Developing a maturity model for infrastructural asset management systems

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Abstract

Since World War II many new structures have been built in infrastructure. Now, some 50 or 60 years later, we see a steady increase in maintenance expenditure, which clashes with the need to limit governmental spending. To assist in the professionalization of the institutional asset management processes, maturity models can be used. In this paper we compare some of the existing maturity models and discuss the characteristics of the models currently applied to analyse the maturity level of organizations. We differentiate between four forms of the models: the conceptual maturity model, the maturity matrix, the maturity check, and the maturity roadmap. We show how the different models can be seen as a maturity development process where the different forms of the models are represented. We state that most of the maturity models developed in domains like software development and manufacturing are not suitable for public infrastructure management. We present the development of our infrastructure management maturity model (IM³) by using a case of a Dutch highway agency. In the conclusion we reflect on the potential impact of infrastructure maturity models for the professionalization of asset intensive organisations in infrastructure.

Keywords: asset management, organisational development, professionalization, transport, infrastructure

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1. Introduction

Since World War II many new structures have been built in infrastructure. Now, some 50 to 60 years later, we see a steady increase in maintenance expenditure which clashes with the need to control governmental expenditure. At the same time governmental agencies rethink their market approach and experiment with innovative contracts and project structures to include the lifecycle thinking in maintaining their assets (Altamirano, 2010). Asset management aims at improving the overall performance of asset-intensive industries by making and executing systematic and highest value decisions about the use and care of assets (Brint, Bridgeman, & Black, 2009; Campbell, Jardine, & McGlynn, 2010; Quak, 2007). Not surprisingly, in the context of high stakeholder expectations and decreasing governmental budgets, asset management is a fast growing field in public infrastructure.

An asset management system for the transportation sector requires system-level performance measures, models, interoperable databases used by asset groups to make evidence-based decisions (Moon, Aktan, Furuta, & Dogaki, 2009). Yet, in the Netherlands asset intensive organisations, such as the National Highway Agency, find it difficult to develop, use and control these kinds of systems. They are therefore currently in urgent need of professionalising their asset management practices. To assist in the professionalization of institutional asset management processes, maturity models can be used.

Recently maturity models have been gaining attention in the field of asset management. These maturity models have been developed following the capability maturity model, developed by the Carnegie Mellon University (Paulk, Curtis, Chrissis, & Weber, 1993). This model was originally developed to assess software development projects. Gradually it has been extended to include a broad array of processes such as systems engineering, collaborative processes, knowledge management and human resources (e.g. Curtis, Hefley, & Miller, 1995; Magdaleno, De Araujo, & Da Silva Borges, 2009).

In this paper we will first explore the elements of capability maturity models and infrastructure asset management. Then we compare some of these existing maturity models and discuss the advantages and disadvantages of the research methods used to fill these models. We conclude that most of the maturity models as developed in domains like software development and manufacturing are unsuitable for public infrastructure management. Then we discuss the need for an infrastructure maturity model and show the development of our infrastructure management maturity model (IM^3) by using a case of a Dutch highway agency. Based on these experiences we reflect on the potential impact of infrastructure maturity models for the professionalization of asset management practice in asset intensive organisations in infrastructure. This is required in order to optimize the balance between institutional and technical coordination of infrastructure and improve overall performances (Finger, Groenewegen, & Kunneke, 2005).

2. The aim and structure of the Capability Maturity Model

The first version of a capability maturity model (CMM) was developed by the Carnegie Mellon University as a tool to objectively assess the ability of contractors in performing a project (Paulk et al., 1993). It was based on data from software projects for the U.S. department of Defence and a process maturity framework for software processes. Gradually it has been extended as an appraisal method into a broader array of areas, such as the IPD-CMM (Integrated Product Development Capability Maturity Model), P-CMM (People Capability Maturity Model), SW-CMM (Capability Maturity Model for Software), SE-CMM (Systems Engineering Capability Maturity Model), SA-CMM (Software Acquisition Capability Maturity Model), and CMMI (Capability Maturity Model Integration). A maturity model can thus nowadays be viewed as a set of structured levels that describe how well different processes of an organisation are able to produce the required outcomes in a reliable and sustainable way.

