a social network through a non-directional graph.

4.4 Demonstrating a change problem

A pertinent empirical demonstration of the method is now offered to provide a clearer understanding of the proposed measurement. As such, in this section, we present the cognitive evidence collected to validate the explanatory potential of dominant logics within an anonymous organization.

4.4.1 Background

'INFRA', a public agency, is responsible for managing infrastructure in the Netherlands. Since the 1990s, its strategy has focused on changing its management practices to boost rational decision-making and encourage employees to adopt uniform ways of working. Over the course of twenty years, they have changed their decision-making models and introduced several information systems to improve their maintenance of the road infrastructure. However, the change programs have failed due to a loss of employee momentum. In 2008, top management attempted a new implementation program, this time focusing on decision-making inside the organization as a whole.

A program team was charged with the task of developing an overall asset management process in which systems would be assigned to specific purposes and to eventually help in implementing the entire process in the organization. The program team consisted of a director and nine advisors, assigned to help with implementing asset management issues such as new outsourcing procedures and the use of information systems.

4.4.2 Study details and purpose

During 2011, we followed the team as it started to implement a newly configured asset management process that spanned several management layers and departments. In many meetings, we observed that the team was confronted with diverse practitioners' perspectives about asset management. For example, during workshops, some practitioners saw no need for change while others thought the changes did not go far enough. In order for the team to communicate the implementation plan consistently, the program director (PD) was interested in whether the team members had similar views on the 'new' asset management approach.

Our objective was to identify the internal shared and dominant views within INFRA on the 'new' asset management process and understand the implications of this for the change effort. We first carried out a preliminary study among team members before a larger study within the organization. This study taps into the long-standing debate on how to change organizational thinking after a change in strategy. Inspired by the dominant logic concept, we developed a methodology that collected empirical individual-level evidence that was representative of the organization as a whole. We then interviewed the ten members of the team to demonstrate the method and the analysis. Figure 3 presents for the study scheme.

Figure 3. Study Scheme

In order to acquire objective insights into the team members' cognitions, we used Markóczy and Goldberg's (1995) procedure to elicit causal maps. This procedure has the ability to elicit team members' views individually and then compare them collectively. Preliminary to the actual causal mapping, we interviewed 23 of their peers to identify relevant decision issues (DI) for use in the causal mapping. From this interview round, we identified 71 decision issues that were deemed relevant, by the interviewees, to the asset management decision-making process at INFRA. For example, interviewees felt that 'determining a risk level for assets' (DI 6) and 'formulating performance requirements' (DI 44) were important decision issues in asset management. Following this, we performed a closed pairwise-comparison procedure to elicit a causal map for each team member (see Appendix A). For practical reasons, we only asked them about what they saw as the ten most important DIs to limit the interview length (Markóczy and Goldberg, 1995).

4.4.3 Analyzing the dominance of 'asset management' logics by selection of DIs

To detect dominant 'asset management' logics at INFRA we reformulated

Proposition 1 to the context of INFRA, such that we could develop testable hypotheses:

Proposition 1 (the Dominance of Asset Management Logics): If a response to asset management details is randomly filtered and independent from every other response, then that response was not caused by a dominant logic.

Testing the responses is important for understanding whether filters (i.e. logics) are applied by the surveyed community. Nevertheless, the decision to perform tests should be a phased process as the

number of tests can easily mount. Testing in phases is possible with causal mapping because questions are elicited sequentially.

First, we want to know whether practitioners apply filters in selecting their ten most important asset management issues. To assess this, we formulate hypothesis tests for each possible response. For example, we want to understand whether ‘determining the risk level for an asset’ (DI 6) is an important decision issue in asset management. We observed that four of the ten team members listed this is in their top ten. To determine whether a filter was applied in all responses to DI 6 we want to know whether H_0 : ‘The selection of DI 6 is random’ (null-hypothesis) or H_1 : ‘The selection of DI 6 is non-random’ (alternative hypothesis) is valid. To answer this, we use a binomial test, with a binomial distribution $B(10, 1/71)$, to calculate the probability of 4 or more individuals selecting DI 6 in a sample of 10 when the random probability of selecting DI 6 is $1/71$. If we sum the probabilities of exactly 4 individuals, then 5, and so on up to 10 individuals selecting DI 6, we find that the probability of DI 6 being randomly selected by 4 or more individuals is 0.0407 (one-tailed test). If we apply a confidence interval of 5%, this result indicates that DI 6 was non-randomly selected by the team. In total, we found that the program team non-randomly selected 8 of the 71 DIs (see Table 2). The responses to DI 1 ‘formulating policy goals’ and DI 44 ‘formulating performance requirements’ most strongly indicated that a filter was applied with 7 of the 10 listing these.

Second, we want to know whether multiple DIs were selected by the same filter. For example, five out of seven individuals who selected DI 1 also selected DI 44, which makes their mutual dependence more likely. In order to determine this we need to test for independence. In effect, we want to know whether H_0 : ‘The choices made regarding the importance of DI 1 and DI 44 are independent’ or whether H_1 : ‘The choices made regarding the importance of DI 1 and DI 44 are dependent’ is valid. To resolve this, we can use a Fisher’s Exact Test with a hyper-geometric distribution $h(5, 10, 7, 7)$, i.e. 5 individuals out of 10 select DI 1 and DI 44, while 7 select DI 1 and 7 select DI 44. The Fisher’s Exact Test indicates that the probability that both these DIs are selected by five individuals is 0.525. Again applying a 5% confidence interval, this result indicates that DI 1 and DI 44 have been independently selected by the team members. That is, they appear to have been selected through separate filters and not by the same filter. Among the possible pairings of DIs in Table 2, only the pairing between DI 41 ‘fulfilling demands from stakeholders and partners’ and DI 71 ‘determining the definition of asset quality’ appear dependent. In other words, both these DIs appear to rely on the same dominant filter.

4.4.4 Analyzing the dominant ‘asset management’ logics inside the team from the selection of DIs

Since the evidence indicates that both DI 41 and DI 71 rely on the same filter, we want to know which part of the community is the source of this filter. To answer this, we focus on dominant coalitions among team members, with Proposition 2 reformulated as:

Proposition 2 (about Dominant Asset Management Logics among Team Members): If all the responses concerning asset management, based on a representative sample of the team, in a causal map are randomly filtered and independent from every response in other causal maps, then the team’s responses are not caused by a dominant asset management logic.

First, to identify whether a dominant coalition is responsible for filtering sets of decision issues (such as with DI 41 and DI 71) we need to test the significance and independence of each pair of causal

maps. For example, having found that the program director (PD) and the top advisor (TOP) both selected the same five DIs, makes it likely that they form a coalition with similar thoughts as to which DIs are important in asset management. To determine this, we want to know whether H0: 'it is a random event when PD and TOP select similar DIs' or whether H1: "it is a non-random event when PD and TOP select similar DIs" is valid. Here, we use a binomial test, with a binomial distribution $B(10, 1/71)$. If we sum the probabilities of exactly 5 similar DIs between PD and TOP, exactly 6 similar DIs, and so on up to 10, we find that the probability of obtaining five similar DIs between PD and TOP is 0.01356 (one-tailed test). Applying a confidence interval of 5%, this result indicates that both PD and TOP selecting these five DIs is a non-random event. Of the 45 possible pairings, we found that the DIs selected by both the lifecycle cost advisor (LCC) and the trainee (TRA), in addition to the above PD-TOP pairing, also amounted to a non-random event. These results indicate that there are two dominant 'asset management' perceptions shared within the team.

Table 2. The decisions issues non-randomly selected by the ten team members

DI #	DI description	Number Selecting (out of 10)	Significance
1	<i>'formulating policy goals'</i>	7	0.0001
4	<i>'determining a level of knowledge about assets'</i>	5	0.0075
5	<i>'determining a standard for registering asset data'</i>	4	0.0407
6	<i>'estimating the risk for an object'</i>	4	0.0407
23	<i>'using a risk method'</i>	4	0.0407
41	<i>'fulfilling demands from stakeholders and partners'</i>	5	0.0075
44	<i>'formulating performance requirements'</i>	7	0.0001
71	<i>'determining the definition of asset quality'</i>	4	0.0407

Secondly, we can ask whether either of these dominant shared perceptions amounts to a dominant coalition. In the case of the PD-TOP pairing, we want to assess whether H0: 'When PD and TOP select DIs, then these choices are independent' or H1: 'When PD and TOP select DIs, these choices are dependent' is valid. Here, we used the Chi-squared test, with a Chi-squared distribution $\chi^2(1)$. Using a confidence interval of 5%, with a rejection region of $\chi^2_{0.05} = 3.841$, we reject H0 since $\chi^2 = 12.407$. This indicates that there is a dependency between the perceptions of the program director (PD) and the top advisor (TOP). The test result for the other pairing also indicates a dependency between the lifecycle cost advisor (LCC) and the trainee (TRA). Hence, from this evidence, we can conclude that there are two dominant 'asset management' coalitions inside the team.

Finally, the big question remains whether either of these dominant coalitions is responsible for the dominant filter, i.e. the pattern of responses stressing fulfilling stakeholder demands (DI 41) and carefully defining asset quality (DI 71). To determine this, we need to know which responses were filtered by each coalition. Although one would intuitively expect a connection between these DIs and the team members, remarkably, none of the PD-TOP and the LCC-TRA pairing members selected both DI 41 and DI 71. In trying to understand why, we measure the effect size between DI 41 and DI 71 in terms of a Phi coefficient (ϕ). This coefficient measures the association between two DIs, i.e. whether the dependence between DI 41 and DI 71 is a reflection of them being shared, or not shared. The calculated ϕ was 0.816, indicating that DI 41 and DI 71 are negatively correlated and mutually exclusive. We also saw that the IT advisor (IT), the lifecycle cost advisor (LCC), the

outsourcing advisor (OUT), and the trainee (TRA) all selected DI 71 but not DI 41, supporting that the LCC-TRA pairing is partly responsible.

4.4.5 Analyzing the co-existence and competition of dominant logics from other responses

The existence of two dominant coalitions in terms of asset management, raises the question as to what extent these logics co-exist and compete inside the team? Does each of these team members rely on specific asset management associations when filtering decision issues? Are there conflicting truths in their versions of events, or simply diverging truths? To resolve this, we investigate the significance and independence of the causal maps in greater detail, analyzing linked nodes, causal links, polarities, and causal strengths.

Relying on the methodological testing routine previously described, we present an overview of all the tests performed for our revised Proposition 1 in Table 3. The first column shows the response type, Column 2 the number of significance tests performed (in an automated excel sheet) for each response type, followed by column 3 showing the number of rejected responses. For example, it is notable that, of the 9,940 significance tests on causal link responses, only 31 responses were deemed significant. Column 4 shows the number of tests for independence (for each possible combination of response types) and Column 5 shows the number of rejections for each response. In total, 271 causal link combinations of responses have been shown to be dependent. The final column shows the number of responses for each type that fully pass both tests. In essence, the dominant logic (or logics) that we are trying to identify will have caused these responses. As such, we have identified evidence of a dominant logic being present. However, we cannot as yet interpret it.

Table 3. Overview of Test Results for the Dominance of Logics

Response	Significance Testing		Testing of Independence		Responses rejected in both tests
	Number of Binomial tests ¹¹	Rejections for $\alpha < 0.05$	Number of Fisher's Exact Tests ¹²	Rejections for $p < 0.05$	
Choice of Node	71	8	4,970	4	2
Choice of Linked Node	4,970	134	3,483,970	106	50
Choice of Causal Link	9,940	31	7,455,000	271	72
Choice of Polarity	19,880	501	9,940,000	132	25
Choice of Strength	59,640	518	30,953,160	95	17

In order to interpret these results, we need to graphically assemble these responses in a causal map, representing all the metrics caused by dominant logics. The first step in interpreting these findings is to draw the map. Several software tools are available and, for reasons of parsimony, we opted for a known software tool that we were familiar with: Pajek© (Batagelj and Mrvar, 2011). Entering a causal map into Pajek requires a simple notepad file (ASCII format). A simple causal map where DI 1 negatively influences DI 2 is expressed as:

¹¹ Number of binomial tests for (a) node, (b) linked node, (c) causal link, (d) polarity, and (e) strength are determined as: (a) 71, (b) 71 x 70, (c) 71 x 70 x 2, (d) 70 x 70 x 2 x 2, and (e) 71 x 70 x 2 x 3 respectively.

¹² Two-tailed test.

*Vertices 2

1 DI-1

2 DI-2

*arcs

1 2 -1

Developing a more complex network that corresponds to our data results in Figure 4. This is a causal map of the causal links represented in our 72 tested responses. Not all these 72 responses are represented in the figure because many indicated a lack of a causal linkage between DIs, resulting in a sparsely linked map. The figure provides a visual understanding of the dominant logic(s) within the overall asset management process. It centers on DI 44 'formulating performance requirements' and reveals some sub-processes surrounding it in the asset management process.

Figure 4. The significant and dependent causal links of the team

To determine the extent that the causal map in Figure 4 is shared, we need to know whose (of the team members) logic is represented by the causal links. Using tests, summarized in Table 4, we were

able to produce a fuller picture by running the tests for every pair of individuals (Proposition 2). The first column shows the nature of the similarity tested in the responses of team member pairings. Column 2 shows the number of significance tests performed for each similar response, followed by column 3 showing the number of rejected responses. For example, of the 45 significance tests on similar choices over causal links, 11 pairs of maps are deemed significant. Column 4 shows the number of tests for independence (for each possible combination of similar responses) and column 5 shows the number of rejections for each response. Here, we see that 24 out of 45 team member pairings were deemed dependent. The final column indicates the number of responses that are relevant to our objective, namely the number of pairs of causal maps that fully pass both tests. Here, we see that no pairings offered support for similar choices over strengths, indicating that the team is imprecise about asset management on that level.

Table 4. Overview of the test results addressing Proposition 2

Pairs with ...	Significance Testing		Testing for Independence		Pairs rejected in both tests
	# Binomial tests ¹³	Rejections for $\alpha < 0.05$	# of Chi-Squared Tests	Rejections for $\alpha < 0.05$	
Similar Choice over Nodes	45	2	45	4	2
Similar Choice over Linked Nodes	45	36	45	42	21
Similar Choice over Causal Links	45	11	45	24	11
Similar Choice over Polarities	45	2	45	4	2
Similar Choice over Strengths	45	4	45	0	0

The grey boxes in the earlier Figure 4 show which groupings responded similarly to which causal link. Remarkably, we see that the dominant PD-TOP and LCC-TRA ‘coalitions’ are responsible for two large portions of the map, and both also feed larger coalitions. This indicates that the team members who fed each of these coalitions not only selected similar DIs but also put forward a consistent version of the asset management process. PD and TOP are part of a coalition seeing an influence of risk estimations (DI 6) on budget (DI 2), strategy (DI 27), and the need for detailed knowledge about assets (DI 4), whereas LCC and TRA focus on the influence of policy goals (DI 1) on risk analysis (DI 23), performance requirements (DI 44), and standardized contracts (DI 49). Overall, the LCC-TRA pairing has greater influence on the sequence of events in managing assets than PD-TOP. Overall, Figure 4 clearly shows that the two dominant logics deviate from each other and are divided over asset management.

Another question is whether there is competition or contradiction between and within the dominant logics of the PD-TOP and the LCC-TRA pairings. To answer this question, we can compare the responses indicating causal links with responses indicating no causal links between the same DI pairs, i.e. the 72 responses on causal linkages in Table 3. Here, we find only two contradictory responses. LCC, TRA, and CA believe that ‘if the agency formulates a performance requirement then this has a causal relationship with formulating policy goals’ (DI 44 → DI 1). Contrarily, PS and OUT agreed that ‘if

¹³ The number of binomial tests required equals the number of unique pair-comparisons. With ten maps, this is $(10 \times 9)/2 = 45$.

the agency formulates a performance requirement then this has no causal relationship with formulating policy goals'. However, since PS and OUT do not share a significant number of other responses, this suggests that their agreement may be coincidental. This indicates that the dominant asset management logics within the team do not significantly compete or contradict each other.

4.4.6 Findings and explanations

The tests we performed generated a set of clear findings. We found the team has deviating views about asset management that are fed by two dominant coalitions, one of the program director and the top advisor (PD-TOP) and another of the lifecycle cost advisor and trainee (LCC-TRA). These dominant logics were found on selected DIs, causal links, and polarities.

The differences between these dominant logics are explained by their specific approaches to asset management. On the one hand, the PD-TOP pair approached asset management from a more practical viewpoint and were interested in uniformity. They understood estimating object risks to be at the heart of asset management and that this should influence the annual maintenance budget, maintenance strategy, and the level of asset knowledge. The top advisor motivated his selection of ten important DIs on the basis of uniformity: "first you want to work uniformly ... in general you want to manage your risks, you need a way to make choices, ... and you are only able to do so if you know which assets you own" (interview top advisor). The program director also focused on uniformity as reflected in his comment: "the PDCA cycle, ... which I think is best reflected in this selection" (interview program director). The perceptions of the IT advisor, the implementation manager, and the contract advisor were closely related to this dominant asset management logic.

