Towards a model for effective Asset Life Cycle Management control – a case study in rolling stock maintenance

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Abstract

The maintenance of physical assets is indispensable for sustainable competitiveness. The discipline of Asset Life Cycle Management (ALCM) shows that assets should be managed in a multidisciplinary way over their complete life cycle. This paper asks how these assets can be managed effectively. The concept of management control is used to develop a conceptual model for ALCM control. This model has guided our case study of ALCM in practice. We conclude that the model allows us to gain a deeper insight in ALCM control and to identify the limits to control faced by an asset manager.

Keywords: Asset Life Cycle Management, Management Control, Maintenance

Introduction

Maintenance is indispensable to create maximum value with physical assets. This holds for long lasting consumer goods such as cars, but even more so for the assets used in industry and infrastructure. An estimate of their value for lies around 400 billion euros the Netherlands alone (Veenman and Besselink, 2010). Next to the financial value, these assets fulfil vital functions in our daily lives, such as bridges and roads for transportation or water treatment plants for drinking water. Hence, the effective management of these assets is of huge importance for sustainable competitiveness.

This paper aims to contribute to our understanding of the effective management of physical assets. First an overview will be given of the field of Asset Management. The ideas found here will be supplemented by the requirements for effective control (REC) taken from the paradigm of 'management as control'. This will result in a conceptual model of effective Asset Life Cycle Management (ALCM) control. This conceptual model will be used in a case study on ALCM: the management of the rolling stock by the means of Asset Life Cycle Plans. The paper will present the results of this case study and draw conclusions from it, useful both for practitioners and theorists in the field of Asset Management.

Theoretical Background

Asset Management

The management of physical assets is addressed by the discipline of Asset Management. In the recent international standard on Asset Management, it is defined as a "coordinated activity of an organization to realize value from assets" (ISO, 2014, p. 16). Value is realized by balancing costs, risks, opportunities and performance (ISO, 2014).

Somewhat more elaborate and precise is the definition of Pudney (2010): "an organisation's coordinated multidisciplinary practice that applies human, equipment and financial resources to physical assets over their whole life cycle to achieve defined asset performance and cost objectives at acceptable levels of risk whilst taking account of the relevant governance, geo-political, economic, social, demographic and technological regimes" (Pudney, 2010, p. 8). This definition adds that Asset Management is a *multidisciplinary* practice that should cover the *whole life cycle* of the asset.

Asset Life Cycle Management (ALCM) pays explicit attention to these two aspects: "the management of assets over their complete life cycle, from before acquisition to disposal, taking into account economic, environmental, social and technical factors and performances" (Haffejee and Brent, 2008, p. 286). However, as Haffejee and Brent conclude, a multidisciplinary approach is often lacking (we discuss this issue in more detail in Ruitenburg et al., 2014). Secondly, the focus is often rather on the short and medium term, than on the full life cycle of the asset (Komonen et al., 2012).

To summarize, ALCM should fulfil at least five requirements: it should be 1. a multidisciplinary practice; 2. in which the whole life cycle of a physical asset is taken into account; 3. with the goal to achieve certain objectives; 4. within the limits of risk and relevant regimes; and 5. it should determine the allocation of resources. An effective management of assets should thus take these requirements into account.

Management control

Now we know *what* Asset (Life Cycle) Management exactly is, it is of course important to know *how* to do it. The question on how to manage, or more specifically: how to exert control, is discussed in great depth by De Leeuw (2002). In his approach to management, control is "any way of purposive influence" (1979, p. 95). This implies a person or organization exerting control and something or someone that is being controlled: a controlling body and a target system (De Leeuw and Volberda, 1996).

The controlling body tries to exert influence on the target system in such a way that the target system does what the controlling body wants it to do. But for such an exertion of purposive influence to succeed, a number of requirements have to be fulfilled. De Leeuw (2002) calls these the 'requirements for effective control' (REC).