The CMM model is increasingly becoming a standard for process evaluation and assessment (Paulk 1993, Tingey 1996). Khoshgoftar and Osman (2009) conclude in their review of maturity models that OPM3 (Organizational Project Management Maturity Model) is the better maturity model for improving organizational performance. Yet, Judgev and Thomas (2002) note that the benefits of maturity models to increase company competitiveness should not be overestimated. Maturity models are prescriptive and capture the know-what of an organization. Therefore Judgev and Thomas (2002) conclude that maturity models are useful but provide temporary competitive advantage for the firms using them. Sustained competitive advantage needs know-how.

The original CMM involves the following aspects (Paulk et al., 1993):

- Maturity Levels: a 5-level process maturity continuum where the uppermost (5th) level is a notional ideal state where processes would be systematically managed by a combination of process optimization and continuous process improvement and the lowest level is a minimum ‘to live’.
- Key Process Areas (KPA’s): a Key Process Area identifies a cluster of related activities that, when performed together, achieve a set of goals considered important.
- Goals: the goals of a key process area summarize the states that must exist for that key process area to have been implemented in an effective and lasting way. The extent to which the goals have been accomplished is an indicator of how much capability the organisation has established at that maturity level. The goals signify the scope, boundaries, and intent of each key process area.
- Common Features: common features include practices that implement and institutionalize a key process area, such as Commitment and Ability to Perform, Activities Performed, and Measurement and Analysis, and Verifying Implementation.
- Key Practices: The key practices describe the elements of the system and practice that contribute most effectively to the implementation and institutionalization of the KPA’s.

The CMM is based on the belief that predictability, effectiveness and control on an organisations' processes are needed on the way to becoming a mature organisation. It provides a theoretical continuum along which process maturity can be developed incrementally from one level to the next. Skipping levels is not allowed/feasible. There are five levels defined along the continuum of the CMM:

- Initial (also chaotic, ad hoc, individual heroics) - the starting point for use of a new or undocumented repeat process.
- Repeatable - the process is at least documented sufficiently such that repeating the same steps may be attempted.
- Defined - the process is defined/confirmed as a standard business process, and decomposed to levels the tactical and operational level.
- Managed - the process is quantitatively managed in accordance with agreed-upon metrics.
- Optimizing - process management includes deliberate process optimization and improvement.

Within each of these maturity levels are Key Process Areas (KPA's) which characterise that level, and for each KPA there are five definitions identified: Goals, Commitment, Ability, Measurement, and Verification. The CMMI (Integrated Capability Maturity Model) was formed in order to outrun the problems of using multiple CMMs and combines the SW-CMM, the SECM and the IPD-CMM. The CMMI distinguishes four categories for the different processes of an organization: Support, Engineering, Project management and Process Management. Support contains processes that do not have an external and/or commercial output, but provide the foundation on which the rest of the organisation can perform an efficient activity, while Engineering contains processes that "do the work" - perform the actual work of the organisation. Project Management contains processes that coordinate to efficiency the "actual work" of the organisation, and Process Management contains processes that set paths for the entire organisation. Because asset management also includes the development of the organisation itself, the People CMM appears to be relevant as well for infrastructure. The People CMM aims at an environment in which practices can be repeated, best practices can be transferred across other groups, variations in performances can be reduced, and practices are continuously improved.