On the other hand, the LCC-TRA pairing approached asset management from a more strategic viewpoint and an interest in their own roles and contributions. They perceived formulating policy goals to be at the heart of asset management and that this influences the risk analysis, performance requirements, and role of standardized contracts. The lifecycle cost advisor motivated his selection from within his role: "of course you want to perform with the lowest integrated costs ... it is about lifecycle costs, my flagship, because it is inconceivable that you govern your organization based on technical issues rather than policy goals" (interview lifecycle costing advisor). The lifecycle cost advisor established a sequence based on "a model in my mind" (interview lifecycle cost advisor). The trainee reflected upon her role: "I based my decisions on what I know about asset management, naturally reflecting on my role working on the corporate level, so I view the bigger picture" (interview trainee). The perceptions of the outsourcing advisor and advisor were closely related to this dominant logic.

In general, we found that the team members were imprecise about the strength of causal relationships between DIs, but that there were no structural contradictory views on the causal relationships. This may be because team members generally agreed who was responsible for deciding on the most frequently selected DIs. For example, all members who selected DI 1 "formulating policy goals" (PS, OUT, LCC, and TRA) thought that their Ministry was responsible for this decision.

After presenting the two dominant logics to the team members, they pointed out that the divide could also be explained by the close collaboration between the program director and the top manager and by the fact that many subject advisors worked within departments specializing in their subject and physically located elsewhere. Therefore, it was concluded that, if asset management was

to be enacted similarly by all employees within the team and later across the organization, the team would have to establish an explicit relevance and roles for the different approaches that are already enacted within it.

4.5 Discussion and conclusions

The proposed method enables more sophisticated academic enquiries into dominant logics than previously possible, enabling a large number of logics to be considered that are enacted by a coalition ranging from the minimal size of the confidence interval up to the entire sample. This helps organizations and managers to understand and then influence the way that people within the organization predominantly approach strategic change. It also opens and complements to exciting new avenues for future research aimed at understanding how structures, e.g. rules, are enacted by practitioners in everyday practices and co-exist and compete.

One important avenue is the recognition of minority logics. These are often overlooked because their visibility is reduced by the influence of dominant players, hampering the importance that less dominant logics may have (Durand and Jourdan, 2014). To address this, a methodology must be able to give voice to dominant and subordinate logics alike, and empirically show how the minority logics are subject to dominant logics. To an extent, our method allows this because the identification of minority (e.g. IT) and dominant (e.g. PD) logics is driven by the input data rather than by definitions imposed prior to data collection.

Another avenue that is opened up is responding to the theoretical puzzle posed by Besharov and Smith (2013). They observed that, in recent years, scholars have offered many conflicting perspectives on the implications of logics, ultimately creating confusion and hampering a deeper understanding. Our method does not focus on a prior definition of what a logic ought to look like but enables that discussion to take place after data collection, in the interpretation stage. For example, in our case, we found that the two dominant logics were explained by specific approaches that the team members applied.

Another avenue lies in responding to the mounting criticism toward the approach of Thornton et al. (2012). Friedland et al. (2014) characterize it as a plastic and synthetic account of institutional logics. The methodological requirement to fix the levels of analysis means the method is unable to collect data on the multiple dimensions that practitioners may enact. Our method enables to analyze any combination of individuals to identify the relevant organizational dimensions that have connected practitioners, which responds to recent calls (Greenwood et al., 2011).

Finally, another promising avenue is in studying how logics develop over time (Souitaris and Zerbini, 2014). This is important because institutional theory often addresses the question as to whether top management should institutionalize or decouple certain practices or processes within an organization (Weaver, Treviño, and Cochran, 1999; Pache and Santos, 2013). Several theoretical explanations have been developed such as those based on the implications of critical events (Nigam and Ocasio, 2010), the use of internal contradictions by institutions to change a logic (Greenwood and Suddaby, 2006), and the distance between practitioners (Lounsbury, 2007). Our method is able to contribute with clearer and more objective data when a consistent procedure is repeated in intervals over time. Also, creating a snapshot offers a direct opportunity to explain the origins of a logic by asking clarifying questions after a respondent has just finished an intermediate step in the analysis. For example, in our case, we found that one of the two dominant logics was fed by the

interest in uniform practices by the PD and the TOP and the other by the roles and contributions of the LCC and the TRA.

4.5.1 Limitations and recommendations

Several issues related to the proposed methodology have not been addressed in this article. We see merits in future research on these issues and we therefore address them explicitly. First, our initial aim was to identify contradictions in people's perceptual filtering, and we have to admit that our attempt to do so using causal maps of an asset management team failed to provide data on distinct contradictions. In a later study, using a larger sample, we saw that a two-tailed Fisher's Exact Test was able to identify opposing views but only with a large sample. It is not yet clear what constitutes a sufficient size, but 81 individuals were clearly sufficient in the latter research. Thus, a limitation of this model is its inability to detect contradictory perceptions within a small sample. Here, we think that adopting the element distance ratio formula (Schaffernicht and Groesser, 2011) provide an alternative.

Another limitation is related to the computational power required to perform these tests quickly, especially the Fisher's Exact Test. Excel, and some alternative software tools, are not able to calculate a p-value with an integer larger than 170. Although there are more powerful software tools and websites that offer this ability with integers up to 1000, provided one p-value is calculated at a time, these will require significant computing power and time given that our demonstration already involved over thirty million Fisher's Exact Test calculations. One option, that we illustrated, is to use the Chi-Squared Test of Independence. However, this rules out any possibility of detecting contradictions in perception since it is a one-tailed test.

Another limitation of our proposed methodology is that one has to assume a probability distribution. The procedure proposed by Markóczy and Goldberg (1995) enabled us to adopt a simple binomial distribution for random events as we had used a closed questioning routine. However, a considerable proportion of the cognitive mapping community opts for free elicitations (Hodgkinson, Maule, and Bown, 2004; Nadkarni and Narayanan, 2005) and, if one favors this option, then it is challenging to find an appropriate probability distribution for use with our approach. As such, we can only recommend our model for closed elicitation procedures.

5 IMPLEMENTING ASSET MANAGEMENT IN PUBLIC TRANSPORT INFRASTRUCTURE AGENCIES: ABOUT THE EMPLOYEES AND THEIR MANDATES¹⁴

Abstract

Asset Management (AM) is increasingly recognized as an intricate component of a core business strategy for transport infrastructure agencies. However, top executives of transport infrastructure agencies and researchers have mostly addressed the implementation of AM as a top-down change and thereby fail to look at the challenges faced by employees who have to work with this change. In this paper, we go inside a Dutch agency during a strategic change in its asset management and measure and test the different viewpoints that employees have regarding asset management within the agency. Our results show that multiple logics exist that differ from and contradict the content of the official asset management strategy and associated implementation plan. We find that these differences and contradictions can be explained by the different mandates that employees refer to when thinking of a strategic change. These results highlight some legitimate concerns that are relevant for top executives and researchers regarding how agencies engage employees in making changes to existing practices.

Keywords: asset management, infrastructure management, public agency, implementation, change, dominant logic, strategy, causal mapping

5.1 Introduction

Over recent decades, transport infrastructure agencies have felt increasing pressure from their environment when managing infrastructure assets (Godau, 1999; Gifford and Stalebrink, 2002). They need to satisfy increasing stakeholder demands through better maintenance and rehabilitation of infrastructure, often while constrained by a decreasing budget (see Andrijcic et al., 2013; Bryce et al., 2014; Mostafavi et al., 2014). These developments push agencies to make decisions on the entire transport infrastructure system that represents an entirely different approach since, traditionally, infrastructure management was seen as specific decision areas for each type of asset, such as pavements or bridges (Flintsch and Chen, 2004; Schraven et al., 2015). In so doing, transport agencies have implemented Asset Management (AM) on a wide scale (Boneset al., 2014) which is also reflected in standards such as FHWA (1999), BSI (2008a, 2008b), and ISO (2013a; 2013b; 2013c). An important early standard, PAS-55, defines AM as “systematic and coordinated activities and practices through which an organization optimally and sustainably manages its assets and asset systems, their associated performance, risks and expenditures over their life cycles for the purpose of achieving its organizational strategic plan” (BSI, 2008a). Hence, *implementing AM* means that separated decisions inside the agency, such as on a bridge, are integrated in an AM decision-making process¹⁵ for the entire transport infrastructure system.

¹⁴ This chapter is under review at the scientific journal *Transportation Research Part A: Policy and Practice*.

¹⁵ We use AM decision-making process and AM strategy interchangeably in this paper. AM strategy refers to the idea of how one conceives the AM process and its decision-making steps.

Despite the transition towards AM, many AM implementations have created serious and long-term challenges for transport infrastructure agencies (Pantelias et al., 2008; Haider, 2013). However, there is still little understanding as to why AM implementation is difficult. One perspective has tried to view the implementation challenge as discrepancies between an agency's top-down strategy (or how AM should be), and the implemented result (or how AM practice is). Several evaluation schemes for AM have been developed to identify such discrepancies, such as maturity checks (Macgillivray et al., 2007; Volker et al., 2011; Brown et al., 2013) and benchmark studies (Ozbek et al., 2012; Zeb et al., 2012). However, this perspective does little more than accept that discrepancies exist between a certain standard and the current practice, and then assume that the issues will be resolved once an agency copies best practices. Another perspective focuses on the role of employees during the implementation. A case study by Povey and Peach (2013) shows that how a new AM strategy is implemented will have practical implications for the meaning of AM in the eyes of employees and the organization. An Australian study confirms that changing the AM strategy affects employees' attitudes toward the implementation (Xerri et al., 2014). Although this is a top-down perspective in looking at the challenges in changing employees views lower down the hierarchy during implementation, it has not yet offered a critical view on why employees' views make implementation difficult.

This paper adopts a bottom-up perspective from inside the agency to address the difficulties of AM implementations at transport infrastructure agencies. We argue that the AM implementation challenge stems from the role perception of employees inducing an AM understanding that can be in conflict with the view of the top management. We regard this as a 'dominant logic' problem. The 'dominant logic' concept is well known in the strategic management literature, and was first developed by Prahalad and Bettis (1986) as a prospective theory to link patterns of corporate diversification (e.g. a portfolio of different business units) to organizational performance. This brought them to the important realization that two dissimilar technologies were simpler to manage using two tailored approaches than with a single approach. Therefore, the dominant logic approach fits the AM implementation challenge of transport infrastructure agencies with their historically developed and separated logics about how infrastructure should be managed. The dominant logic concept suggests that the official top management view as to which AM process should be implemented, which we refer to as the *agency's logic*, would indeed be challenged by dominant and conflicting viewpoints held by employees inside the agency, which we refer to as *employees' logics*. Employees' logics here refer to the dominant views that employees have regarding the transport infrastructure decision-making process, and these can potentially contradict with the agency's logic.

We have two objectives: (a) to identify the extent to which employees have different and conflicting logics about the AM process; and (b) explain why *employees' logics* potentially conflict with the new *agency logic*. The paper builds upon a large case study of AM implementation in the Public Works and Water Management Agency of the Netherlands. On the one hand, the responsibility, to manage the major road and waterway networks of the Netherlands, make this case unique from an organizational context. On the other hand, the agency has been recognized for its comprehensive AM ambitions (see Moon et al., 2009; Van der Velde et al., 2013), making it a representative case of the implementation challenge. The agency's aim was to implement AM as part of their core business, and address the challenge in a top-down way with maturity checks, benchmarks, and sessions to change employees' attitudes. Yet, to avoid the type of employee challenges that the agency had experienced during previous strategic changes, they also wanted to be better prepared for the

employees' views. Using a bottom-up approach, we exposed relevant details on how the employees' thought about AM and how their ideas contradicted the agency logic.

Our principal finding is that the employees' logics seem to collide most strongly with the agency's logic over resource allocation topics and to a lesser degree on non-financial topics. Our data explain these contradictions by differences in the employees' perceived job mandates. Although the AM concept has generated a lot of diverse views, the AM implementation can only be challenged when these views contradict the course of the decision-making process. In the agency, we failed to find any dominant logics held by a majority of the employees, but rather multiple logics about AM. Moreover, we found that the agency logic was only supported by some of the multiple logics, and that opposing ideas contrasted with the agency logic in terms of budget, risk management, contractors, policymaking, and knowledge. Employees mostly held these differing positions because they referred to their own work mandate in existing practices when thinking of strategic change.

5.2 Research methodology

5.2.1 Case context

The Public Works and Water Management Agency manages major Dutch roads, waterways and coastlines for the Dutch government. The agency employs 8000 personnel and has a corporate department in the country's government-capital, The Hague, and several support departments dealing with procurement and engineering services for the numerous regional, local and project departments working in specific areas of the country.

The Public Works and Water Management Agency started with the implementation of AM ideas in 1990. Back then, the agency proposed more-objective decision-making practices in allocating resources, selecting contractors, and determining intervention strategies for the major highway and waterway systems in the Netherlands. A few years later, employees had already lost interest in the intended improvements. In a renewed attempt, top management proposed new information systems to collect data about asset deterioration but, as time progressed, employees became discouraged about using the many new systems. To avoid this during a third implementation, this time involving AM, the agency wanted to be better prepared for the employees' views or logics. In investigating the range of these *employees' logics*, we received full cooperation during the agency's third effort to implement their new *agency logic*. We discuss the details of the agency's logic and the implementation plan, and show the generalizability and relevance of this case study.

The Agency's top management assigned several tasks to a program team. The first task for the program team was to develop a new agency logic based on AM. In so doing, they developed a transport infrastructure decision-making process involving three phases that resembled a plan-do-check-act cycle, inspired by PAS-55. They described the phases of the agency's logic in a document published in 2010 (Public Works and Water Management Agency, 2010), which we summarize in Figure 1. In the first phase, the agency intended to establish frameworks that translated policy goals set by its Ministry (or the European Union) into alternative maintenance strategies. In the second phase, the agency would translate these alternatives into plans to deal with risks and performance and then submit these plans to the Ministry for a decision. In the final third phase, the agency would agree a four-year plan with the Ministry and then translate this agreement into internal management contracts between the corporate office and the support and regional offices.

Figure 1. Agency logic on AM decision-making and its planned changes derived from the program team's internal publications

Once the developed logic was approved, top management assigned the program team the task of implementing the new agency logic uniformly, such that employees would not deviate from it across the entire work process in the organization. The program team planned five changes (see Figure 1) to achieve the implementation of the new logic (Public Works and Water Management Agency, 2011).

First, the program team set a target of implementing a uniform and always available online system to provide *information on asset conditions*. They anticipated that having more uniform and online information on the condition of assets would improve the trade-off between different maintenance strategies through having better informed scenarios such that the strategy selected would meet the required asset performance. This AM-based change is also relevant beyond the case studied since associated research has proposed also using condition information to address uncertainty in deterioration rates when developing maintenance policies (Durango and Madanat, 2002) and applying evidence-based decision-making (Bones et al., 2013).

Second, the program team planned to implement *long-term planning of maintenance needs*. They expected such planning to help the agency anticipate the consequences, in terms of risk and performance issues, and the need for maintenance over the long term so as to be in a position to offer sound plans to the Ministry and agree on a procurement strategy. This AM-based change is also recognized within transport infrastructure research as vital for closing the gap between short-term commitments and longer-term needs (Andrijic et al., 2013).

Third, the program team aimed to implement *frameworks that connect maintenance strategies to the performance and risks of assets* so that trade-offs could be made. They expected such frameworks to improve the agency's ability to consistently translate agreements between the Ministry and the corporate department in all three phases of the process. Again this AM-based

change has relevance outside this particular case since frameworks are formulated and applied to more quantitatively define a range of decision problems linked to transport infrastructure, such as resource allocation problems (Durango-Cohen, 2007) and structural health monitoring (Chen et al., 2007).

Fourth, the program team aimed to implement a *long-term procurement strategy with new contract formats*, such as performance contracts and contracts with greater devolved responsibility such as the 'Design Build Finance and Maintain' contract approach. They expected that a long-term procurement strategy, with new contract formats, would optimize cooperation between the agency and contractors. This AM aspect is similarly addressed elsewhere in transport infrastructure research, such as when addressing the effectiveness of safety-based initiatives between public and private partners (Rangel et al., 2012).

Finally, the program team aimed to implement *lifecycle costing techniques*. They expected lifecycle costing techniques to influence long-term maintenance needs through enabling informed decisions and evidence-based policymaking with the EU and with the Ministry. Again, transport infrastructure research has developed many methodologies to minimize lifecycle costs for various types of assets (Mishalani and Gong, 2009) including pavements (Gu et al., 2012).

In an attempt to implement these new practices uniformly, the program team held (among other things) training sessions and undertook benchmark studies and pilots to increase awareness of these new practices in all departments from the corporate level down to the local and project levels. It was during these activities that the program team was confronted with employees' diverse perceptions and perspectives of AM. For example, when they asked each regional department to make a strategic plan to move toward a uniform AM practice, they received different proposals. More specifically, some employees did not see any need to change current practices, whilst others perceived AM as a vague term that lacked clarification and attention in the agency. Although the program team had developed a defensible and reasoned decision-making process and associated changes, that alone was clearly insufficient to make employees receptive to the proposed implementation.