The first requirement for purposive influence to succeed is that there exists *a purpose* that is aimed for. This implies that a goal has been set (either explicitly or implicitly) and that there is a way to evaluate whether this goal is being reached or not. Next, there is a need for *an understanding of the target system*. If one wants to reach a certain goal with the system, one needs to know how the system will behave. In other words: one needs a model of the target system in order to predict its behaviour. Thirdly, there is the need for *information on the target system and its environment*. Only if one knows the current state of the system, one will be able to exert the right influence on the system. Otherwise one cannot know what the result of a control measure will be. The fourth requirement is that the controlling body has a *sufficient number of control measures* at its disposal. Or more specifically: at least one control measure for every state of the target system. If this is not the case for a particular state, the target system can be called

uncontrollable. Finally, there is the need for a sufficient *capacity to process information*. This is related to all previous requirements: information on the current state of the system, capacity to compare this state with the goals that apply, etcetera.

Asset Life Cycle Management control

When the description of ALCM as a 'coordinated activity of an organization to realize value from assets' is combined with the concept of control, we get the concept of Asset Life Cycle Management control: 'the active and purposive influence of asset performance over the complete life cycle'. Only by exerting active and purposive influence, the asset owner can be sure value is realized with the assets. For this control to be effective, the asset manager(s) as the controlling body should fulfil the REC, while at the same time the five characteristics of ALCM should be covered.

By combining the five requirements for effective control with the five characteristics of ALCM, an imaginary 5 by 5 matrix arises. To simplify and operationalize this matrix into a clear and workable conceptual model, we remove two characteristics of ALCM. Objectives can be removed as these are covered by the goal-requirement in the REC. And we remove resource allocation, as we assume that every control measure will deploy at least some resources. To continue, we will apply the remaining ALCM characteristics to the five requirements for effective control, which will result in a verbal description of our conceptual model, which is summarized in Table 1.

To start, the model of the system should be understood as a description of the asset(s) to be controlled, including an understanding of its behaviour. As the value of the asset lies in its functions, we will limit ourselves to the performance of the asset.

For the performance, certain goals will exist, which the asset has to fulfil. These goals need to be multidisciplinary, which we take to cover at least technical, economical, compliancy and commercial (TECC) perspectives (Ruitenburg et al., 2014). The technical perspective is operationalized further into reliability, availability, maintainability and safety (RAMS) (Smit, 2010), while we expect the economical perspective to cover different types of costs, including operational, maintenance and project cost. Furthermore, these targets need to cover the asset's whole life cycle, operationalized as both the short (<5 years) and long (>5 years) term.

To reach these targets, it is important that sufficient information is available: on the current and expected future performance of the system and its environment. For the performance, we expect that all the same disciplines and timeframes are covered as discussed before. And for the environment of the system we will limit ourselves to the (identification of) risks limiting the value realization with the asset.

If the expected future state of the system does not match the desired future state of the system, control measures will be needed. Finally, the information processing capacity of the controlling body should be sufficient to identify these mismatches and to come up with suitable control measures in time.

Table 1 – The conceptual model for ALCM control,

	Requirements for Effective Control	**ALCM specifics**
1	model of the system	an understanding of the performance of the asset
2	goal	multidisciplinary (TECC), short and long term
3	information on the performance	multidisciplinary (TECC), short and long term
	and the environment of the system	the identification of risks
4	control measures	measures to influence the asset's performance
5	information processing capacity	capacity to process all relevant information

The conceptual model of ALCM control as described in this section and shown in Table 1 covers both the five requirements of effective control as well as the five characteristics of ALCM. This model will serve as the foundation for our case study of ALCM in practice, which will be presented now.

Methodology

To study Asset Life Cycle Management control in practice, we have carried out a case study. Case studies are highly suitable for understanding complex phenomena and for charting new areas of study (Kumar, 2011). Both of these properties fit nicely with this exploratory research project on Asset Life Cycle Management control.