In general the use of maturity models provides a number of advantages. First of all, maturity models provide a normative description of good practices. That is, the maturity levels set an ideal standard that organisations can strive for (Tiku, Azarian, & Pecht, 2007). Another benefit of maturity models is that they are a discussion tool for engaging interviewees and enable reflection on the current status of an organisation. The resulting identification of strengths and weaknesses can act as a framework for prioritizing actions and can help raising awareness about a particular strategic process among the employees and board members (Judgev & Thomas, 2002). Finally maturity models can be used to benchmark (parts of) organisations (Ligtvoet, Van der Lei, & Herder, 2010; Marshall & Mitchell, 2007). Judgev and Thomas (2002), however, note that the benefits of maturity models should not be overestimated because they provide only temporary competitive advantage to the firms using them. Van der Lei et al (2011) mention the positive link between the implementation of other standards, such as PAS55, and the maturity level of an organization. This implies that increased attention for quality improvements and strategic asset management could improve performances just as much as a maturity model or other kinds of standards could contribute to business results.

3. Infrastructure Asset Management

Moon, Aktan, Furuta & Dogaki (2009) identify five requisite attributes of a transportation asset management system:

(1) Policy-driven. In general, these policy goals and objectives should address: (a) asset condition, levels of performance, and quality of services to meet customer needs, and (b) Transition to asset management broader economic, community, and environmental concerns.

(2) Performance-based. All goals and objectives incorporated within the AM system must be tied to clear measures of performance and used to guide decisions.

(3) Capable of analysing various options and trade-offs of investments.

(4) Based on quality, objective information to link to the physical infrastructure.

(5) Monitored to provide clear accountability and feedback about the degree to which system performance is meeting agency goals, and to offer a rational means of improving and maintaining the system.

According to Malano, Chien & Turral (1999) general principles and functions of asset management for irrigation and drainage infrastructure include asset planning and creation strategies, operation and maintenance, performance monitoring, accounting and economics, and audit and renewal analysis. Asset management therefore includes maintenance, renovation as well as reconstruction of a variety of assets. Maximizing value and minimizing risks are important drivers for optimization of the asset portfolio and system. Asset management systems, such as PAS 55, distinguish different levels (e.g. Strategic, Tactical & Operational Level; Policy, Strategy, Objectives & Plan) and actors (e.g. Asset owner, Asset Manager & Service provider) to be included in asset management. Of course differences exists in the types of assets (Van der Lei, Wijnia, & Herder, 2010). Moon et al (2009) conclude that the following building blocks are required before advances in technology in the highway transportation community can be fully exploited:

(1) System-level performance measures and objective measurable indicators should be defined.

(2) Performance measures and indicators for specific asset groups should be defined.

(3) A system performance model incorporating the performances of each asset group and the interactions between these should be constructed, and the associated data needs and measurement standards to quantify and validate this model should be established.

(4) Interoperable databases, composed of both legacy data for various asset groups and measured objective data, should be developed.

(5) The value and performance of each major asset group, and how individual asset groups influence others should be established based on the data and models in points (3) and (4) above.

This system-level valuation and performance modelling will lay the groundwork for the simulations and trade-off identification needed to inform decisions on asset management. When measuring the maturity level of organizations that are active in the field of infrastructure, these characteristics have to be taken into account.

4. Maturity Models for Infrastructure – an explorative comparison

Nowadays the concept of the maturity model has been applied by others outside the Carnegie Mellon University in a diversity of development processes and organisations with the intention to improve them. We compared several of these maturity models for their potential to be applied on infrastructure. The results are shown in Table 1 in the Appendix. The inventory shows that there are differences between 1) the process and domain areas included in the model, 2) the nature of the assets within an organisation, 3) the levels of maturity measurement, 4) a qualitative versus qualitative approach, and 5) the measurement methods to collect the data.

First we distinguished four different kinds of domains: software, HRM, manufacturing, and management of assets. Some of the models were set up for a specific domain, but on a conceptual level they are similar. That is, all models use the levels depicted in the capability maturity model but vary the process and domain areas.