5.2.2 Data collection and analysis

Dominant logic is a well-known concept in strategic management. This highlights that proposing a new logic, i.e. another way to make business decisions, may fail as a result of the diverse and opposing conceptualizations that employees deem relevant to AM (e.g. Bettis and Prahalad, 1995), for example resulting from a tension between public and commercial interests (Sanders and McClellan, 2014). Detecting logics helps to identify dominant AM decision-making process that operation-level employees find logical, and these logics indicate aspects where an organization is likely to experience a strong reluctance to change. As such, detecting the dominant logics indicates whether an elaborated decision-making process will be seen as logical or illogical by employees and why.

After preliminary discussions with the program team, we focused on three main research steps. First, we explore which decisions mainly come to mind in the decision-making over transportation in the infrastructure agency across the relevant management and job occupations. Second, we measure the extent to which the employees' asset-management logics are dominant in these transportation decisions. In the third and final step, we seek the reasons why certain logics are the most dominant when it comes to AM in the decision-making.

5.2.2.1 Step 1: Main transport infrastructure decisions according to employees

The *first* step is to clarify which decisions are likely to be part of a dominant AM logic, and what job occupations are relevant in preparing or executing these decisions. Dominant logics are seen as conceptualizations of a process and these may be filtered by strong preferences for a specific perspective (Lane and Lubatkin, 1998) or through common references that people have (Lampel and Shamsie, 2000; Garg et al., 2003; Novicevic and Harvey, 2001). In discussions with three experts from the program team, we identified the most relevant roles as top management, corporate staff, policy advisors from support and regional departments, and the planning and project teams of local and project departments.

For our research, it is important to develop a quantitative means to collect individual conceptualizations while ensuring the answers are comparable across the sample since subsequent questions depend on answers to the previous ones. Causal mapping is an approach that captures and builds a mental model of causal relationships among concepts related to a person or an entity (Langfield-Smith and Wirth, 1992). By employing these techniques, we can first employ preliminary and open interviews to produce an inclusive set of concepts (Markóczy and Goldberg, 1995; Langan-Fox et al., 2000) that cover the decisions that employees most probably associate with AM. This output can then be used in formulating later questions.

During the preliminary interviews, we asked employees to tell us what they thought the goal(s) of AM were, the related problems they face, the solutions they have, and linkages between actions and desired results. These aspects were included in earlier studies on logics (Lengnick-Hall and Wolff, 1999). Also, more indirectly, we asked them to indicate frameworks, agreements, or plans that have arisen from decision moments. To ensure the inclusiveness of our decision set, we asked people to think back to other decisions that they could recall. We fully transcribed all the explorative interviews and coded consistent remarks that described the events that several respondents addressed.

5.2.2.2 Step 2: Employees' logics regarding asset management

In our *second* research step, we want to identify the dominant logics among employees. Research has shown that communities of employees, such as hospital employees (Vardaman et al., 2012) and teachers (Chong, 2005) share logics within a dominant coalition. In order to determine which AM logics are dominant, we analyzed which conceptualizations are shared by groups of employees. For this, we interviewed workers across the hierarchy.

In total, we selected 82 employees in accordance with the key job occupations we had identified earlier. An overview is provided in Table 1. Employees were selected from three support departments (engineering, procurement, and ICT) and two regional departments, each with three local departments and four project departments. We had to drop one interview (with a project risk and control specialist) from the final analysis because we adjusted the protocol after the first interview (with this specialist), leaving a total of 81 interview results for further analysis.

In these interviews, we followed the questioning routine proposed for the causal mapping procedure by Markóczy and Goldberg (1995). This involved the interviewees in:

- Selecting a pool of 10 key decision events in AM;
- Reflecting on the 90 causal relationships between these events over time;

- Considering the causal polarity (what decisions influence the direction of a subsequent decision event);
- Assessing the perceived causal strength of the indicated direction of influence.

Table 1 – Respondents and their occupations at the Pubic Infrastructure Agency

Departments and Occupations	Number of Respondents
<i>Corporate department (1 office)</i>	3
– Top Management (head)	1
– Corporate Staff	2
<i>Support departments (3 offices)</i>	13
– Director of Support Operations (head)	1
– Program Manager	1
– Asset Management Advisors	5
– Engineering Advisors	2
– Procurement Advisors	2
– ICT Advisors	2
<i>Regional departments (2 offices)</i>	18
– Regional Director (head)	2
– Business Control Advisors	2
– Regional Procurement Advisors	2
– Middle Manager	2
– Strategic Planning Advisors	4
– Asset Quality Advisors	3
– Traffic Advisors	3
<i>Local departments (6 offices)</i>	26
– Infrastructure Zone Manager (head)	6
– Senior Maintenance Planner	6
– Maintenance Planner	9
– Senior Legal Affairs Planner	3
– Response Team Manager	2
<i>Project departments (4 offices)</i>	22
– Senior Project Planner (head)	2
– Project Leader	4
– Tender Specialist	4
– Environment Specialist	4
– Technical Specialist	4
– Project Risk and Control Specialist	4 (1 dropped)

If respondents had been allowed to include an unrestricted number of decisions in their causal map, this would result in considerable fatigue (Hodgkinson et al., 2004). Others have concluded that setting a limit of 10 decisions allows for sufficient variance in the data and avoids fatigue (Markóczy and Goldberg, 1995).

It is also important to find a coding scheme to record the responses of employees during an interview since successive questions are contingent on previous answers. This further enabled us to compare employees' views by counting the number of times given responses occurred and pairs of responses co-occurred in the data using the distance ratio and central maps approaches of Markóczy and Goldberg (1995). Calculating a *distance ratio* (DR) is a commonly accepted approach in analyzing the differences between any pair of maps (Langfield-Smith and Wirth, 1992; Markóczy and Goldberg, 1995). The DR is a single indicator that sums all the individual differences between two maps and

divides this total by the greatest possible difference between the maps. This generates a number between 0 and 1, where 0 indicates identical maps, and 1 indicates completely different maps. A *central map* is a causal map that reflects the views of the majority and, in our case, identifies the ‘dominant’ perceptions of AM.

To gain greater insight into what led to the differences in the causal maps, we triangulated the findings on DR means and central maps with the *probability of responses*. The adopted closed elicitation procedure of Markóczy and Goldberg (1995) resembles a multiple-choice questioning routine that allows a statistical analysis of the likelihood of responses, i.e. testing the significance of a selected top-10 decision, and the independence of responses, i.e. the joint probability of selecting both decision 1 and decision 2. In this approach, significant and dependent response patterns are seen as indicators of AM logics.

5.2.2.3 Step 3: Dominant and minor asset management logics

In our *third* step, we want to explain why certain dominant coalitions between employees exist. Therefore, we asked all the respondents to explain the reasons for including decisions in their top 10, who they perceived as having responsibility for each decision, and what they referred to when seeing causal relationships in the process. It is important to note that the answers obtained refer to the same agency and the same implementation. We also included questions about the interviewees’ backgrounds. The background information concerned their education and previous work experience, both in and outside the agency.

5.3 Results

In this section, we present the results related to the three questions in our empirical study.

5.3.1 Important transport infrastructure decisions according to employees

Employees offered ample qualitative data on critical decision moments that they had either experienced or knew about from work documents such as procedures, frameworks, or business plans. We collated similar events, labelled the underlying decisions and actions starting with a verb to signify a human action, and simplified the range of possible actions for the causal mapping procedure to a binary choice. For example, we described one decision issue as ‘formulating policy goals’ with a binary choice set of ‘either generic or specific policy goals’. In due course, we verified the representativeness of the labels and the comprehensiveness of the 71 identified decision and action events by relating them to AM documents and in discussions with the agency’s program team. To summarize, this list encompasses the decision events that employees repeatedly encounter in the agency, and covers an extensive range of issues that we would expect their peers to relate to AM¹⁶.

5.3.2 Employees’ logics regarding asset management

5.3.2.1 Related and unrelated views

Table 2 shows the DR means measured between each office type. For example, the average of all the DRs calculated between every corporate office employee and every support office employee was 0.24. As such, these two groups appear less distant than the local and regional offices with a mean DR of 0.36. Overall, Table 2 shows that the corporate, support and regional offices have lower DR means to each other than that between the local and project offices. This indicates that employees

¹⁶ See Appendix B for the full list.

whose jobs offer greater jurisdiction have more similar views about AM than do lower-level office members.

Table 2. Distance Ratio of the Offices

	Corporate office	Support office	Regional office	Local office	Project office
Corporate office	0.17	0.24	0.23	0.29	0.28
Support office		0.31	0.29	0.36	0.35
Regional office			0.28	0.34	0.33
Local office				0.40	0.39
Project office					0.38

The DR means highlight the similarity or otherwise of views between and within predefined groups. In terms of occupation, we found a higher level of agreement within the corporate department between the top manager and the corporate staff (DR = 0.18). The top manager also shows shared views with most other office leaders - with the director of support operations (DR = 0.25), regional directors (DR = 0.20), the senior project planner (DR = 0.18) and the infrastructure zone managers (DR = 0.30). Interestingly, this suggests that heads of department and corporate staff have more similar views about AM with each other than with their own department members.

Inside the other key jurisdiction departments (regional and support) we see that regional infrastructure policy experts, i.e. the middle managers, strategic planning advisors, asset quality advisors, and traffic advisors have relatively low DR means (between DR = 0.18 and DR = 0.23) within and between each group. The business support functions, namely business control advisors, regional procurement advisors, and ICT advisors have higher DR means (between DR = 0.48 and DR = 0.50). This indicates that, inside the regional offices, the views of infrastructure policy experts on AM are more alike than those of employees in business support functions.

Inside departments lower down the hierarchy, we see that both those employed in planning functions in the local department and those in contract and technical functions in the project department tend to have views unrelated to their colleagues on AM (between and within the groups the DR values are > 0.40).

These patterns of related and unrelated views give an initial feel for which predefined groups appear to agree about what AM is. However, it does not show what leads to these patterns and why employees seem divided or agreed about the subject.

5.3.2.2 Most important AM decisions in maps

In Table 3, we show the ten decisions most frequently selected by the entire sample. A central map reflects the causal map shared by the majority and this indicates the 'most dominant' perceptions, in this case about AM (Markóczy and Goldberg, 1995). To be truly dominant, a map should be shared by more than half of the sample (in our situation, at least 41 out of the 81 maps). However, even the most 'popular' decision was selected by less than the half: allocating the maintenance budget by objective criteria [2] was present in only 38 maps (see Table 3). This shows us that employees have multiple distinct ideas about the relationships between decisions.

Table 3. The ten most important decisions across the entire agency

Description of Main Decision [identifier]	In maps
Allocating maintenance budget [2]	38 / 81
Determining a desired level for asset quality [46]	35 / 81
Estimating the risk for an object [6]	30 / 81
Determining a standard for registering asset data [5]	29 / 81
Applying a maintenance management system [7]	27 / 81
Determining a level of knowledge about assets [4]	26 / 81
Formulating performance requirements [44]	26 / 81
Assuring presence of knowledge about infrastructure within the agency [21]	25 / 81
Determining a maintenance strategy [27]	25 / 81
Determining the definition of asset quality [71]	24 / 81

5.3.2.3 Probability of response patterns

We systematically tested all the components of the causal map in the following order: 1) selecting decisions, 2) linking decisions, 3) causally relating decisions, or not, 4) causally polarizing decisions, and e) assigning a causal strength between decisions. It was not until we tested the second aspect, i.e. 'linking decisions', that an array of multiple patterns became detectable. This indicates that employees have multiple distinct ideas on the relationships between these decisions.

A node in Figure 2 indicates that employees have sufficiently frequently linked two decisions for this linking to be statistically significant. Further, a straight line between two nodes indicates that employees have simultaneously linked two pairs of decisions sufficiently often for this to appear statistically dependent, i.e. that the two pairs of 'decision linkages' are mutually dependent. The software program CFinder places colored shapes around the distinct patterns that these nodes and lines produce (see Figure 3).

In Figure 2, two patterns are placed in the center, signifying that these are the dominant ones. The upper pattern concerns decisions that seem related to budgeting issues; for example, decisions about allocating the maintenance budget [2], allocating human capacity to project work [26], and estimating costs [68]. The lower pattern consists of decisions that seem related to risk issues; for example, estimating risk levels of objects [6] and applying a probabilistic approach to maintenance [65]. From this analysis, we conclude that, inside the agency, most views on AM are dominated by the idea that it is either essentially related to a 'Budgeting' strategy or to a 'Risk Management' strategy.

There are also several patterns in the peripheral areas of Figure 3. A few of these seem to focus on similar topics. For example, there are four patterns that focus on the relationships between the agency and its contractors. There appear to be different strategic intentions in these relationships, such as applying greater quality control on contractors [14] or, conversely, allowing contractors to plan the maintenance rather than the agency [15]. Figure 3 also highlights four patterns related to 'knowledge' management' and two about 'policymaking'. In all three topics, the patterns highlight different viewpoints on these aspects, which might explain the differences and similarities we saw between people. Following from this, it seems that there are multiple minor disagreements inside the agency on how the AM strategy is supposed to deal with 'Contractor Relationships', 'Policymaking', and 'Knowledge management'.

5.3.3 Dominant and minor asset management logics

Our results provide empirical evidence suggesting that there are two strong patterns reflecting the two most dominant logics inside the agency. By combining the background and reasoning of employees holding these logics, we can discover why employees hold them.

5.3.3.1 The 'Budgeting' Logic

Twenty-two employees in our sample adhere to the 'Budgeting' logic in which AM is thought of as a budgeting process. The strategy is seen as structuring a basic process for justifying and allocating budget plans so as to create economies of scale in the execution of maintenance and construction projects.

In the 'Budgeting' logic, justification and allocation are the most dominant issues in structuring a basic process. Figure 4 shows these decision issues and their causal relationships. To justify a budget, the agency needs to determine the desired asset quality [46] and to formulate performance requirements [44]. Most adherents to this logic believe that these issues are decided internally by the corporate and support offices and externally by the Ministry of Infrastructure.

To allocate a budget, using this logic, the agency must determine which maintenance strategy [27] to apply to execute the maintenance work and must allocate a maintenance budget using a set of criteria [2]. Most supporters of this logic believe that the corporate, support, and regional offices decide these issues. The engineering department of the support office is seen as determining the maintenance budget, and both the engineering and the procurement departments decide the maintenance strategy.

When the agency makes clear decisions on these issues it enables it to deal with lower-level issues and create efficiencies of scale in the execution of maintenance and construction projects. Examples of such issues that came to light in our analysis were of bundling projects [57] and in allocating human capacity to project work [26]. These matters are dealt with by the support, regional, and project offices. The regional office bundles the projects. Both the head of the project office and the procurement department of the support office allocate human capacity.

Figure 4. The 'Budgeting' logic

5.3.3.2 The 'Risk Management' Logic

Twenty-three employees in our sample held the 'Risk Management' logic, and see adopting AM as a process about '*managing the risks*' that can occur with assets. The strategy is seen as facilitating interaction and developing a clear procedure for estimating risks and applying certain approaches to monitor risks.

In the 'Risk Management' logic, the most dominant issues in facilitating interaction and developing a clear procedure are estimating risks [6], prioritizing between types of assets [17], and approaching maintenance using a probabilistic approach [65] to cover the risks. Figure 5 shows these decision issues and their causal relationships. Many of the adherents to this logic believe that the engineering and procurement departments in the support office and the regional office decide upon these issues.

Provided the agency makes clear decisions on these matters it can then deal with more minor issues to capture and reduce risks for the agency. Clear examples of such issues are determining a desired level of asset quality [46], applying a maintenance management system [7], and inspecting assets [55]. Most supporters of this logic believe that the engineering department determines the desired level of asset quality, and that the procurement department applies the maintenance management system [7]. Both the engineering and procurement departments decide on inspecting assets [55].

Other issues that these decisions affect are allocating the maintenance budget [2], determining the condition of assets [3], and determining the maintenance strategy [27]. Most supporters of the 'Risk Management' logic believe that the corporate and support offices allocate the maintenance budget, and that the procurement department and local and project offices determine the condition of assets [3]. The engineering department determines the maintenance strategy.

Figure 5. The 'Risk Management' logic

5.3.3.3 Minority Logics concerning 'Contractor Relations', 'Policymaking', and 'Knowledge Management'

On the periphery of Figure 3b, there are several minor logics¹⁷ that reflect the importance attached to AM for contractor relationships. In a general sense, these focus on managing the relationship between the agency and contractors in order to improve the quality of the public works output. For example, the agency can decide to allow a contractor to plan maintenance [15].

Another set of minor logics sees the importance of AM as focusing on policymaking. This set of logics links AM to policymaking in translating policies to achieve greater goal clarity. For example, these logics see a prominent decision as that the agency is able to formulate policy goals in either general or specific terms.

A final range of logics sees the importance of AM in that it can capture and preserve knowledge about infrastructure. In general terms, by using these logics, the agency is expected to manage and safeguard existing knowledge within the agency.

¹⁷ We refer here to multiple logics regarding 'Contractor Relations', 'Policymaking' and 'Knowledge Management', since there is more than one pattern related to each aspect.