To study ALCM control, we have looked for a case where experience has been gained in ALCM and where access is easy. Hence we have selected NedTrain: the company responsible for the maintenance and asset management of the rolling stock used by the Netherlands Railways, holding over ten years of experience with ALCM. Different types of trains in different life cycle phases are maintained (stopping trains vs. intercity trains), all with expected lifetimes of 30 years. This allows us to study ALCM control for different assets of different ages within the same setting.

Asset Life Cycle Management within NedTrain is concentrated in one type of document, the so-called Asset Life Cycle Plan. This plan mainly describes the outlook of the asset manager on the future of a train series and its performance. It is this document that has been selected as the core object of this study and has been studied as 'artifact of ALCM control'. Eight of these ALCPs have been selected, covering the different life cycle phases and train types NedTrain works with, see Table 2.

Table 2 – Overview of the ALCPs selected for this research

code	train type	bought	revision	life cycle phase	ALCPs selected
TST	trad. stopping train	1975-84	2002-09	securing - phasing-out	2013, 15
MST	mod. stopping train	2009-13	-	investing	2012, 15
ICT	intercity train	1983-93	2006-11	securing	2005, 10, 12, 15

To study these ALCPs in a sound and structured way, a coding scheme has been developed based on the conceptual model introduced earlier in this paper. Based on the conceptual model we have coded the ALCPs using top-down coding (Silverman, 2006).

The findings from the document study have been supplemented with three semi-structured interviews (from 1 to 2 hours) with the asset managers responsible for writing these ALCPs. These interviews have been transcribed and analysed. Furthermore, three group meetings on the development, strengths and weaknesses of the current ALCPs have been attended (all sessions lasted between 2 and 4 hours). Finally, some additional relevant company documents have been read to triangulate the findings of this study.

Introduction to the case study and the ALCPs

NedTrain is the company responsible for the maintenance, management and performance of the trains used by the Netherlands Railways. In other words: NedTrain is the service provider for Netherlands Railways as the asset owner. For each train type, there are two asset managers: one from NedTrain and one from the Netherlands Railways. In this way, both asset owner and service provider are represented. The asset managers are supported by a dedicated "rolling stock team", consisting of a number of experts, amongst others a maintenance engineer, a reliability engineer, a supply chain manager, a production manager and a business analyst. It is the asset managers, supported by the rolling stock team, who write the ALCP.

The ALCP

The first ALCP has been written in 2004 on the ICT. It was introduced as follows: “The Asset Life Cycle Plan (ALCP) is a plan that describes which performance objectives will be realised at what costs in the coming ten years. And what measures will be necessary to realise this performance”. The ALCP was explicitly introduced as a ‘living document’ which needed updating each year with the latest insights and choices. Since its introduction, ALCPs have been (re)written every year. The ALCP is still in development, as the needs of the company change and further improvements are made.