This is related to the second aspect that differentiated the models; the nature of the assets. For asset management purposes, the inclusion of the specificity of the assets could be important. When appraising the asset management process the status and lifecycle path of the assets provide important input for the asset management process. For example, the model of Winter & Farby (forthcoming) acknowledges this and distinguishes different kinds of assets when measuring the maturity level of the organisation.

A third aspect we studied were the maturity levels and their implication areas, which we identified as key process areas. The different levels that were developed in the original CMM (from initial to optimizing) are maintained in almost all maturity models we reviewed. The variety of these models lies in the processes and the key domain areas that are defined differently. The different key process areas usually include issues on a strategic level, such as leadership and policy, topics on a tactical level, such as quality management and process re-design, and issues on operational level include items such as data management, planning & scheduling or supply management. These issues can be operationalised in different levels, such as centralised, standardised, virtualised, service based, and policy based. Also we see that process areas and domain areas are sometimes used interchangeably, which is for example the case in the OARISK model and the model of Winter and Farby (2011).

Fourthly we found differences in the method of maturity appraisal, which related to the fifth aspect: the approach of the measurement. Appraisal can be done quantitatively (e.g. Marshall & Mitchell, 2007), qualitatively (e.g. Ligtvoet et al., 2010), or by mixed methods (e.g. Winter & Fabry, forthcoming). Other models were just intended as normative frameworks and not applied to collect data or assess the maturity status of an organization (e.g. British Standards Institute, 2004; Port, Ashun, & Callaghan, 2010).

Based on these findings we conclude that these kinds of differences relate to the different forms of maturity models that are currently in use to evaluate and guide the process of maturity development. We can distinguish four forms of maturity models as follows: a maturity roadmap, maturity check, maturity matrix and a maturity model. As Table 1 shows, all forms exist next to each other but follow naturally when applying the concept of maturity to evaluate processes and advice on process improvement. This is schematically shown in Figure 1. A *maturity check* can be regarded as an appraisal, a *maturity matrix* is a structure - for example for data collection or policy planning- and a conceptual *maturity model* can be regarded as the integration of goals, levels and process areas on a conceptual level. By using a maturity model, an organisation can compare the scores of the appraisal to the targets and strategic goals by using the matrix structure. Whereas the maturity model helps an organisation to identify the current weaknesses and strength within an organisation, the roadmap is needed to implement changes (Hauge & Mercier, 2003). In a roadmap levels grow from Initial, Repeatable, Defined, Self-sustaining, and Continuous improvement.

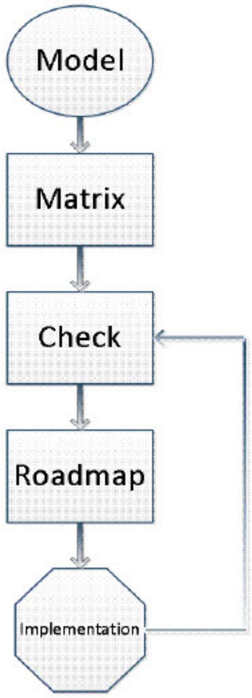

Figure 1: Maturity development process where the different forms are distinguished

Further analysis showed that most maturity models are developed from the perspective of the agent and its primary production process, for example, software or product development in a manufacturing context. Most manufacturers depend on their suppliers in the value chain for the delivery of parts that the agent assembles in one or several central places. This means that they produce their product within the organisation of the agent, while being surrounded by a network of suppliers. Usually only one supplier is needed per part of the value chain. If one of the suppliers fails to deliver, they have to replace the supplier in order to keep the value chain and production line intact. This is normally no real problem since often there are several suppliers available in the market able to deliver similar products, and several buyers that produce comparable products.