5.3.4 Contradictions between employees' logics and agency logic

The multiple employees' logics that this empirical study exposed also appear to have inconsistencies and contradictions that divide employees on the issues that the agency is attempting to implement through a single AM decision-making process. Table 4 summarizes the most apparent contradictions. The table shows that several contradictions exist both within and between the 'Budgeting' and the 'Risk Management' logics. It also shows that several of the minority logics conflict where their subjects overlap, namely contractor relationships, policymaking, and knowledge management. Here, we discuss why these *employees' logics* conflict and why these challenge the agency logic.

Table 4. Overview of contradicting logics

Contradiction	Opposing views	
1. Between 'Budgeting' and 'Risk Management' logic	• <i>Demand-based resource allocation*</i>	• <i>Supply-side resource allocation</i>
2. Within 'Budgeting' logic	• <i>Budgeting has no impact on other decisions*</i>	• <i>Budgeting has impact on other decisions</i>
3. Within 'Risk Management' logic	• <i>Managing risks impacts on other decisions*</i>	• <i>No impact of managing risk on other decisions</i>
4. Between minority 'Contractor Relations' logics	• <i>More responsibility to contractor*</i>	• <i>More control over contractor</i>
5. Between minority 'Policymaking' logics	• <i>Performance-driven policymaking*</i>	• <i>Problem-driven policymaking</i>
6. Between minority 'Knowledge Management' logics	• <i>Creating new knowledge base*</i>	• <i>Preserving old knowledge base</i>

* This viewpoint tolerates the agency logic

5.3.4.1 Contradiction #1: Supply or demand?

The 'Budgeting' and 'Risk Management' logics contradict as to whether budget or risk priorities come first when allocating resources. The 'Budgeting' Logic (supported by a large proportion of the project office) approaches AM from the supply side and autonomously allocates the entire set of resources intended for maintaining assets. For example, one environmental specialist remarked, "*we have already for a long time planned the entire budget for construction and maintenance needs by ourselves*". The 'Risk Management' logic (supported by many local department employees) approaches AM from the demand side by finding motivation for allocating resources to risk priorities or non-functioning assets. A typical response was given by an infrastructure zone manager who "*was continuously thinking about maintenance needs in terms of risk and the necessity for resolving these*".

The implementation plan goes against the idea that budget priorities should come before risk priorities. In the agency's logic, the conceptualization is that maintenance plans are detailed in terms of risk and performance parameters, and then the Ministry prepares a budget. To do this, the agency requires the ability to predict maintenance needs, and risks, over the long term and to do this prior to a budget being established. Consequently, the program team focuses on a demand prediction (a risk management logic) before determining the budget (a budgeting logic). However, the 22 employees who adhere to the 'Budgeting' logic see the sequence as the other way around or do not

perceive such a sequence exists. A corporate staff employee mentioned this conflict of logics *“there is quite some discussion on the extent to which a maintenance budget can be justified or not”*.

5.3.4.2 Contradiction #2: The impact of budgeting

Employees who support the ‘Budgeting’ logic are not entirely in agreement over whether determining a budget in advance has a direct impact on other decisions and thus constitutes an effective AM strategy. They seem to disagree on the causality between determining the desired level of asset quality [46], allocating the maintenance budget [2], determining the maintenance strategy [27]. They also seem to disagree on the causality between the maintenance strategy [27] and the allocation of human capacity to project work [26]. Particularly employees from the project department believed such relationships existed and based their thinking on their desirability. For example, a project leader who related the maintenance strategy [27] and human capacity [26] to each other believed that *“at least the decision on capacity is an important influence on asset management”*, whereas a procurement advisor (support department) did not see that influence because *“in many practical examples, I can find many additional influences rendering each decision an independent choice”*.

The implementation plan contradicts the idea that allocating the maintenance budget will impact on other decisions. In the agency’s logic, the Ministry prepares the budget based on the reworking of the maintenance plans into a tactical plan by the support and corporate departments of the agency. Since the budget is prepared after the plans are made, the agency needs to protect itself against political influences changing the budget. Here, the program team uses lifecycle costing techniques and provides the Ministry with a long-term plan for maintenance needs. Nevertheless, some of those adhering to the ‘Budgeting’ logic still reason that the budget needs short-term flexibility to be able to reallocate resources such that projects can be bundled or project teams can boost their capacity when needed.

5.3.4.3 Contradiction #3: The impact of managing risks

Employees adhering to the ‘Risk Management’ logic do not fully agree on whether prioritizing risk management has a direct impact on other decisions and thus constitutes an effective AM strategy. They seem to disagree on the causality between applying a maintenance management system [7], estimating risk levels for objects [6], and applying a probabilistic approach to maintenance [65]. They also seem to disagree on the causality between allocating budget by objective criteria [2], applying probabilistic approach to maintenance [65], and estimating risk for objects [6]. The employees in the local departments largely believe that causality exists because they see it is their role to make risk-related decisions. For example, a senior maintenance planner saw a causality between applying a maintenance management system [7] and choosing a probabilistic approach to maintenance [65] because she thought that the causality was desirable. Other departments did see the possibility of causality between the maintenance management system and applying a probabilistic approach but were less certain. For example, a top manager admitted that *“causal relationships might easily exist, but I cannot say whether this is the case if I am not aware of it”*.

The implementation plan contradicts the view that managing risks does not impact on other decisions. In the agency’s logic, risk parameters are conceptualized as a core ingredient of the tactical plan that the Ministry uses to prepare a budget. Since the Ministry therefore considers the risks involved, the agency can use risks to bring a strong case for alternative plans. This means that the

program team needs to implement a uniform, continuous online flow of information about assets and their condition, and long-term plans for maintenance needs. However, some of the 22 'Risk Management' logic adherents do not see risks as such a self-evident measure for influencing the budget or other decisions.

5.3.4.4 Contradiction #4: Contractors - control or give responsibility?

Several minor logics exist that view contractor relationships as important in AM, but there are two camps that disagree about the form of contractor relationship that the agency should engage in. On the one hand, there are logics that see AM as *controlling the contractor*, i.e. in which the agency decides whether to apply a quality control on a contractor [14] and whether to deliver asset information to a contractor [13]. In general, employees from the corporate and project departments support this approach in order to ensure that contractors perform, or to ensure that the agency can prevent contractors from taking risks. On the other hand, there are a few logics that express AM as being about giving *more responsibility and freedom to the contractor*, i.e. in which the agency decides whether to adopt improvement suggestions made by a contractor [38], allows contractors to plan maintenance [15], lets contractors govern the maintenance management system [24], and lets contractors do the inspecting [56]. Mostly, it is employees from the local and project departments and those with a civil engineering background that support giving more responsibility to contractors, because they see such developments as the right thing to do.

The agency's implementation plan goes against the idea of having more control over contractors. In the agency's logic, it was conceptualized that the regional departments would establish the rules and guidelines for contractors performing public works. Worldwide, private firms are increasingly maintaining public infrastructure and, as such, the agency is experimenting with the effectiveness and efficiency that individual contractors can bring to the process. As part of this, the program team is implementing a long-term procurement strategy with new contract formats that establish greater freedom for contractors. However, many of the employees in favor of more control emphasize the importance of the in-house expertise, arguing that *"if a contractor brings you an innovative idea, you need to be prepared for determining its feasibility"* (interview with a senior maintenance planner).

5.3.4.5 Contradiction #5: Performance or problem-driven policymaking?

There are minor logics present that see policymaking as an important aspect of AM, but there are two camps when it comes to the desirable purpose of policy goals [1]. On the one hand, there is a minor logic that believes that AM should be concerned with formulating policy goals to resolve other *relevant issues*, such as concerns with the budget, information, performance, and knowledge. It is employees from the local departments that mostly support this idea and they typically see policy as a tool to solve the problems they experience. On the other hand, there is a minor logic that expresses the idea that policy goals should be formulated so that performance can be reported. Here, policy particularly needs to include clear definitions of asset quality [71]. This logic tends to be supported by employees from the regional and support departments. Most of them are in advisory roles and they apply the theory that policy is driven by performance definitions and measurement systems.

The agency's implementation plan goes against the idea that policymaking should primarily solve practical problems in other areas. In the agency's logic, policy goals are, in a top-down approach, translated into strategic, tactical, and operational frameworks that, eventually, the regional departments will follow. With stakeholders becoming increasingly outspoken, the agency feels under

pressure to measure its accomplishments in a top-down manner. This is why the program team is implementing long-term plans for its maintenance needs and a framework that links the maintenance strategy to asset risks. However, many employees are in favor of solving practical problems with policy, and they reason that a lot of work needs to be done before new ambitions are introduced. A clear example was brought up by a maintenance planner who said *“the least clear assets to manage are the low-value assets, it is important to understand that a lot of policy issues are unresolved”*.

5.3.4.6 Contradiction #6: Old or new knowledge base?

Some minor logics regard knowledge as an important source in managing assets, but again there are two camps that, this time, see AM as needing to use different knowledge bases. One set of logics expresses the idea that AM should preserve the existing knowledge base [21] and quickly adjust plans [37] in response to changing risks or budget cuts. Supporters of this idea frequently have civil engineering degrees. Another set of logics expresses the view that AM should focus on creating a new knowledge base, with improved ways to register data [5] and a systems-engineered architecture of decomposed assets in place [59]. Employees in favor of this idea often have second degrees and see knowledge as an essential resource that can be used in a multidisciplinary way.

The implementation plan contradicts the idea that AM should first and foremost preserve the old knowledge base. In the agency's logic, the concept is that the agency will make many frameworks and subsequently plans that are based on the policy goals of the Ministry. Since stakeholders are increasingly demanding to know how public money is spent, the agency wishes to more directly justify its plans using reliable and robust information. It is with this goal in mind that the program team is implementing a uniform, continuous online information system of assets and their condition. Despite this, many employees in favor of preserving old knowledge continue to appeal to the human expertise that is required for managing assets. A clear example was conveyed by an infrastructure zone manager: *“I think we need to be well aware of the kind of knowledge needed in a local department ... because as experts we need to know which data are relevant in specific cases, such as how a contract was put together”*.

5.4 Discussion

In the result section we showed that the AM process was subject to unrelated views, dominant and minor logics and that the implementation plan faced several contradictions. These results contribute to the current AM literature on specific points.

5.4.1 Diverse nature of the AM concept

To a large degree, the difficulties in implementing AM have been attributed in the literature to the diverse nature of the AM concept. For example, it has been recently shown that sectors can have different drivers, constraints, and benefits in implementing AM (Cardoso et al., 2012). This has been viewed as especially difficult when the intention is to integrate historically separated ways of managing infrastructure into one AM decision-making process (Moon et al., 2009). The relatively high DR (distance ratio) means between and within many groups (like departments and functions) in our study confirm such diversity is present in AM. For example, both those employed in planning functions in the local department and those in contract and technical functions in the project department tend to have different views compared to their colleagues on AM (between and within the groups the DR values were > 0.40). More specifically our study identified contradictions indicative

of implementation challenges. For instance, the program team focused on a demand prediction (for maintenance) before determining the budget. Here, the contradiction between the 'Budgeting' and the 'Risk management' logics indicates an obstacle because employees doubt whether maintenance plans can be fully justified in advance. Therefore, diverse views of the AM concept do not necessarily serve as a precursor for problems, rather it becomes a problem when different perspectives contradict each other.

5.4.2 Discrepancies between logics at the top and bottom

In the literature, the difficulties in AM implementation have also been attributed to discrepancies between how infrastructure should be managed and the way it actually is managed. This has been the main reason found in maturity checks (Macgillivray et al., 2007; Volker et al., 2011; Brown et al. 2013) and benchmark studies (Ozbek et al., 2012; Zeb et al., 2012). In adopting AM approaches, transportation agencies often set criteria on what makes AM mature or a best practice, often inspired by or even following standards such as FHWA (1999), BSI (2008a, 2008b), and ISO (2013a; 2013b; 2013c). Two observations from our study raise an important cautionary tale on the discrepancy perspective.

In the lower-level departments, we see that personnel have views that are more unrelated than those working in higher-level departments. Local and project departments' personnel view AM as their department's business before it is the agency's business. Local department personnel reason that the old knowledge base, managed by them, needs to be preserved. Project department personnel differ greatly from the views of others, particularly when it comes to the contractor relationship and the 'Budgeting' logic. The most recurring reason was that employees in the lower-level offices view AM in terms of their personal mandate or desirability. This shows that the diverse mandates at the bottom of the hierarchy are not unified in the strategy at the top. In the main, this restricts the practicality of benchmarks and maturity to help indicate challenges that stem from contradicting views.

Higher up the chain, we see that employees in the corporate, support and regional offices exhibit fewer contradictions. A recurring explanation for this is that corporate staff and regional infrastructure policy experts often work as advisors and participate in discussions regarding strategic changes. Examples included a corporate staff employee who was aware of a budgeting discussion and policy experts who had explored theoretical ideas on formulating policy goals as performance targets. Nevertheless, here also, employees seem to view AM from their personal mandate. This shows that employees working near the top have a mandate to continually discuss strategic changes, which results in AM being an emerging topic in terms of strategy. In essence, this limits the usefulness of static approaches such as benchmarks and maturity checks and using standards such as PAS55 or ISO55000 lower down the hierarchy.

5.4.3 Employees and their mandate

Recently, another perspective has emerged that suggests that the role of employees can be affected by AM implementations (Povey and Peach, 2013; Xerri et al., 2014). Our study contributes an important aspect regarding why employees make implementation difficult.

In searching for dominant logics, we failed to find any AM logic supported by a majority of employees within this agency. The central map approach failed to even find a majority for any specific decision. However, the 'Budgeting', 'Risk Management', and the minor logics discussed earlier do reveal that

decisions are linked to certain views that constitute distinct logics about AM. This means that instead of there being dominant AM logics shared by most employees of the Dutch agency, we found several contradictory logics about the AM process that individuals conceptualize from their personal mandates.

Our results related to these distinct logics show that employees can affect the implementation when they have contradictory views on similar decision areas. For example, the 'Budgeting' and 'Risk Management' logics, supported by project and local departments respectively, contradict as to whether budget or risk priorities come first when allocating resources. This directly impacts AM implementation, as it amounts to a disagreement over how resources, which both the project and local departments need, are allocated. For this reason, understanding the mandates that employees stick to is critical for top management when integrating the decision areas that employees work in.

5.4.4 Managerial implications

Our findings lead to some tangible implications for top executives who are responsible for AM.

Firstly, AM implementation should focus on removing contradictions between decision areas where people are working and in the relationship between decision areas. Our results have shown that a change an agency wishes to make can be either hampered or strengthened by its various receptions, depending on employees' mandates in their current jobs. This indicates that management should map potential conflicts (Tam and Tong, 2011) and address the corporate cultures (e.g. Meding et al., 2013) in the job occupations affected. For example, in planning more freedom/control for the contractors, the program team is implementing a long-term procurement strategy with new contract formats that establish greater freedom for contractors. Here, they could remove contradiction #4 by giving more freedom to the in-house experts to execute controls over the contractors' work.

Secondly, AM implementation should focus on the development of previously underdeveloped decision areas. Some studies have addressed the role of employees during an implementation by seeking strategies that can influence the attitude of employees (Xerri et al., 2014). Here, the dominant logic approach shows that the need is not to change employees' attitudes but rather their perceived purpose since their logic is tied to their job mandate. Therefore, management needs to establish a new mandate for the employees before the employees will be able to change to new AM-like practices. For example, in changing the knowledge base and predicting the demand for resources, the program team is implementing a uniform and online information system. Here, at least one difficulty exists since justification based solely on automated systems weakens the much-needed contextual judgment by experts in making a sound plan. They could make employees mandate more meaningful in the process with the greater use of online asset monitoring and diagnostics (e.g. Bones et al., 2013).

5.4.5 Limitations, Recommendations and Future Research

The method applied in this paper has certain limitations. First, the causal mapping elicitation procedure involves a fixed, limited, number of concepts in quantitatively comparing the issues relevant to a phenomenon. In our application of the method, there were several concepts that practitioners in the causal mapping elicitation round were surprised that their peers had not already raised in the preliminary interview round. Nevertheless, it is encouraging that the program team recognized the set we did use, showing the relevance of this set to the agency's AM change agenda.

Another limitation is that the procedure involving physical interviews is time consuming. We had to travel around to personally meet all the 81 respondents and interview them according to the same protocol. Such requirements limit the number of employees one can realistically include in future investigations. However, achieving a large reach is important if one wants to quantitatively compare a realistic representation of a large agency.

Finally, the contradictions we identified and described are not direct evidence of problems in practice, rather they are indications of agency mandates and employee mandates competing with one another. Because the method focuses on individuals' perspective, it can point to less apparent convictions that can lead to difficulties for implementing changes.

Some recommendations for transport infrastructure researchers can be made based on this study. Firstly, the literature suggests that agencies are finding more inclusive ways to change their asset management. For example, Popovic et al. (2010) note that AM enables an agency to manage and clarify the demands that regulators, customers, and other stakeholders seek from assets by defining the optimum balance between risks, costs and lifecycle activities. Future research in AM implementation could usefully generate more information on contradictions in an agency's environment by extending our approach to include external stakeholders of the agency.