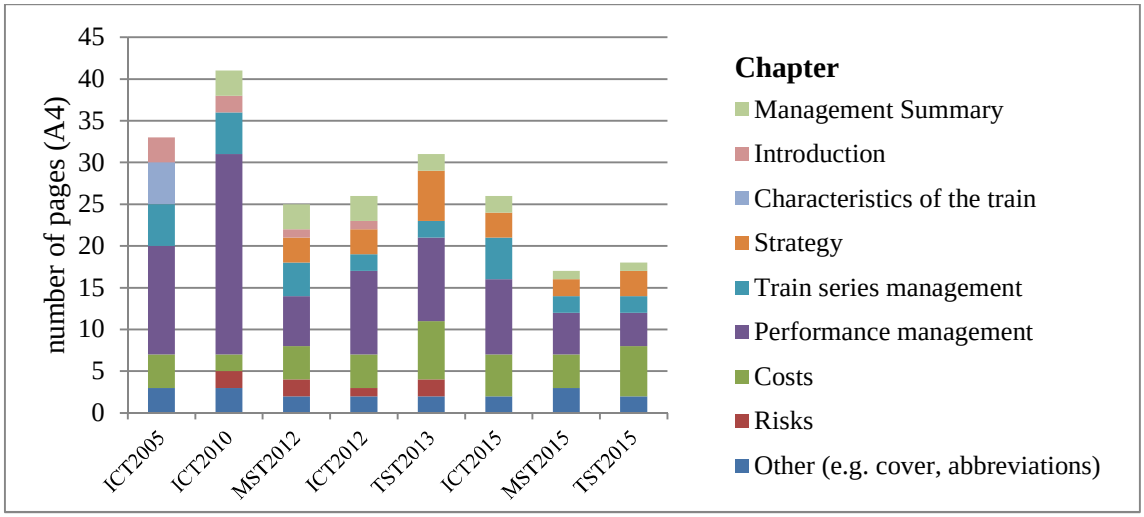

Figure 1 – Overview of the contents of the ALCPs studied for this paper

Figure 1 shows the contents of the different ALCPs studied for this paper. When comparing the first (ICT2005) ALCP with the 2015 ALCPs, we see that in ICT2005 no management summary, strategy chapter or risks were given. However, what was given in (only) this ALCP is an overview of the characteristics of the train: static information. In later ALCPs this information was given in the appendix (not shown in the figure). In 2015 on no appendices were included in the ALCP. Here we see clearly how the ALCP developed from a ‘handbook’ for the asset manager, including design information, to a strategic document with a chapter on strategy and a summary for the management as the target audience. This also explains the reduction in length: from an average of 37 pages (excluding appendices) for the first 2 ALCPs listed to an average of 20,3 pages in 2015. A second explanation for this reduction can be found in the status of the ALCP: where in the early years a lot of elaboration and substantiation was needed, currently the reputation of the asset managers and their teams allows them to keep it short.

Over the years, the ALCP has gained a prominent role in the asset management at NedTrain. Starting with a request from the asset owner for a certain deployment for the next year, the feasibility and costs of this request are given in the ALCP. This is an input for the budget and deployment planning process, where the performance and costs of all train series are combined and optimized. The resulting performance for the next year is used in a performance contract between both companies.

Results

In this section, the main results from our case study will be presented, addressing the five requirements for effective control from an ALCM perspective. Our focus will lie on the performance of the train series as discussed in the different ALCPs.

A model of the target system

An important requirement is that the asset manager has a model of the target system that has to be controlled. The target system managed in this case is the train series including all scheduled maintenance. It is assumed that the train series will continue to operate as it currently does, based on the current operating instructions and the current maintenance activity descriptions. In case the performance of the train series or external developments ask for it, control measures are needed to alter the target system.

What we find here is that control may be limited by the understanding of the target system. An example of this is the newest train series, the MST, which been purchased from 2009 till 2013. In MST2012, this train was described by the asset manager as "in many respects still a black box for NedTrain". Not only does this hold for the software in the train, but also for the physical design, as NedTrain was less involved in the design of this train than for previous trains. This has important consequences for the control that can be exerted: making design changes is more difficult and more risky, which has caused the asset managers to choose the slogan 'keep it standard' for this train series.

A different type of model of the target system is the prediction of performance in relation to a control measure. Interestingly, in two of the 2015 ALCPs it is stated that one does not understand the relation between customer satisfaction and its "underlying (suggestible) factors such as cleanliness" (MST2015). This finding has led to the development of a new KPI, namely the number of 'comfort failures' instead of customer satisfaction itself (see Table 3).

Targets

In the ALCP three types of targets are mentioned: 1. general company ambitions; 2. life cycle strategies for specific train series; and 3. targets on the different KPIs.

The first type of targets are general company ambitions, such as cost reduction or customer intimacy. These descriptions are used as inputs for more specific KPI targets.