In infrastructure management however the product is different and consists of a network of roads, pipes or other kind of assets that needs to be maintained and that most often lie in public space (Herder & Wijnia, forthcoming). The agent determines which part of the network needs to be maintained to keep the production process (transport, delivery of energy stream etc.) running but in such a way that process is not disrupted, and the agent puts these requirements into the market. Procurement determines which supplier (or service provider in asset management terms) can deliver which service to which place in which time (Altamirano, 2010). Of course products are needed for the network but are rather facilitating, not part of the primary production process. The suppliers that deliver different services in different parts of the network usually stay the same. In some cases, such as the railway or energy sector, the market only has very limited and specialised suppliers in the market.

The different types and specificity of infrastructural assets differentiate the asset management process from other processes as manufacturing and software development (Van der Lei et al., 2010). In order to keep the value chain intact, agents and suppliers depend on each other in a different way. In this relationship trust is important but there is a push from the principal to squeeze budgets and outsource risks. Suppliers, on the other hand, are pushed to deliver the bare minimum as margins are tight. New ways of contracting between the agent and suppliers are therefore sought in order to professionalize this complex relationship (Altamirano, 2010). A first step that many companies have taken is the description of clear roles (like in PAS 55 or ISO trajectories). The interpretation of these roles varies and will vary between different organizations and the technical network specificities (Finger et al., 2005).

5. Development of a Maturity Model for Infrastructure

We decided to develop the Infrastructure Management Maturity *Matrix* (IM³) that could perform a maturity check, because our primary aim was the appraisal of the maturity status, and not the development of an internal quality improvement. Especially the CMMI appears to be interesting in this context because it addresses the entire product life cycle from conception, development, delivery and maintenance. Our matrix is based on existing structures, such as CMMI, P-CMM and PAS55, and can be adjusted to the situation of the client organisation.

We developed the first version of the maturity matrix for road infrastructure because of requests of the Dutch Highway Transport Agency. The IM³ for road infrastructure consists of five maturity levels on the vertical axis (ad hoc, repeatable, standard, managed, optimal) and seven asset management dimensions on the horizontal axis (information management, internal coordination, external coordination, market approach, risk management, processes & roles, and culture & leadership) (see Figure 2). The main differences between our matrix and the other models that we analysed in Table 1 are the inclusion of stakeholders and communication issues (Internal and External communication), and the specific purchase model that is adjusted to a public market in which procurement is necessary (Market approach).

We chose to collect data by doing interviews with key players in the organisation, because this would provide us with qualitative information, and the opportunity to explain the model and the elements when needed. Previous research (van der Lei et al., 2011) revealed the benefits of this research method, such as the relatively short time period to collect data and the in-depth information.

	Information management	Internal coordination	External coordination	Market approach	Risk Management	Processes & Roles	Culture & Leadership
Optimal							
Managed							
Standard							
Repeatable							
Ad hoc							

Figure 2 Infrastructure Management Maturity Matrix: maturity levels against maturity dimensions

The asset management dimensions that are included in IM³ can be defined as:

- *Information management*: The availability and use of (standardized) static and dynamic databases for decision making.
- *Internal coordination*: Coordination and problem solving between the different departments of the organisation.
- *External coordination*: Coordination and problem solving between the different stakeholders of a project, including communication with users.
- *Market approach*: Strategy about and implementation of integrated and performance based contracting and innovative procurement methods.
- *Risk management*: The use of risk management methods and Life Cycle approaches in decisions on strategic and operational asset management level.
- *Processes and roles*: Clarity, definition and implementation of job responsibilities and roles within the organisation.
- *Culture and leadership*: Level of knowledge, implementation and support of asset management related issues.

6. A case in Dutch highway infrastructure

In the beginning of 2011 we conducted interviews with all regional departments of the largest Dutch highway agency called Rijkswaterstaat. Rijkswaterstaat is responsible for the design, construction, management and maintenance of the main infrastructure facilities in the Netherlands. The organization consists of ten regional departments (including 19 road districts and 16 water districts), one project organisation, and five centres of excellence concentrated on its specialised knowledge. For each department we spoke with two operational employees (such as data managers and team leaders) and two employees at the tactical / managerial level (directors and strategic advisors), so we performed 20 interviews in total. The interviews were conducted by two interviewers (one from university and one externally hired consultant). The interview reports were sent to the interviewees for verification. Based on the results of the interviews a report was written (van den Boomen, Wessels, Ligtvoet, Volker, & Leijten, 2011).