Secondly, we observe that, in the literature, increasing emphasis is being placed on a decision-making process that includes more steps of an organizational process. For example, Pascual et al., (2013) present an AM-oriented multi-criteria methodology that is able to identify trade-offs within a system, thereby standardizing judgments in decision-making. Similarly, Islam and Moselhi (2012) argue that a multiyear plan for the maintenance of municipal networks, drawing on knowledge about these assets, makes it possible for municipalities to avoid costly duplication of work and disruption of services. Here, we would encourage extending the identification of AM logics to a broader range of agencies such that a fuller account of difficulties in decision areas can be established.

5.5 Concluding remarks

This study has identified the different and conflicting logics held by employees concerning the AM decision-making process and explained why employees' logics potentially conflict with the new agency logic.

In this study, we have empirically shown that employees, when conceptualizing AM, refer to their own mandates. By this, we mean that employees have a strong disposition to judge a new strategy from the perspective of the existing practices in which they operate and work. Empirically, this notion seems to be strongest in lower-level departments. For example, the local department and project department employees most often applied the reasoning that a certain view best reflected their mandate or offered the most desirable route for achieving their purpose. We also uncovered employees referring to their mandates in higher-level departments. For example, experts on regional infrastructure policy theorized on how to formulate policy in terms of performance targets. They also participated in discussions involving their department heads on the same topic.

Further, we have empirically shown that when employees conceptualize AM the likely result is a multitude of independent and potentially contradictory logics. In our study, it was in the lower-level departments that employees tended to more often adopt contradictory positions. For example,

employees in the project department disagreed with the local department's personnel over the resource allocation.

6 CONCLUSIONS

In this chapter, an overview of the main findings is provided along with a reflection on the methods used and feedback from practitioners in Section 6.2. Section 6.3 discusses the scientific and practical contribution. The overall conclusions and recommendations for further research are provided in Section 6.4.

6.1 Introduction

Given climate change, a decreasing maintenance budget, and increasing demands of stakeholders, many transport infrastructure agencies are implementing asset management (AM) techniques. Although AM has promising ideas regarding the management of infrastructure assets, its implementation is challenging for agencies because AM is a fluid, integrative, and dynamic concept. Previous investigations have mainly focused on identifying discrepancies between the top-down AM strategy (how AM decision-making should be) and the implemented result (how AM practice is), thereby ignoring the more complex nature of managing infrastructure assets. The aim of this research has therefore been to understand the challenge of implementation taking into account the integrative, fluid and dynamic nature of the AM concept and that transport infrastructure agencies are also changing existing practices.

Although AM research has mainly focused on the discrepancies between a static view of an ideal AM and AM practice, some scholars have recognized the importance of employees in AM implementation. However, attention has not been given to the perspectives of agency employees regarding AM and the consequences of this for the consistency of AM decision making and its implementation. This matters because top management and the employees lower down the hierarchy might have different views of AM. This could well be a factor in the reality that AM implementation is a serious and lengthy exercise for public agencies. Therefore the main research question of this dissertation is:

- What viewpoints are present on the management of infrastructure assets, and how should these be addressed when implementing AM at public agencies?

To answer this question we approach the implementation challenge as a dominant logic problem. The concept of a 'dominant logic', developed by Prahalad and Bettis (1986), is recognized in strategic management as a theoretical linkage between corporate diversification (e.g. a portfolio of different business units) and organizational performance. Recognizing this link, they argued that two different technologies were less complicated to manage using two tailored approaches than with a single approach. As such, dominant logics would seem to suit the challenge of implementing AM within public agencies as these have historically developed and retained separate logics on how infrastructure should be managed.

We measured the views of a large number of employees, and these data can serve as evidence of the dominant and conflicting viewpoints held by employees of a Public Works and Water Management Agency regarding the AM decision-making process. We found several viewpoints that contradicted the official top-management line on how AM should be implemented. Further, the data on the mixed viewpoints drove the investigation to seeking an explanation for the challenges faced in AM

implementation by taking account of the roles of employees and the complexity of the AM concept in which change was introduced.

6.2 Main findings

In this section, we first discuss the way in which researchers have understood, used and investigated infrastructure asset management in Section 6.2.1, and describe the issues that arise inside the Dutch Public Works and Water Management Agency as a result of daily managerial practice trying to achieve its organizational strategic plan in Section 6.2.2. We then demonstrate a method that is developed in this dissertation to address the issues that arise in daily practice in Section 6.2.3, and then summarize the key results of a major application of this method in the same organization in Section 6.2.4. In Section 6.2.5, we reflect on the feedback provided by practitioners during a workshop on the meaning of these results for the Public Works and Water Management Agency and the implications of dominant logics for AM implementations at other transport infrastructure agencies.

6.2.1 Research orientations in studying the management of infrastructure assets

An objective bibliometric analysis and literature review were conducted to answer the first research question:

- What research orientations are used in studying the management of infrastructure assets?

It is useful to understand the prominent views on managing infrastructure assets given that there has been considerable research on how infrastructure should be managed inside agencies. It is important to gain an overview on how researchers see the management of infrastructure assets. Therefore, we explored the literature to determine how the management of infrastructure is seen by researchers in their investigations.

We offer an overview of the literature on a wide variety of AM topics that have received attention in a large number of publications and the overall structure of the most frequently cited sources. These findings encourage a narrative that researchers largely focus on object-oriented studies, such as on pavements, bridges, water, or utilities. In particular, interest seems to have increasingly been on research into life cycle decision making and organizational aspects. These aspects include the largely strategic topics of managing infrastructure assets and the question of how to operationalize decisions. Although AM is about managing all the assets within an organization in an integrated way, it seems that organizational aspects are only weakly integrated with knowledge on object-oriented research, and researchers have not tried to use knowledge on non-technical aspects in their various models or in practical instruments. This supports the remark, made by Moon et al. (2009), that the integrated management of assets is unclearly differentiated from the separate and fragmented management of asset groups. In other words, it appears that the research community lacks a shared understanding of what AM is and what is managed within it.

Despite the integrative AM concept is challenged by such object-specific fragmentation, we do observe that different research paths address similar types of problems. For example, justifying budget plans based on infrastructure conditions features in research on the management of both pavement and water infrastructures. In another area, we see that attention to the inaccuracies of deterioration models features in both the pavement and the water infrastructure management literature streams. This common orientation on certain research problems suggests that connecting

their contributions could generate a clear research agenda and contribute to providing an integrated approach to managing all assets.

The research question was approached using a widely accepted bibliometric approach to identify a large number of publications related to infrastructure asset management and then analyze their major and minor topics and how these topics are related. However, one has to accept that bibliometrics has some drawbacks. First, our chosen bibliometric method, referred to as the intellectual structure approach, complements, but cannot replace, extensive reading and fine-grained content analysis (White and McCain, 1998). Second, the search query chosen in terms of coverage can always be questioned, and this is especially true in our study since the infrastructure domain has a broadly defined scope. This can mean that the identified publication set might exclude publications that other researchers would place under infrastructure asset management. Nevertheless, given that our challenge was to clarify the ambiguous and unclear conceptualization of managing infrastructure assets, we would argue that our approach is more objective than if we had restricted our study to one definition or perspective. Third, in bibliometrics, citations are used as an indicator of influence, and co-citations as an indicator of structure. Given that our empirical study addresses a domain with multiple perspectives on what should or should not be covered, our dataset will inevitably have limitations. Therefore, we should emphasize that the descriptions and indicators pertain to the data set collected.

To sum up, our research based on a large number of publications has facilitated a narrative that, between 1996 and 2013, researchers have mainly advanced an object-oriented understanding of managing infrastructure assets but that emerging research has shown a more integrative orientation by including life cycle decision-making and organizational aspects. This shows that AM is integrating different disciplines, and covering different assets and different life cycle phases of these assets. Nevertheless, the results indicate that organizational aspects are only weakly integrated with knowledge from object-oriented research, and that researchers tend not to use knowledge available on non-technical aspects in their various models and practical instruments. More specifically, it suggests that research finds such integration difficult and that many studies choose to adopt a specific perspective. This makes it difficult to identify a commonly shared view on AM in the research community and suggests that a common view is also missing in practice.

6.2.2 Employees perspective on asset management within an agency

An in-depth analysis was conducted of employee experiences at the Dutch Public Works and Water Management Agency to answer the second research question:

- What role do employees' viewpoints play in the implementation of AM at public agencies?

The starting point for this component of our research program was the assumption that if there is no common view of AM in the research community then there will be a similar lack in practice. This situation should be taken into account when implementing AM, and implementers should explicitly address the possibly different related views of their employees. This requires a greater understanding of how AM is seen in daily practice and what challenges employees face and overcome along the way. Therefore, in our second step, it was important to identify issues that arise from the differing viewpoints on managing infrastructure assets inside a public agency.

The case study in the field generated clear examples of employees experiencing challenges while managing infrastructure assets within the agency including when attempting to replace a traffic light or repair the road along the top of a dam. From these examples, it became clear that such personal experiences helped employees develop their understanding of the unique operational environment in which asset management activities and decisions are coordinated in order to realize the organizations' strategic plan and to identify specific issues therein. Their individual experiences contained detailed descriptions of the process of managing various infrastructure assets and highlighted the dynamic, integrative, and fluid character of AM.

Another important finding in this phase was that similar examples were described by many employees. These collective accounts of experiences revealed that the challenges they face made employees blinkered and focused on achieving a single goal. For example, a local maintenance planner continued to investigate alternatives to replacing a traffic light despite being discouraged by the national department. This shows that employees seem to pursue what they see as a justifiable mandate. In many of the examples, the observed 'blindness' of employees was driven by the desire to gain subsidies, to meet national plans or to comply with AM decision-making instruments¹⁸. This blindness highlighted that employees pursued various artefacts as their single goal, and thereby showed inertia when expected to address other goals or to change activities.

We applied a criteria-free method, called Rumelt's tests, to explore how employees who are close to asset management in practice deal with the management of infrastructure assets inside the Public Works and Water Management Agency. We compared the results from this approach with another using a 'maturity check' based on the same case (same agency, same period, and same topic) to see whether this confirmed the results. This comparison showed that Rumelt's tests have the advantage that they generate a more detailed account of employees' experiences than the maturity check approach. Despite these benefits, the Rumelt's tests have their own limitations. First, there are limitations when it comes to generalizing the findings. In our study, Rumelt's tests were used to draw out close and personal examples of challenges. If an organization wishes to follow-up on suggestions to improve their work, then Rumelt's test results are insufficient because they do not provide sufficient information on the extent to which the example challenges reflect generic challenges in the organization. A second limitation is that Rumelt's tests require considerable amount of time and involve a large number of interviews. In order to evaluate the different organizational layers and units, a considerable number of employees, connected through working relationships, need to be interviewed. As such, Rumelt's tests are only advised when the focus is on clear working relationships that would not be sufficiently explored by less costly and less time-consuming methods such as maturity models. If there is a dedicated goal to explore or validate challenges, then we believe Rumelt's tests can add significant value to other benchmarking techniques such as maturity models.

To conclude, our study has shown that employees' views play a role and that the current way of implementing AM overlooks this. Uncovering the employees' experiences revealed how asset management activities and decisions are coordinated, and the employees' collective accounts showed how the challenges they face made them blinkered and focused on achieving a single goal. In

¹⁸ We use some concepts to describe observations in chapter 3. We describe that employees have a single goal when we observe employees focusing on one direction while addressing a challenge. We base employees' blindness on observations of employees who disregard other directions to address the same challenge.

essence, employees' views need to be taken into account in an AM implementation but current tools (such as maturity checks) fail to take these sufficiently into account.

6.2.3 Dominant logics at the employee-level of an organization

A literature review and case study were conducted to answer the third research question:

- How can employees' viewpoints about AM be analyzed on different layers of management within a public agency?

As summarized in the previous section, we had found situations where the decision-making process related to managing infrastructure assets was challenged by employees who, in creating their personal perspective about AM, invoked a selective blindness regarding the goals set by the agency. In other words, their views contained distinct foci that made them work towards one specific goal, and disregard other goals. This observed phenomenon resembles employees holding a dominant logic about AM. This would suggest that these different employee views should be accommodated in the implementation of AM. Therefore, the next step in our research aimed to develop an analytical approach to uncover whether these different interpretations of AM are accidental or structural, and why. We needed a method that could deal with a large sample, delve into the detailed views, and handle a large number of group comparisons within the organization. This would enable the more structural role of employees' views in AM implementation to be better understood and addressed in the Public Works and Water Management Agency.

To measure the dominant logics, we developed a method able to detect dominant logic filters in large quantities of data and compare an even larger number of pairings. Here, we found causal mapping useful for measuring large volumes of individual views and presenting them in maps. The way in which causal maps are generated enables detailed comparisons and allows patterns to be recognized. We then applied statistical tests to validate the significance of patterns and used graphical approaches to be able to show the structure of these patterns.

In a demonstration exercise, we explored the causal maps on asset management among a small sample of team members responsible for implementing asset management at the transport infrastructure agency. We then analyzed whether we could identify dominant logics based on the statistical tests and graphical approaches used in the method. From the results related to the key AM decisions, we saw that two dominant asset management logics existed within the team. These two dominant logics also seemed to persist on a more detailed level. Pairs of team members who hold the same views in terms of the two dominant logics also share similar patterns in their ideas on the process of AM decision-making. Prior to the causal mapping exercise, we asked each team member to reflect on the reasons they provided the map they did. From these data, we were able to derive that each dominant logic had its own distinct reasoning structure deployed by the employees holding that logic. This particularly involved the relevance and the role of their work to the overall AM process.

Although these results indicate the full potential of the method, several issues related to the proposed methodology were not been addressed in Chapter 4 and deserve further reflection here. First, our initial aim was to identify contradictions in people's views, and we have to admit that our demonstration exercise with a team of ten members failed to provide data on distinct contradictions. We have concluded that larger samples are needed to identify these contradictions. Another

limitation of the approach is that one has to assume a probability distribution. This is straightforward with our proposed causal mapping procedure, developed by Markóczy and Goldberg (1995), because it involves a closed questioning routine. However, a significant proportion of the cognitive mapping community opts for free elicitations (Hodgkinson, Maule, and Bown, 2004; Nadkarni and Narayanan, 2005). If we were to adopt this approach, then it would be challenging to find an appropriate probability distribution. As such, we would only recommend our model for closed elicitation procedures.

Clearly, this element of our research supports the argument that measuring the dominant logics within an organization can reveal conflicting and multiple logics about the same managerial practice, or work process, among unsuspected combinations of individuals and constructs. In addition, it has been shown in the demonstration exercise that it creates a possibility to enquire into why distinct dominant logics exist among a population. This can help in understanding, and also point to ways to address, possible different and conflicting viewpoints related to implementing AM, in our study within the Public Works and Water Management Agency.

6.2.4 Implications of differing viewpoints for AM implementation

An in-depth analysis was conducted at the Public Works and Water Management Agency to answer the fourth research question:

- What are the implications of employees' viewpoints for the implementation of AM inside a public agency?

At the time of this study, the Dutch Public Works and Water Management Agency was in the midst of implementing AM. The agency had to cope with many staff who were already experienced in managing assets with existing practices. This challenge was a relevant situation in which to investigate the implications of the viewpoints present. To do so, we applied the method discussed in Chapter 4. This method is designed for analyzing logics within a large organization. It is able to identify multiple dominant views and their differences and similarities. Further, we extended the analysis by asking agency employees why they held the views they did. In this way, we gained a deeper understanding of the persisting views of agency employees about the AM decision-making process.

The first conclusion drawn from our findings was that many of the implementation challenges came from the inherent diversity of AM itself. For example, both those employed in planning functions in the local department and those in contract and technical functions in the project department tended to have unrelated views on AM that were distinct from immediate colleagues in the same function. This diverse interpretation of the AM concept also led to contradictions between employees' views on AM decision-making and the implementation plan. For example, we found two dominant logics inside the agency with one group of individuals focused on predicting demand (for maintenance) before determining the budget (the Risk Management logic) and another group focused on ascertaining the budget before determining its allocation (the Budgeting logic). This shows how having diverse views of the AM concept only imply coordination problems in the AM process if the perspectives are contradictory.

Second, it also appeared that there was a gap between how top management thought that infrastructure assets should be managed and how they were being managed. We found that this gap

varied depending on the level of the department being evaluated. The gap was greater in the lower level departments. For example, personnel in the local and project departments viewed AM as primarily their departments' business rather than the agency's business. Higher level departments showed fewer contradictions. Our analysis of the reasoning structure revealed strong similarities between high-level personnel across departments. A recurring reference was the frequent discussions between corporate staff and regional infrastructure policy experts on how the AM decision-making process should be. This suggests that AM implementation is quickly agreed by high-level departments but is not clearly conveyed to lower levels. As a result one lower level department may conclude that certain decision steps should be taken first whereas another department thinks otherwise.

Third, we saw that employees by and large conceptualize asset management based on their personal mandate. For example, the 'Budgeting' logic and the 'Risk Management' logic were largely supported by members of the project and local departments respectively. These two views are contradictory in terms of whether budget or risk priorities come first when allocating resources. This directly impacts on AM implementation as it amounts to a disagreement over how resources, which both the project and local departments need, are allocated. For this reason, it is critical that top management understands the mandates that employees cling to when attempting to integrate decision areas.

Although this study revealed several interesting findings, the method applied has certain limitations. First, the causal mapping elicitation procedure by Markóczy and Goldberg (1995) involves a fixed, and limited, number of concepts in quantitatively comparing the issues relevant to a phenomenon. In our application, there were several concepts that practitioners in the causal mapping elicitation round were surprised that their peers had not already raised in the preliminary interview round. Nevertheless, the program team did recognize the set we used, indicating that it was relevant to the agency's AM change agenda. Another constraint is that the physical interviews required with this methodology are very time consuming, and this limits the number of employees one can realistically include. We had to travel around to personally meet all the 81 respondents and interview them using the same protocol. A large reach is important if one wants to quantitatively compare a realistic representation of a large agency and, in other situations, this might be beyond the resources available.

Finally, this element of our research program gave rise to the idea that, at the employee level of a transport infrastructure agency, it is quite possible that there is no dominant logic about asset management that is supported by a majority of the employees. Rather, there may be multiple logics that employees recognize or reject in the context of their personal mandate. This implies that asset management potentially faces conflicts between different combinations of these logics. Hence, an AM implementation needs to address these personal mandates and the various expectations of different departments if it is to achieve a consistent decision-making process.

6.2.5 Addressing the viewpoints held within the transport infrastructure agency

The main findings from the research components outlined above are now reflected upon to answer the final part of the main research question:

- How should the various viewpoints be addressed when implementing AM at public agencies?

Following the data collection and analysis outlined in 6.2.4 above, we held feedback workshops with agency employees. Some of the feedback from these workshops enriches the discussion of the main findings from Chapters 2 to 5 regarding the dominant logic approach and the consequences for the agency. We now briefly introduce the set-up of the workshops and its purpose before presenting the output from the discussions¹⁹.

The workshops were designed to provide feedback on the similarities and differences in the views of different departments identified in the measurements and to receive feedback on these results and their practical meaning. The feedback exchange between the agency and the research project was organized six-months after the interview round had taken place. It involved three feedback sessions with agency employees representing the departments (local, project, regional, support and corporate) where our interviewees worked. Each feedback session had six or seven participants from a range of departments to stimulate discussion with different viewpoints being present. The participants did not have prior knowledge of the findings from the earlier interview round. The workshop sessions lasted on average two to three hours and started with a brief introduction to the ins and outs of the dominant logic approach. The participants were then asked to answer a few questions that were similar to those posed in the interviews related to the choice of decision issues and to the causal mapping elements. These answers were then discussed so that the participants could reflect on the range of answers, the reasoning behind them, and the questioning technique. Following this, the participants were provided with the overall results on the different views between departments and discussed these results.

The feedback revealed some important points concerning how to address conflicting views during the AM implementation. First, some of the departmental preferences that led to conflict situations seemed to reflect what could typically be expected of these departments. For example, when we revealed the major differences between local department and project department personnel on the most important AM decisions, the discussions made clear that such differences were expected given the role of each department. The discussions showed that the specific conflict between the local and the project departments was based on a fundamental difference in the mandates that each department proclaimed. This is not altogether surprising given that these departments have specific tasks and positions in the Public Works and Water Management Agency. This suggests that, rather than attempting to enforce a single decision-making process, top management should tailor two decision-making approaches, that reflect the two conflicting logics.

Further, we revealed some unexpected characteristics of departments. For example, we showed to the workshop participants that employees of the regional department saw determining policy goals as a more important feature of AM than their corporate department colleagues did. Conversely, we showed the work shop participants that corporate department personnel thought determining the maintenance strategy was more important than the regional department personnel did. The majority of the workshop participants seemed astonished that members of the corporate and regional departments both made decisions that could be expected of the other party. During the discussions, the main feedback on these unexpected differences was that these departments seemed to expect more of others than from themselves. In the implementation of AM this means that there are instances where departments look to one another regarding the decision-making process.

¹⁹ See the Appendix C for detailed information on the set-ups.

Essentially, this emphasizes that implementing AM is much more than developing and integrating systems, it is also about the coordination of decisions and the expectations of the parties involved within the agency. In the discussed situation, the regional and corporate departments should share their expectations and include requirements of the other party in their own role to make decision-making more consistent across these departments.

Even more strongly than the previous point, the workshops revealed that views on AM are mostly determined individually and do not necessarily pertain to departments where individuals work. On a deeper level, employees explained that they make a lot of assumptions about words that are used in the overall AM decision-making process such as a 'maintenance management system' or 'performance requirements'. In discussions between the agency employees, it became clear that these interpretations acted as filters through which each agency employee filtered out a single understanding that was closest to their personal mandate. They appeared to use these understandings to form opinions on how things should be implemented in AM, leading to the different viewpoints. This insight should be used to make clear to departments how the concept and scope of such decision aspects are understood in order to clarify their position in a consistent overall decision-making process.

Second, the feedback from the workshops revealed some important points on the dominant logic approach itself. During the workshop, it became clear that some of the words on the cards were themselves a factor in the different views expressed by the agency employees. Some of the workshop participants remarked that the decision descriptions on the cards were not exhaustive in describing decisions. This is a valuable comment regarding the limitations of the dominant logic approach in practical use: revealing apparently different views does not identify bottlenecks or an actual problem if there is confusion due to the semantics. Yet, the intent of the dominant logic approach is to collect information about the subconscious filtering process, in our case of an agency employee when conceptualizing AM. Therefore confusion is meaningful data for AM-related terminology that has not reached a point of meaningful development and implementation in the existing practice.

Another critique coming from the workshop is that some employees selected decisions (from the selection of cards they were offered) somewhat arbitrary in the exercise. The workshop participants argued that the limit on the number of constructs (decisions in our case) using the causal mapping approach forces a choice employees might not make in reality. This remark indeed reflects a second limitation of the dominant logic approach in that including an infinite number of decisions to select exceeds the approach's capability. The intent of the dominant logic approach is to measure the filtering process, in other words to identify an individual's prime focus and the reasons for this. While some employees had serious doubts over which of the two answers to select, others felt they were given sufficient choice within the limits of the method. The method does not identify how sufficient the selection is according to employees. This is unfortunate since it would also reveal what employees believe the scope of the AM concept. Although the scope of the AM concept appears to be an important part of the filtering process, the method still provides a valuable insight into what employees filter, what they conceptualize AM to be, and why. It remains an important first step into improving and refining a measurement for dominant logic filters of individuals.

To summarize, the workshop discussions confirmed that employees are inclined to apply different perspectives on asset management when filtering information. The dominant logic approach is able to reveal the similarities and differences between these perspectives and opens up the possibility for a more in-depth inquiry into the reasons for the patterns uncovered. The workshop sessions showed the importance of semantics in forming these patterns and explained the relationship between the availability of previous information on AM to employees and their construction of different perspectives about AM. These semantics and assumptions provide information on the way that employees frame AM within their previous experiences.

6.3 Discussion

In this section, we discuss the scientific contributions and managerial implications of the main findings of the dissertation in Sections 6.3.1 and 6.3.2 respectively.

6.3.1 Scientific contribution

In terms of scientific contributions, this study made contributions both to AM research and to dominant logic literature in general.

First, in terms of AM research, this study has contributed the finding that employees play an important role in AM implementation as a link between strategy and realization. Unlike most other investigations, which have mainly focused on a top-down approach, we adopted a bottom-up approach to the implementation problem. Our examination of dominant logics inside the specific organizational context of a transport infrastructure agency revealed conflicting logics among many of the agency employees. For example, we saw distinct 'Budgeting' and 'Risk Management' logics. Such differences have not been addressed in previous studies on AM implementation. This is a significant aspect since such conflicts offer information to top executives on the potential challenges that an agency is likely to face when attempting to change practices and move in another strategic direction. We were able to show that employees form strong coalitions about how a work process should, according to them, look. Such coalitions constitute a force that needs to be addressed in relation to the ideas of top managers.

In addition, whereas previous research (with approaches such as maturity checks) has mainly focused on integration challenges, our study provides insights that add to the knowledge on coordination challenges in AM implementation. Our study revealed clear cases of several employees facing decision-making challenges when managing infrastructure assets. These showed that an agency's employees are vital contributors to a consistent decision-making process. Compared to maturity checks that only focus on the integration of systems (e.g. Nastasie et al. 2013), our approach revealed a range of challenges that hamper consistent decision-making.

Further, this study contributes to AM research by addressing the unclear boundary, observed by Moon et al. (2009), between the integrative elements of managing infrastructure assets and the separated management practices for specific asset types. Our review showed that AM researchers have gradually adopted a discipline-specific body of knowledge, shared research problems, and developed a potential path for integrating the twenty-year-old distinct specializations on the management of pavements, bridges, and water infrastructures, and the related organizational aspects. We suggest that the boundaries between specific disciplines and AM research can be broken down by focusing on commonly shared coordination challenges such as justifying budget plans, redefining the role in AM, and ensuring the fitness of decision-making (e.g. Wagner et al., 2011).

Second, turning to the dominant logic literature in general, the main contribution made is the recognition that multiple dominant logics can coexist within a large organization, and indeed even within a small implementation team. Further, we have uncovered the reality that these logics are distinct in terms of both the held view as well as the reasoning structure regarding the task in hand. This shows a promising new avenue for dominant logic research: uncovering persisting logics concerning the full cycle of work processes (what is done, how it is done, and why it is done).

The approach we have developed covers both the apparency and the dominance of logics, whereas previous attempts to operationalize dominant logics have addressed either their apparency or their dominance, but not both. Our approach enables one to fully measure logics that are similar between combinations of individuals without predetermining groups. This is an important contribution to organizational science in general, especially given that, in today's fast changing society, individuals increasingly bond in communities of content, rather than within departments or offices built of bricks and mortar.

6.3.2 Practical contribution

In terms of practical relevance, this study has contributed knowledge that can be used by the Dutch Public Works and Water Management Agency in particular, and by other transport infrastructure agencies in general.

First, for the Public Works and Water Management Agency, the main practical contribution of our research is that it shows that, in order for the agency to implement a consistent decision-making process, it needs to resolve the contradiction between employees' logics and the agency's logic (how AM should be). A traditional way of resolving such contradictions is to somehow align the employees' logic to the agency's logic or vice versa. However, changing attitudes or documents does not resolve the underlying reason why the contradictions existed in the first place. Therefore, we believe that the Public Works and Water Management Agency could better coordinate its AM by adopting two tailored AM strategies (or decision-making processes) rather than attempting to use a single strategy (or decision-making process) for these contradictory beliefs. In particular, we saw a contradiction between whether the budget (a view supported by many employees of the project department) or the risks (support by many employees of the local departments and indicated in the implementation plan) were prioritized when allocating resources inside the agency. This could be mitigated by separating these logics by two approaches: one in which the risk priorities are set by the local departments and top management before the budget is allocated, and another one in which this allocated budget is an important factor for the project department to focus upon for identifying the risk priorities. Such a separation allows the budget to incorporate a risk priority identified by multiple departments.

In addition, the research can contribute to AM implementation by the Public Works and Water Management Agency in the sense that it informs the agency that attention needs to be given to addressing its employees' assumptions. The workshop revealed that words that could seem like jargon within the agency could lead to misguided coordination. For example, it became clear that the corporate department assumed that the 'maintenance management system' was a core system of the agency, whereas the regional department assumed that the 'maintenance management system' was the responsibility of contractors. Since AM is supposed to be an integrated way to connect

different aspects of decision-making, the agency needs to actively identify and remove such misinformed assumptions.

Other transport infrastructure agencies could also benefit from this research in meeting the coordination challenge in their AM implementation. The research identifies recurring coordination challenges both in the AM literature and in the Public Works and Water Management Agency case study. The review and the dominant logic study identify shared research problems and coordination challenges, such as the justification of budget plans and the decision whether to control contractors or give them greater responsibility. These findings should help other agencies identify similar challenges in their own organization.

Further, this study elaborates on methods that other agencies can use to analyze coordination challenges and contradicting logics in their own organizational context. The Rumelt test and the dominant logic approach are criteria-free approaches. They are not prescriptive in terms of an ideal view of how AM should be. Rather, these methods allow an organization to investigate how employees understand AM that is being implemented. This enables agencies to investigate the issues that are specific for their own operating context instead of purely following a fixed, normative approach that only tells an agency how it should be and ignores existing practices.

6.4 Limitations, final conclusions and recommendations for further research

This dissertation provides various insights into the employee perspective when implementing AM inside a public infrastructure agency but also raises additional questions that could not be addressed due to various limitations. This section reflects on limitations, draws final conclusions and then, for each of those, offers recommendations for further research.

Some choices that we made in the design of this study need to be reflected critically.

Single agency investigated: One limitation is the fact that the empirical work focuses on a single organization. We recognize that collecting empirical evidence from a single organization makes it hardly possible to state propositions about the AM implementation generally applicable to transport infrastructure agencies. More specifically, the empirical work points to contradictions between employees from a single agency, but these do not immediately say whether these are also contradictions for other agencies.

A fruitful direction for future research will be to compare dominant logic patterns in multiple organizations. This could significantly help to understand whether specific contradictions in one agency matter to more agencies, such as between the 'Risk Management' logic and the 'Budgeting' logic. This is especially important for the AM implementation challenge to further investigate, because transport infrastructure agencies often work for different countries, provinces or states and therefore likely have very different organizational strategic plans and existing practices.

Single perspective used: Another limitation is that a single theoretical perspective was used, dominant logics. We have seen many instances that mark the complexity of the implementation challenge, which illustrates the limitation of one theoretical perspective to understand it. More specifically, more theoretical perspectives can look at more facets of the implementation challenge.

Further research regarding comparisons of multiple theoretical perspectives can be beneficial. Other perspectives add alternative aspects in an empirical study, and thereby these can enrich the understanding of the implementation challenge. The dominant logics perspective specifically looks at the views on what AM is and why. One perspective that can add a significantly different light in the implementation challenge includes the resource based view (Too, 2012). This perspective focuses on the identification and development of capabilities for an agency to achieve its organizational strategic plan. It adds insight with its focus on the resources and competences that the agencies should have derived from the organizational strategic plan.

From our study some relevant conclusions can be drawn about AM on the employees level of an agency.

AM as a discipline: First, for AM to become a discipline researchers should address integrated shared research problems across different research domains. We found that in the current AM literature there are multiple research domains oriented on objects in which the integrative character of AM is not being well captured. Wagner et al. (2011) argue that for a concept to become a discipline, articles require a central problem with aspects, that are considered to be relevant to that problem, and with explanations, theories, and goals that are related to the problem. Since, many of the research problems are seemingly shared across the object-oriented research domains these form a pathway to AM as a discipline.

Future research should investigate whether merging similar problems could also lead to integrated solutions within a single organization, and whether the ideas found in the literature could be implemented as an integrated AM concept. For example, AM implementation can benefit by knowledge on what coordination challenges are similar across transport infrastructure agencies in general. Such knowledge would be an asset for practitioners in the transport infrastructure agencies.

Conflicts in decision preparation: Second, for AM decision-making to become more consistent, employees should not pursue conflicting goals. Rumelt (1979) pleads that an effective strategy requires consistent goals, solutions for problems and a clear end-result. Our case study showed that there is considerable interaction between employees when they are preparing decisions. However, these employees were each focused on achieving goals that they themselves had in mind. We saw that this leads to difficulties when employees are collectively working on solutions to a problem because the AM approaches do not fit with the employees' various views of the desired end result.

Our findings are only indicative, and solid evidence that such a relationship exists would be valuable for practice because it would show that a different form of coordinating decision-making would be beneficial. More detailed, research on the problems that employees face when pursuing multiple conflicting goals rather than a single shared goal would advance knowledge in this area and suggest a way forward.

Coordination of conflicting mandates: Third, two contradicting employees' mandates in asset management are easier to manage as two separately coordinated processes than as a single coordinated process. This is the focus of the dominant logic perspective developed by Prahalad and Bettis (1986). In the in-depth study, we found evidence of various contradictions in the dominant views of staff within the agency. We have described situations where the implementation plan was about which direction to take given the preferences for one view or another. We saw that this poses

a challenge in attempting to coordinate the process with a single approach ('the implementation plan').

Future research is needed to reveal more on the effects of coordinating two separate processes as against a single process when managing two contradicting employee mandates in AM. This research did not go as far as to address which extent the substantive differences and contradictions in dominant logics have disruptive effects for the decision-making process. Hence, more knowledge could be generated on the disruptive effect that contradicting views can have on AM decision making.

Addressing semantics, assumptions and personal mandates: Final, semantics, assumptions and personal mandates are addressed more explicitly by a bottom-up AM implementation than by a top down approach. The sessions showed the importance of semantics in these patterns and that these could explain the relationship between the varying availability to employees of existing information on a subject and their construction of different perspectives about the concept. Once employees had individually filtered their views, the feedback showed that they were often surprised by how colleagues had approached the same subject in the same organization differently. These insights and evidence support the argument that people subconsciously make certain assumptions about information in forming an opinion or judging something. The workshop discussions on semantics provided information about the assumptions of employees without them being explicitly stated. This approach is therefore a potential way to generate knowledge on the relationship between semantics, assumptions, and the personal mandates of employees in a work process.