The interviews were conducted using the IM^3 matrix as shown in Figure 2. After we had introduced the research project shortly, we handed them the matrix. Each interviewee was asked per dimension how they would assess their own department on a scale from ad hoc to optimal. The results of the interviews were compared between departments, between interviews (tactical / operational or management level), and between the different themes. In some cases, the interviewees indicated that there was a difference between dry (highways, crossovers) and wet sectors (canals, Delta works). This distinction has been made visible in the spider diagrams that were used to display the results, just as the relative score of a department in comparison to the organisation as a whole. Figure 3 shows an example of the results of one of the departments of the organisation. Based on the data, the researchers determined a general 'asset management maturity level' for the whole organisation. This level was determined by discussing the results of the interviews, reading the strategic asset management plans, and using other kinds of background information. It should be noted that it is not methodologically sound to translate, sum up, or average these ratings into quantitative values. The levels are therefore described as qualitative scores per dimension. The maturity level of an organisation thus exists of seven scores as shown in the matrix, which also shows the diversity of asset management (see Figure 4).

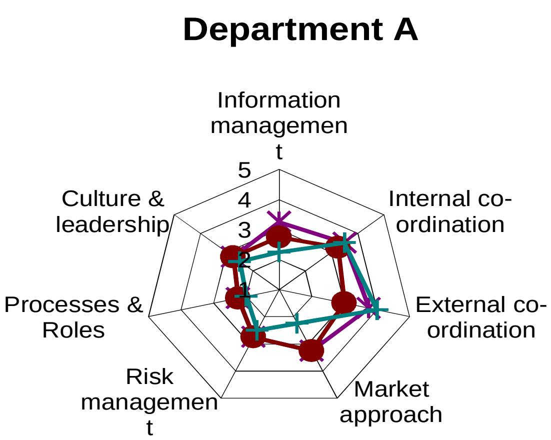

Figure 3: Example of the maturity rating results of department A

	Information management	Internal coordination	External coordination	Market approach	Risk Management	Processes & Roles	Culture & leadership
Ad hoc							
Repeatable							
Standard							
Managed							
Optimal							

Figure 4: Example of the Infra Maturity Level of an organization

7. Reflection

We found that asset management was still relatively hidden in the organisation. The highway agency in our case study used to be focused on developing projects instead of maintaining assets. Although the organisation relied heavily on constant maintenance of the assets, maintenance activities were somehow considered as projects. The implementation of asset management made people aware of the fact the strategic maintenance decisions have an impact on the status of assets. In order to start more integrated contracting practices, data needs to be accurate, reliable and complete. Just as noted by Marshall & Mitchell (2007), we found that all of the processes are interrelated to some degree, particularly through shared practices and the perspectives of the seven dimensions. For example, it showed to be very difficult to apply risk management systems without good information, and information management is complicated when the processes and roles within the organisation are not entirely clear, as also noted by Moon et al (2009). The introduction of asset management within an organisation should therefore be regarded as an iterative process whereby the elements interact. It's a learning process for both the principal agent and the players in the field.

For the maturity check this meant that it was hard to find the people that were responsible for asset management activities which could provide us the right kind of information. Without the inside help of the client we could not have found the right persons to talk to. Yet, we also realize that all information and ratings are relative and heavily rely on the interviewee and period that the data were collected. We therefore underline that the ratings are qualitative data and just as important as the examples and explanations that were given by the interviewees. As also addressed in the previous sections, a maturity check should be considered as benchmark instrument. This means that the first measurement should be considered as zero-reference and used in comparison to other measurements. As counts for every benchmark, a stable structure and list of dimensions seem to be essential.