Future research could usefully focus on the relationship between semantics, assumptions, and personal mandates in a top-down approach to AM implementation. We did not examine these concepts in detail since this is outside the scope of this research. Future research should investigate whether this is generally true in practice and whether this approach could generate valuable additional information about the existence of dominant logics in asset management implementation and generic change efforts within organizations.

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APPENDICES

Appendix A. Example of Interview Questions based on Markóczy and Goldberg (1995) elicitation procedure

- Step 1: The interviewee is shown a set of cards. Each card represents a Decision Issue. The interviewee is then asked:
 - “Which ten of these decision issues are the most important for Asset Management in your Organization?”
- Step 2: The interviewer notes the chosen issues in an automated sheet and suggests causal relationships between each decision issue. The following example illustrates a typical set of three questions:
- “If a decision has been made to determine the Risk Level for an Asset, would this then directly influence the decision determining the Maintenance Strategy?”
- If the answer is yes, ask the following question:
 - “When you determine a High Risk Level for an Asset do you then determine a Corrective or Preventive Maintenance Strategy? Does the chosen Risk Level then weakly, moderately, or strongly influence your determination of the Maintenance Strategy?”
 - “And, when you determine a Low Risk Level for an Asset, do you then determine a Corrective or Preventive Maintenance Strategy? Does the chosen Risk Level then weakly, moderately, or strongly influence your determination of a Maintenance Strategy?”

Table 1. Example of testing screen.

Appendix B. Decisions elicited from preliminary and open interviews with peer respondents.

In the table below decisions elicited are depicted which were derived from the preliminary and open interviews with peer respondents.

Table 1. Decisions elicited at Public Works and Water Management Agency

#	Description	Option 1 – The agency either ...	Option 2 – or the agency ...
[1]	the agency formulates policy goals	formulates generic goals	formulates specific goals
[2]	the agency allocates maintenance budget	allocates by objective criteria	allocates without objective criteria
[3]	the agency determines the condition of assets	determines by description	determines by measurement
[4]	the agency determines a level of knowledge about assets	determines at an abstract level	determines at a detailed level
[5]	the agency determines a standard for registering asset data	determines a uniform standard	determines a less uniform standard
[6]	the agency estimates the risk for an object	estimates a high risk	estimates a low risk
[7]	the agency applies a maintenance management system	applies an abstract system	applies a detailed system
[8]	the agency allocates budget to an asset	allocates a large budget	allocates a small budget
[9]	the agency initiates an exploration for new construction	initiates an exploration	does not initiate an exploration
[10]	the agency outsources asset data management	outsources	does not outsource
[11]	the agency awards a contract	awards with stringent criteria	awards with flexible criteria
[12]	the agency dictates tasks in a contract	dictates tasks	does not dictate tasks
[13]	the agency delivers asset information to the contractor	delivers information	does not deliver information
[14]	the agency applies a quality control to a contractor	applies a quality control	does not apply a quality control
[15]	the agency allows contractor to plan maintenance	allows a plan	does not allow a plan
[16]	the agency prioritizes between road sections	prioritizes between sections	does not prioritize between sections
[17]	the agency prioritizes between types of assets	prioritizes between types	does not prioritize between types
[18]	the agency finances a project at the	finances at that expense	does not finance at that

	expense of future budget		expense
[19]	the agency determines an interval between recurring tasks	determines a longer interval	determines a shorter interval
[20]	the agency determines project scope	determines a large scope	determines a small scope
[21]	the agency assures presence of knowledge about infrastructure within the agency	assures by archiving knowledge	assures by training knowledge
[22]	the agency determines height of main budget	determines a larger main budget	determines a smaller main budget
[23]	the agency uses a risk method	uses uniform method	uses a multiform method
[24]	the agency allows contractor to govern maintenance management system	allows governance	does not allow governance
[25]	the agency determines contract duration	determines a longer contract duration	determines shorter contract duration
[26]	the agency allocates human capacity to project work	allocates more capacity	allocates less capacity
[27]	the agency determines a maintenance strategy	determines a corrective strategy	determines a preventive strategy
[28]	the agency determines supervision to contractor	determines more supervision	determines less supervision
[29]	the agency executes maintenance tasks without retaining budget	executes without retaining budget	does not execute without retaining budget
[30]	the agency determines executive freedom of contractor	determines more executive freedom	determines less executive freedom
[31]	the agency determines number of contracts in an area	determines more contracts in an area	determines fewer contracts in an area
[32]	the agency couples failure causes per object	couples causes more explicit per object	couples causes more implicit per object
[33]	the agency determines planning horizon	determines a longer planning horizon	determines shorter planning horizon
[34]	the agency adjusts planned maintenance	adjusts plan	does not adjust plan
[35]	the agency finances a project through multiple subsidies	finances through multiple subsidies	does not finance through multiple subsidies
[36]	the agency chooses a funding body	chooses regular funds	chooses a one time subsidy program
[37]	the agency allows a new task in the planning	allows a new task	does not allow a new task
[38]	the agency adopts improvement suggestion	adopts an improvement	does not adopt an

	from the contractor	suggestion	improvement suggestion
[39]	the agency corners budget from regular financing for an asset or project	corners budget	does not corner budget
[40]	the agency liberates money for an asset or project at the expense of regular budget	liberates money	does not liberate money
[41]	the agency fulfills demands from stakeholders and partners	fulfills demand	does not fulfill demand
[42]	the agency requests help from internal advisors	requests help	does not request help
[43]	the agency clarifies ambiguous criteria for asset performance	clarifies criteria	does not clarify criteria
[44]	the agency formulates performance requirements	formulates with concrete measurements	formulates with open descriptions
[45]	the agency initiates a study to failure causes on an object	initiates a study	does not initiate a study
[46]	the agency determines a desired level for asset quality	determines more abstract desired level	determines more specific desired level
[47]	the agency determines a procurement strategy based on task information	determines based on tasks	does not determine based on tasks
[48]	the agency makes changes in a signed contract	makes changes	does not make changes
[49]	the agency standardizes contract-format(s)	standardizes more uniform format(s)	standardizes less uniform format(s)
[50]	the agency deviates from internal agreement	Deviates	does not deviate
[51]	the agency prepares a project	prepares a project earlier	prepares a project later
[52]	the agency provides own asset data to other departments	provides to other departments	does not provide to other departments
[53]	the agency collects asset information separate from central data collection	collects separately	does not collect separately
[54]	the agency applies operating-year-end in budget allocation	applies operating-year-end	does not apply operating-year-end
[55]	the agency inspects assets	inspects more generically	inspects more specifically
[56]	the agency executes inspections	executes themselves	lets other parties execute
[57]	the agency bundles projects	bundles by asset types	bundles by geographical area
[58]	the agency repeats number of inspections	repeats more frequently	repeats less frequently
[59]	the agency makes an asset decomposition	makes a more detailed	makes a less detailed

		decomposition	decomposition
[60]	the agency extends a contract	extends	does not extend
[61]	the agency executes a project	executes faster	executes slower
[62]	the agency applies integrated contracts	applies these contracts	does not apply these contracts
[63]	the agency contracts out finance component	contracts out the component	does not contract out the component
[64]	the agency contracts out maintenance component	contracts out the component	does not contract out the component
[65]	the agency applies probabilistic approach to maintenance	applies approach	does not apply approach
[66]	the agency determines criteria for calamities on the road	determines stringent criteria	determines flexible criteria
[67]	the agency estimates costs	estimates more precisely	estimates less precisely
[68]	the agency determines a period for which to estimate costs	determines a longer period	determines a shorter period
[69]	the agency applies a few risk methods per tasks	applies one risk methods	applies more risk methods
[70]	the agency uses risk method	uses one standard	uses more standards
[71]	the agency determines the definition of asset quality	determines one definition	determines more definitions

Appendix C. Set-up of feedback workshops

The aim of the workshop was to discuss, explain and address the findings of the dominant logic research. Therefore we presented the similarities and differences in views at the Dutch Public Works and Water Management Agency to representatives of its participating departments. Representatives came from the:

- Corporate department-level;
- Support department-level;
- Regional department-level;
- Local department-level;
- Project department-level.

In order to discuss, explain and address the findings comprehensively, we held three workshops with the intent of inviting representatives of each department-level. This exposed discussions to the reflection and input to participants of all these levels. However, not all workshops were completely represented and some missed one department-level. See below for the details on the department-level coverage for each workshop.

Table 1. Coverage of department-levels in feedback workshops

Workshop:	Session 1	Session 2	Session 3
<i>Held on:</i>	<i>29-3-2012</i>	<i>4-4-2012</i>	<i>24-5-2012</i>
Corporate Department	1 participant	1 participant	No participant
Support Department	1 participant	1 participant	1 participant
Regional Department	2 participants	2 participants	2 participants
Local Department	1 participant	2 participants	2 participants
Project Department	1 participant	No participant	1 participant

During the workshop we conducted the following steps:

Part A

1. Ask participants to select 2 out of 9 most important decisions for asset management inside the Dutch Public Works and Water Management Agency.
2. Discuss their differences and the underlying reasons.
3. Discuss the most prominent similarities and differences between the different department-levels.

Part B

1. Ask participants to causally relate decisions in several proposed relations in AM decision-making.
2. Discuss their differences and the underlying reasons.
3. Discuss the overall differences in these cases.

Part C

1. Ask participants to polarize the related decisions in several proposed relations in AM decision-making.

2. Discuss their differences and the underlying reasons.
3. Discuss the overall differences in these cases.

Part D

1. Show dominant relations between employees of the overall organization.
2. Show dominant relations between employees of each department-level.

SAMENVATTING (Summary in Dutch)

In veel landen verandert de praktijk van het beheren van infrastructuur. Hieruit is Asset Management (AM) opgekomen als een veelbelovende aanpak om infrastructuurbeslissingen bij elkaar te brengen en op één lijn te krijgen. Echter, vanwege het integratieve, vloeiende en dynamische karakter²⁰ van AM lijkt de implementatie een moeilijk en lang traject voor vele infrastructuuragentschappen, en is het bereiken van een consistente besluitvorming een uitdaging. Een dieper begrip van de redenen voor de implementatiemoeilijkheden van AM zou infrastructuur agentschappen kunnen steunen bij hun inspanningen om tot een grotere effectiviteit en efficiëntie in het beheer van infrastructuur te komen.

Dit onderzoek richt zich op de AM implementatie vanuit het perspectief van de werknemers. Beelden van medewerkers kunnen helpen om een goed begrip te verkrijgen van de mogelijke conflicten en verschillen in het huidige AM besluitvormingsproces en om de AM implementatie te zien als een continu proces dat contextueel gebonden is aan de bestaande manier van werken. Dit onderscheidt deze studie van eerder onderzoek, waarin de AM implementatie vooral is bestudeerd door de werkprocessen te beoordelen op discrepanties met geïdealiseerde AM visies en modellen.

De centrale vraag van dit onderzoek is:

- Welke beelden bestaan er over het beheer van infrastructuur en hoe moeten deze worden aangepakt bij de implementatie van AM bij publieke agentschappen?

Aanpak en ontwerp van het onderzoek

We stellen dat de uitdaging van de AM implementatie bij publieke agentschappen komt door de percepties van werknemers over beslissingen en rollen in AM, waar een begrip over AM van bepaalde werknemers strijdig kan zijn met de beelden van andere medewerkers. We beschouwen dit als een 'dominante logica' probleem. Dominante logica is een bekend concept uit de strategisch management literatuur dat past bij de AM-implementatie uitdaging van publieke agentschappen wegens hun historisch gegroeide en gescheiden beelden over hoe infrastructuur moet worden beheerd. Samenhangende beelden over een AM aanpak kunnen een dominante logica vormen binnen een agentschap. Wanneer er verschillende beelden bestaan over de AM aanpak die geïmplementeerd moet worden dan is er sprake van conflicterende logica's. Deze hebben bijzondere aandacht nodig bij de implementatie van AM.

Om de belangrijkste vraag te beantwoorden zijn vier stappen in het onderzoek ontworpen. De eerste twee stappen zijn exploratief en beschrijvend. Zij omvatten een onderzoek naar de wijze waarop het beheer van infrastructuur wordt begrepen in de wetenschappelijke literatuur en binnen een bepaald agentschap: Rijkswaterstaat. De laatste twee stappen hebben een verklarend karakter en bestaan uit

²⁰ We houden rekening met de vele perspectieven die onderzoekers en professionals kunnen hebben van AM. Om dit weer te geven, zijn we bewust van enkele kenmerken die bijdragen aan de complexiteit van AM. Met het kenmerk 'integratief' bedoelen we dat een aantal AM beslissingen vaak worden samengebracht in beslissingsmodellen van AM. Met het kenmerk "vloeiend" bedoelen we dat AM vele versies kent, afhankelijk van het toegepaste perspectief. Met het kenmerk 'dynamisch' bedoelen dat beslissingen kunnen invloed hebben op elkaar ongeacht of ze nog worden gemaakt of al eerder gemaakt zijn.

de ontwikkeling en toepassing van een methode om de dominantie logica's van bestaande en tegenstrijdige beelden te onthullen bij Rijkswaterstaat en hun implicaties vast te stellen voor de implementatie van AM.

Tabel 1. Beschrijving van Kennisgroepen in Intellectuele structuur van Asset Management²¹

Component Nummer - Kennisgroep Label	Gedeeld Onderzoeksdoel
Centrum van het figuur	
2 - Statistische Verouderingsmodellen	– Verbeteren van verouderingsvoorspellingen van grote assets
17 - Brug Management Systemen	– Onderhoudplannen op basis van een Brug Management Systeem
Levenscyclus Besluitvorming en Organisatie Pad	
3 – Levenscyclus aanpak voor Bruggen	– Introduceren van een Betrouwbaarheidsaanpak voor bruggenbeheer
6 – Onderhoudsbeslissing over Vervanging of Renovatie	– Optimaliseren van lange termijn vervangings- en renovatieplanning
7 - Levenscyclus en Preventief Onderhoud van Verhardingen	– Modelleren van stroefheid op de lange termijn en plannen van preventieve maatregelen
8 - Resource Based View	– Gebruikmaken van menselijke competenties in organisaties
9 – Onderhoudsbeslissing over Reparatie en Inspectie	– Optimaliseren van reparatie- en inspectiebeleid
12 - MR&R beslissingen met Genetische Algoritmen	– Vergelijken van trade-offs tussen onderhoud of renovatie
18 – Conditievoorspelling voor Betonnen Bruggen	– Verbeteren van verouderingsvoorspelling van betonnen bruggen
18 – Multicriteria besluitvorming	– Vereenvoudigen van complexe besluitvormingskwesities
19 – Prestatiemeting	– Balanceren van prestatiemeetcriteria
Verhardingsmanagement Pad	
4 - Management van verhardingen op netwerkniveau	– Optimaliseren van interventies tussen homogene wegvakken
11 – Geoptimaliseerd Management van Verhardingen	– Voorspellen van verhardingsveroudering met Markov Process
13 – Verkeers- en Onderhoudseffecten	– Begrijpen van interactie tussen storing en omgeving
14 – Richtlijnen voor Asset Management op Wegen	– Informeren over de Amerikaanse richtlijnen voor AM voor wegen
Water- en Utiliteitsinfrastructuur Pad	
1 – Informatie- en Datakwaliteit	– Bepalen van de kwaliteit van bedrijfsinformatie om doelen te bereiken
5- Verouderings- en Beslissingsmodellering voor Rioleringspijpen	– Verbeteren van verouderingsvoorspelling van rioleringsystemen
10 – Modelleren van Breuken in de Hoofdwaterleiding	– Optimaliseren van de vervangingstijd om breuken in de hoofdwaterleiding te voorkomen
16 – Internationale Richtlijnen van Asset Management	– Verantwoorden van budgetten om verouderende assets te onderhouden

Asset Management implementeren

In stap 1 onderzoeken we of de wetenschap een gedeeld begrip heeft van het beheer van de infrastructuur assets. Deze stap is belangrijk omdat onderzoekers waarnemen dat er een potentieel ongecontroleerde groei is in de omvang van het onderzoek naar het beheer van infrastructuur. Onderzoekers maken zich ook zorgen dat het ontbreekt aan een duidelijke focus, gezien de brede

²¹ Deze tabel is gereproduceerd en onderdeel van Hoofdstuk 2. De tabel wordt daar verder toegelicht.

waaier aan onderwerpen. Wij hanteren een systematische methode genaamd de 'intellectuele structuur' aanpak voor het verzamelen en analyseren van relevante wetenschappelijke publicaties. Dit helpt om te begrijpen hoe het conceptuele begrip en de reikwijdte van AM is ontwikkeld op basis van het onderzoek dat wetenschappers lezen en citeren.

Uit onze evaluatie blijkt dat er geen gedeeld begrip is. Tabel 1 toont de kennisgroepen die wij aantreffen in onze analyse. Onderzoekers bouwen tussen 1996 en 2013 vooral voort op een object-georiënteerd begrip van het beheer van infrastructuur assets. Toch zien we ook dat het opkomende onderzoek meer aandacht bevat voor levenscyclus besluitvorming en organisatorische aspecten. Dit ondersteunt dat AM verschillende disciplines integreert, en verschillende assets en de verschillende levensfasen van deze assets omvat. Niettemin geven de resultaten aan dat de organisatorische aspecten slechts zwak zijn geïntegreerd met kennis van object-georiënteerd onderzoek en dat onderzoekers meestal geen kennis gebruiken over niet-technische aspecten in hun verschillende modellen en praktische instrumenten. Dit suggereert dat onderzoekers de integratie moeilijk vinden en dat vele studies een specifieke invalshoek nemen. Het maakt het moeilijk om een gemeenschappelijk gedeeld beeld te identificeren over AM in de wetenschap en suggereert dat een gemeenschappelijke visie ook ontbreekt in de praktijk.

Stap 2 onderzoekt hoe een AM-strategie wordt begrepen door de werknemers en in welke mate de Maturity check (een volwassenheidstoets voor AM) in staat is om de uitvoering van een AM-strategie te ondersteunen. Dit is belangrijk aangezien AM meer is dan een reeks documenten en instrumenten. AM voegt een 'strategische theorie' toe, dat wil zeggen een set van systematische en gecoördineerde activiteiten en praktijken om het strategisch plan van een organisatie te bereiken (BSI, 2008a). Met het gebruik van Rumelt's testen, ontwikkeld door Richard Rumelt (1979), bestuderen we diepgaand de beelden van medewerkers die samenwerken in AM om het strategische plan van Rijkswaterstaat te bereiken.

In de studie vergelijken we de Rumelt testresultaten met de resultaten van een Maturity check, ook uitgevoerd bij Rijkswaterstaat in dezelfde periode. De vergelijking van de twee methoden (zie tabel 2) laat zien dat ervaringen van medewerkers onvoldoende belicht worden bij het gebruik van de huidige instrumenten en methoden (zoals de maturity check), die niet de AM implementatie ondersteunen. Het blootleggen van de ervaringen van werknemers laat bijvoorbeeld zien hoe activiteiten en beslissingen over het vervangen van een verkeerslicht of het onderhouden van een dam worden gecoördineerd, en de collectie van ervaringen laat zien hoe de uitdagingen waarmee werknemers worden geconfronteerd hen blind maakt voor andere doelen en hen richt op het bereiken van één enkel doel²². Tevens spelen de beelden van werknemers een rol in de uitkomst van een werkproces en de Maturity check ziet deze wisselwerking over het hoofd. Daarom moet er rekening gehouden worden met de beelden van werknemers bij een AM-implementatie, maar de huidige instrumenten (zoals Maturity checks) nemen dat niet mee.

²² Wij gebruiken een aantal concepten op de opmerkingen in hoofdstuk 3. We beschrijven dat medewerkers één enkel doel hebben wanneer we waarnemen dat werknemers zich op één richting focussen als zij de aanpak van een uitdaging beschrijven. We baseren 'blindheid' bij medewerkers op waarnemingen van werknemers die alternatieve oplossingsrichtingen negeren om hetzelfde probleem aan te pakken.

In stap 3 ontwikkelen we een empirische methode om dominante 'asset management' logica's van de medewerkers te detecteren en te identificeren, en bespreken we waar inconsistenties in de AM besluitvorming liggen. De werkwijze gebruikt causal maps om individuele beelden te detecteren, voert statistische tests uit om veel gedeelde beelden te identificeren en past grafen toe om de verbinding tussen deze beelden over AM te tonen.

Table 2. Meenemen van ervaringen van werknemers via Rumelt's Testen en Maturity modellen²³

Rumelt's serie van testen	Maturity model
– Richt zich op de uitdagingen tussen begrip en actie	– Richt zich op uitdagingen en goede situatie zoals gedefinieerd door criteria
– Ontlokt opmerkingen met veel details die de ontwikkeling van een probleem beschrijven	– Ontlokt opmerkingen die de eigenschappen beschrijven van een situatie
– Kan niet specificeren of gedetailleerde voorbeelden uit de praktijk ook generiek zijn	– Kan niet specificeren hoe een generieke observatie in praktijk tot uiting komt
– Biedt een richting voor verbetering door problemen te verwijderen	– Biedt een richting voor verbetering door de ideale situatie te beschrijven
– Vereist volledige transcripties van interviews	– Vereist commentaar bij maturity level scores
– Geselecteerde werknemers hebben een werkrelatie nodig	– Geselecteerde werknemers hebben ervaring met de criteria nodig

In stap 4 wordt de methode toegepast bij Rijkswaterstaat. De studie suggereert dat het heel goed mogelijk is dat er geen dominante logica over AM wordt ondersteund door een meerderheid van de medewerkers. Integendeel, er kunnen meerdere logica's zijn die werknemers erkennen of verwerpen in het kader van hun persoonlijke mandaat. Dit houdt in dat het officiële AM besluitvormingsmodel wordt geconfronteerd met potentiële conflicten tussen verschillende combinaties van deze logica's. Tabel 3 toont de tegenstellingen tussen de verschillende 'asset management' logica's van medewerkers en het officiële AM-besluitvormingsproces. De meest prominente tegenstelling vinden we tussen de 'Budgettering' logica en de 'Risico Management' logica. Er is hier één groep medewerkers die vindt dat middelen worden toegewezen op basis van de vraag, terwijl anderen vinden dat de toewijzing van middelen wordt gebaseerd op het aanbod. Dit toont aan dat AM implementatie de persoonlijke mandaten en de verschillende verwachtingen van de verschillende afdelingen moet op één lijn moet brengen om een consistente besluitvorming te bereiken.

Workshop discussies bevestigen dat werknemers geneigd zijn om verschillende perspectieven toe te passen op AM bij het filteren van informatie. Ten eerste onthullen we de grote verschillen tussen de werknemers van de lokale afdelingen en de project afdelingen over de belangrijkste AM beslissingen en dat het specifieke conflict tussen deze afdelingen is gebaseerd op een fundamenteel verschil in de mandaten die elke afdeling beweert te hebben. Ten tweede komen we tegen dat een aantal verschillen onverwacht zijn; bijvoorbeeld, op vertoon van de verschillen tussen de regionale en corporate afdeling over de vaststelling van beleidsdoelstellingen was de meerderheid van de deelnemers verbaasd, dat leden van beide afdelingen beslissingen namen die van de andere partij verwacht werden. Tot slot, de workshops tonen dat beelden over AM meestal individueel worden bepaald en niet noodzakelijkerwijs betrekking hebben op afdelingen waar mensen werken. Het werd

²³ Deze tabel is gereproduceerd en onderdeel van Hoofdstuk 3. De tabel wordt daar verder toegelicht.

bijvoorbeeld duidelijk dat de interpretaties over het woord “onderhoudsmanagement systeem” de basis was voor de deelnemers om meningen te vormen over hoe AM moet worden geïmplementeerd. Dit inzicht moet worden gebruikt om afdelingen te verduidelijken hoe AM wordt begrepen en welke positie afdelingen innemen bij een consistent besluitvormingsproces.

Tabel 3. Overzicht van tegenstrijdige logica's²⁴

Tegenstrijdigheid		Tegenovergestelde beelden	
1.	Tussen 'Budgettering' and 'Risico Management' logica	• <i>Vraag-gebaseerde middelenallocatie*</i>	• <i>Aanbod-gebaseerde middelenallocatie</i>
2.	Binnen 'Budgettering' logica	• <i>Budgettering heeft geen invloed op andere beslissingen*</i>	• <i>Budgettering heeft wel invloed op andere beslissingen</i>
3.	Binnen 'Risico Management' logica	• <i>Beheersen van risico's heeft invloed op andere beslissingen*</i>	• <i>Beheersen van risico's heeft geen invloed op andere beslissingen</i>
4.	Tussen minderheids logica's over 'Relaties met de Aannemer'	• <i>Meer verantwoordelijkheid naar aannemer*</i>	• <i>Meer controle op aannemer</i>
5.	Tussen minderheids logica's over 'Beleid maken'	• <i>Prestatie-gedreven beleid maken</i>	• <i>Probleem-gedreven beleid maken</i>
6.	Tussen minderheids logica's over 'Kennis Management'	• <i>Creeëren van nieuwe kennisbasis*</i>	• <i>Behouden van oude kennisbasis</i>

* Dit beeld tolereert het officiële beeld van Rijkswaterstaat

Conclusies en discussies

Wat betreft het eerste deel van de centrale onderzoeksvraag, noch in de literatuur noch in de praktijk lijkt er gemeenschappelijk begrip over AM te zijn. In de huidige AM literatuur zijn er meerdere onderzoeksdomeinen gericht op objecten waarin het integratieve karakter van AM niet goed wordt vastgelegd. In de praktijk toont onze case studie aan dat medewerkers gericht zijn op het bereiken van doelen die zij zelf in gedachten hebben bij de gezamenlijke voorbereiding van beslissingen. Bovendien suggereert het bewijs van de laatste stappen, dat er geen dominante logica door een meerderheid van de werknemers wordt gedeeld. In plaats daarvan bestaan er meerdere logica's die werknemers herkennen of afwijzen op basis van hun eigen mandaat. Uit de workshops blijkt ook dat semantiek de relatie kan uitleggen tussen de variërende beschikbaarheid van bestaande informatie voor medewerkers en de verschillende perspectieven van AM.

Wat betreft het tweede deel van de centrale onderzoeksvraag, moeten infrastructuur agentschappen de tegenstrijdige beelden tussen de medewerkers aanpakken. Vanuit een kennisoogpunt kan dit worden bereikt door de verschillende onderzoeksdomeinen te concentreren op hun gezamenlijke onderzoeksproblemen in AM als een discipline. In praktische zin moeten agentschappen hun besluitvorming meer consistent maken, door te vermijden dat werknemers tegenstrijdige beelden nastreven. Om dit te laten gebeuren moet een organisatie de persoonlijke mandaten van de werknemers en de semantiek die zij toepassen nog eens tegen het licht houden en zorgen dat rollen

²⁴ Deze tabel is gereproduceerd en onderdeel van Hoofdstuk 5. De tabel wordt daar verder toegelicht.

duidelijk zijn in de AM-besluitvorming. Agentschappen kunnen dit doen door het besluitvorming proces te scheiden op de plaatsen waar tegenstrijdige logica's bestaan en juist besluitvorming te integreren waar een dominante logica bestaat. De mandaten en semantiek van werknemers bieden aanwijzingen over de reden en achtergrond waarom delen van het AM-proces moeten worden gescheiden of geïntegreerd.

De studie levert een aantal wetenschappelijke bijdragen. Ten eerste, in termen van AM onderzoek, heeft deze studie bijgedragen aan de bevinding dat werknemers een belangrijke rol spelen bij de AM implementatie. Zij vormen een link tussen strategie en uitvoering. Bovendien, terwijl eerder onderzoek (met benaderingen zoals Maturity checks) voornamelijk is gericht op de integratie uitdagingen, geeft onze studie inzicht in de coördinatie uitdagingen bij AM implementatie. Ten tweede, de belangrijkste bijdrage voor de dominante logica literatuur in het algemeen betreft de erkenning dat meerdere dominante logica's naast elkaar kunnen bestaan in een grote organisatie. We hebben de realiteit bloot gelegd dat deze logica's zijn te onderscheiden in termen van zowel het beeld, als de redeneringslijn met betrekking tot de taak van de medewerker. De aanpak die we hebben ontwikkeld, heeft zowel betrekking op de zichtbaarheid en de dominantie van de logica, terwijl eerdere pogingen om dominante logica te operationaliseren ofwel de zichtbaarheid ofwel de dominantie, maar niet beide, hebben aangepakt.

In termen van praktische relevantie, levert deze studie kennis die door Rijkswaterstaat en door andere infrastructuuragentschappen kan worden gebruikt. Ten eerste, voor Rijkswaterstaat is de belangrijkste praktische bijdrage de boodschap dat om een consistente besluitvorming te implementeren, zij de tegenstellingen tussen de logica van medewerkers en de officiële logica van het agentschap (hoe AM zou moeten zijn) moet oplossen. De tegenstellingen kunnen worden gebruikt om met afdelingen te bespreken wat hun positie is in het officiële besluitvormingsproces. Als een tegenstelling komt door verschillende veronderstellingen over de betekenis van vaktermen (semantiek) dan kan RWS een woordenlijst opstellen zodat werknemers dezelfde taal spreken en dezelfde betekenis aan een term hechten. Als een tegenstelling komt door persoonlijke mandaten, dan kan het besluitvormingsproces worden opgesplitst om deze conflicten uit het proces te halen. Andere infrastructuur agentschappen kunnen ook profiteren van dit onderzoek bij het voldoen aan de coördinatie uitdaging in hun AM implementatie. Het onderzoek identificeert terugkerende coördinatie uitdagingen, zowel in de AM literatuur (bijvoorbeeld trade-offs) alsmede in de case studie bij Rijkswaterstaat (bijvoorbeeld mandaatverschillen). Verder gaat deze studie in op methoden die andere instanties kunnen gebruiken om de coördinatie uitdagingen en tegenstrijdige logica's te analyseren in hun eigen organisatorische context.

Sommige keuzes die we hebben gemaakt in het ontwerp van deze studie moeten kritisch worden belicht. Een beperking is dat het empirische werk zich richt op één organisatie. Wij erkennen dat het verzamelen van empirisch bewijs van één enkele organisatie het nauwelijks mogelijk maakt om beweringen te doen over de AM implementatie die algemeen van toepassing zijn op infrastructuur agentschappen. De empirie toont tegenstrijdigheden tussen medewerkers van een enkele instantie, maar deze zeggen niet direct of deze zelfde tegenstrijdigheden ook gelden voor andere instanties. Een andere beperking is dat één theoretisch oogpunt werd gebruikt. We hebben veel gevallen gezien die de complexiteit van de AM implementatie markeren. Dit illustreert de beperking van één theoretisch perspectief om het probleem te begrijpen. Meer theoretische perspectieven kunnen naar meer facetten van de implementatie uitdaging kijken.

ABOUT THE AUTHOR

Daan was born in Breda, the Netherlands, on the 30th of September 1984. He attended his highschool education (Atheneum) at the Mencia de Mendoza, in the same city, with a direction in Economy and Society. After his graduation in 2003, he went to Tilburg University to study business administration with a specialization in cultural differences.

During his study at Tilburg University, Daan developed an interest for the way in which workers coordinate their operations in line with their organizations' strategy and the challenges in doing so. Daan spent half-a-year abroad in Aarhus, Denmark, where he was inspired by Total Quality Management, a philosophy combining mindset and behavioral aspects as an intricate part of work processes. This led Daan to choose Logistics and Operations Management for his Master. During the three years at the end of his higher education Daan combined his studies with several internships on strategy development and implementation at large companies in the oil industry. At Fluor Daniels, he developed a quality assurance approach for the start-up construction phase of a petrochemical plant in Kuwait. At Exxon Mobil, Daan developed a maintenance management strategy for a lube oil blending plant. Daan graduated with distinction in 2007 as Master of Science in Logistics and Operations Management at Tilburg University.

In Februari 2009, Daan joined the Construction Management and Engineering department at the University of Twente to start his PhD research on asset management in the infrastructure sector. In this project Daan partnered with Rijkswaterstaat to facilitate their implementation activities and study the reception of their asset management strategy at several departments. He published findings in international peer-reviewed journals, like Built Environment Project and Asset Management, Structure Infrastructure Engineering, International Journal of Strategic Engineering Asset Management and Organizational Research Methods. Daan also communicated his work at Rijkswaterstaat and international conferences, like the World Conference of Engineering Asset Management, the Engineering Project Organization Conference and the CIB World Conference.

Daan continued his work at Delft University of Technology on organizational issues with a specific focus on challenges occurring at multiple levels of office. Since 2013, Daan conducts advice and research studies on the implementation of new strategy inside public organizations, which so far included asset management, urban regenerative sustainability initiatives and business intelligence.

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Asset Management (AM) implementation appears a difficult and lengthy exercise for many public infrastructure agencies, and hard to understand because of the many contexts in which these agencies are situated. The main objective of this research project is to understand the challenges in AM implementation by taking into account that AM is an integrative, fluid and dynamic concept and that transport infrastructure agencies have an existing way of managing infrastructure before the change. The research design involved four steps. The first two steps are explorative and descriptive, and explore how the management of infrastructure assets is understood. We do so by reviewing the relevant literature and the agency's practical context regarding the management of infrastructure assets. The final two steps include the design and then application of a method to understand the implications of existing viewpoints, and how these should be addressed, within public agencies when implementing AM.

Daan Schraven (Breda, 1984) graduated with distinction in 2007 as Master of Science in Logistics and Operations Management at Tilburg University. During his studies, he developed an interest for the way in which workers coordinate their operations in line with their organizations' strategy and the challenges in doing so. In February 2009, Daan started his PhD research on implementing Asset Management in the infrastructure sector at the Construction Management and Engineering department of the University of Twente.

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