Interviewing all departments cost a lot of time and energy but also created a lot of insights in a relatively short amount of time. It was good that we used tandem interviewing (two interviewers), and duo-interviewing (two interviewees), at the same time. The interview report was written by the interviewer that took most notes, checked by the other interviewer, and then sent to the interviewees. This proved to be a successful method. From a principle perspective one could argue that duo-interviewing was not necessary. Especially when the interviewees represented different kinds of assets, the rating became somewhat complicated. Yet, it created a good opportunity for the employees to discuss their shared experiences.

The Infra Management Maturity Matrix provided a good structure during the interviews. Although we did not send the matrix to the respondents beforehand, they were able to understand the dimensions and rating scale rather quickly. Conducting the interviews gave the researchers the possibility to explain the dimensions when this was necessary. It also provided enough opportunity to continue asking questions when the rating as indicated by the interviewee did not provide enough exemplary details to believe it was on the right level as intended by the matrix. At the same time we found that some of the dimensions showed overlap and the rating scale was not always fully comparable. Therefore we will continue developing the matrix and test it on other infrastructural fields, such as energy providers, harbours and railways.

In the future we will plan a general feedback meeting for all respondents to decrease the large gap between strategic decisions and operational activities. We found that, since asset management was rather new in (public) organisations, there was a strong need for debate and reflection about the current strategy and implementation projects. We expect that other organisations also have difficulties with making this kind of strategic plans visible in the organisation. We are also considering a survey questionnaire for a generic inventory of the maturity level of organisations. This way quantitative data can be gathered among all groups and layers of an organisation and the inventory can be broadened. This set of questions could for example be part of a yearly employee satisfaction or general audit.

8. Conclusion

We see that when organisations want to develop or change their asset management processes maturity models can be of help. When these maturity models are represented in a matrix they can be used to perform a check the maturity of different organizations. A maturity model on conceptual level can provide a frame for strategic discussions and support organizations in implementing asset management within their organisation. The model may vary depending on the purpose of the development. Maturity models that are used to compare different organizations (e.g. Ligtvoet et al., 2010) have a higher aggregation level and are less domain specific than maturity models used to compare divisions within an organisation, such as the original CMM of Paulk et al (1993). This explains the need for specific models for different purposes.

Important regarding the development of the model is that the key domain areas need to be formulated clearly and without overlap. This has implications for the consistency of the check and the reliability of the results, as results may overlap and thus influence multiple key domain areas. A two dimensional matrix with maturity levels and domain areas also has limitations. In order to have a complete overview of the maturity level it could be interesting to include the process areas in the domain areas. Whether these process areas should be included in the domain areas, or the domain areas should be included in process areas is an issue for further development.

We expect that the use of maturity models will increase. We see a joint role for practice, consultants and science. Our IM^3 model is an example of such collaboration. Universities may have an important role in the development of maturity models as they can deliver the structure of the models in a transparent and consistent way for specific purposes. Consultants can help with the periodic execution of the check and formulation and implementation of the roadmap. Concerning our IM^3 model a suitable roadmap still needs to be developed for the highway agency. This roadmap should answer the question how to translate the results of the maturity check back into the organization in order to increase performances. This could be another challenging project in collaboration with consultancy firms to valorise our academic concepts and contribute to knowledge development in practice.

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Appendix I

Table 1 Overview and comparison of existing maturity models

Maturity Model	**Process areas**	**Key domain areas**	**Maturity Levels**
Paulk 04 et al – CMMI: Capability Maturity Model Integration	Support Engineering Project Management Process Management Different for different disciplines: systems engineering, software engineering, integrated product and process development, supplier sourcing.	Example system engineering: 1. Causal Analysis and Resolution 2. Configuration Management 3. Decision Analysis and Resolution 4. Integrated Project Management (the first two specific goals) 5. Measurement and Analysis 6. Organisational Innovation and Deployment 7. Organisational Process Definition 8. Organisational Process Focus 9. Organisational Process Performance 10. Organisational Training 11. Product Integration 12. Project Monitoring and Control 13. Project Planning 14. Process and Product Quality Assurance 15. Quantitative Project Management 16. Requirements Development 17. Requirements Management 18. Risk Management 19. Supplier Agreement Management 20. Technical Solution 21. Validation 22. Verification	0 Incomplete 1 Performed 2 Managed 3 Defined 4.Quantitatively Managed 5 Optimizing
P-CMM: People Capability Maturity Model	Developing individual capability Building workgroups and culture Motivating & managing performance Shaping the workforce	Different process areas per Level: 5: Continuous Workforce Innovation, Organisational Performance Alignment, Continuous Capability Improvement 4:Mentoring,Organisational Capability Management, Quantitative Performance Management, Empowered Workgroups, Competency Integration 3:Participatory Culture, Competency-Based Practices, Career Development, Competency Development, Workforce Planning, Competency Analysis	Initial Managed Defined Predictable Optimal

		2:Compensation, Training and Development, Performance Management, Work Environment, Communication and Coordination, Staffing 1: none	
KPMG (08) – SAM: Software Asset Management Optimization Model	Processes Tools & Platforms Learning & Culture Sponsorship Estimated savings at this level	Organisational management (Throughout organisation, Self Improvement Plan) SAM Core Inventory (Hard-&Software inventory, Accuracy of inventory) SAM Core Verification (Entitlement Records, Periodic self evaluation) SAM Core OM & I (Operations management record interfaces) Lifecycle Process Interfaces (Acquisition, Deployment, Retirement)	Basic Standard Rationalized Optimized
BSI (04) - PAS 55-1 & 55-2 for Asset management	AM enablers & controls Implementation of AM plan(s) Performance assessment & improvement	Structure, authority & responsibilities Outsourcing of AM activities Training, awareness & competence Communication, participation & consultation AM system documentation Information Management Risk management Legal & other requirements Management of change	Plan Do Check Act
Winter & Fabry (11) – IH Check & FMEA-Analyzer (RCM roadmap)	Improvement opportunities: low, medium, high	Maintenance policy & strategy Maintenance organisation Maintenance staff Information & knowledge management Maintenance object Materials Management Partnerships Maintenance controlling Customer	0-100% - collective score Improvisation Orientation Commitment Implementation Optimisation
OARISK – AM Maturity Tool		Policy, Strategy & Objectives Ownership & Responsibilities Leadership & communication Training & development Business planning Operate & maintain Health & Safety Risk management Asset design Continuous improvement Information management	Chaotic Applying Embedding Integrating Optimising
Port et al (10) – AM framework for	Leadership & people		Innocence Awareness

optimizing equipment life-cycle decisions	Methods & processes Material & physical plant Systems & technology		Understanding Competence Excellence
CSS UK (04) - Asset management framework (roadmap)	1. Starting Point 2. Levels of service 3. Option identification 4. Decision making 5. Service delivery 6. Reporting & monitoring	Goals, objectives, policies; Inventory Condition assessment; Demand aspirations Performance gaps; Lifecycle planning Optimisation & budget consideration; Risk management Forward work programme; Physical works & services Performance management; Improvement actions	
Adams of Gartner (03) - Process Maturity Model for IT	People Inventory Processes		Chaotic Reactive Proactive Service-oriented Value Creation
Browstein/TPG (04) – Model of Maturity Levels & Attributes	Processes Tools & Platforms Learning & Culture Sponsorship Estimated Savings at this level		Chaotic Progressive Business Integration Optimized Transformation
Ligtvoet et al (10) – Comparing different organisations	Strategy Tools Environment Resources		Initial Repeatable Defined Managed Optimized