The second type of targets are specifically life cycle related. NedTrain uses three different 'life cycle strategies': investing, securing and phasing-out. For each of these different life cycle phases, different targets apply. For the investment phase, the goal is to increase performance. For the securing phase, the goal is to secure performances while reducing costs. And for phasing-out, the focus shifts even more to cost-savings and design changes are to be avoided, even if this may result in lower performance. Each train series is assigned to a certain life cycle phase, primarily based on its age. These 'life cycle strategies' are translated to specific KPI-targets as well. But they also set a specific mind-set and priorities for the asset management of the train series.

Finally, there are KPIs as specific targets. Based on the conceptual model, we expect multidisciplinary targets, at least covering technical, economical/financial, compliancy and customer aspects. Table 3 shows the performance areas covered in the ALCPs.

Table 3 – Overview of the targets (codes) and performance (formatting) covered in the ALCPs

	Production	**Technical**				**Economical**				**Compliancy**	**Commercial**				**Operator**	**Sustainability**		
	km	**R**	**A**	**M**	**S**	**M**	**O**	**P**	**o**		**C**	**S**	**F**	**o**	**satisfaction**	**E**	**N**	**W**
ICT2005	-	**q**	Q	-	**Q**	-	-	-	-	-	*d*	-	-	-	-	-	-	-
ICT2010	**Q**	**Q**	**Q**	-	**Q**	-	-	Q	-	-	*Q*	*Q*	-	*Q*	*d*	*d*	*d*	*d*
MST2012	**Q**	**Q**	**Q**	-	**Q**	**Q**	**Q**	**Q**	**Q**	-	**Q**	*d*	-	-	*d*	*d*	*d*	*d*
ICT2012	**Q**	**Q**	**Q**	-	**Q**	**Q**	**Q**	**Q**	**Q**	-	**Q**	*Q*	-	-	*d*	**Q**	*d*	*d*
TST2013	**Q**	**Q**	**Q**	-	**Q**	**Q**	**Q**	**Q**	**Q**	-	Q	*Q*	-	Q	*d*	d	d	d
ICT2015	**Q**	**Q**	**Q**	-	**Q**	-	**Q**	**Q**	**Q**	-	**Q**	-	Q	-	-	-	-	-
MST2015	**Q**	**Q**	**Q**	-	**Q**	-	**Q**	**Q**	**Q**	-	**Q**	-	Q	-	*d*	*d*	-	-
TST2015	**Q**	**Q**	**Q**	-	**Q**	-	**Q**	**Q**	**Q**	-	**Q**	-	Q	-	-	-	-	-

Legend										
Codes		**Technical**		**Economical**		**Commercial**		**Sustainability**	
d	description	R	reliability	M	maintenance	C	cleanliness	E	energy consumption
q	partly quant.	A	availability	O	operational	S	customer satisfaction	N	noise production
Q	quantitative	M	maintainab.	P	project costs	F	comfort failures	W	waste
		S	safety	o	other costs	o	other		
Formatting									
B	current and expected performance			*i*	only current	U	only expected performance		

Table 3 shows that the performance areas covered are clearly multidisciplinary. From the technical perspective, maintainability is not covered in the ALCP, which is not surprising as this is more a characteristic of the design than a dynamic performance characteristic. Compliancy targets are not stated explicitly, the implicit goals seems to comply with all legislation. The final performance area we expected is the commercial perspective, which is covered by cleanliness, customer satisfaction and comfort failures.

Next to these targets expected from the conceptual model, some additional targets are mentioned in the ALCP. The most important is the 'production' of the train: the amount of kilometres the train will drive throughout the year. Next to this target, there are targets for the operator satisfaction and sustainability. Sustainability is in most ALCPs divided in noise, energy and waste. Interestingly, one can see that the ALCP started as a predominantly technical document, while other perspectives were included later. Sustainability is still covered in the 2015 ALCPs, but no targets are given here. Clear quantitative goals are given for most areas. For operator satisfaction and sustainability, descriptions of the desired situation are given, e.g. the satisfaction of operators.

All these KPI targets are set for the next five years. As discussed earlier, for the first year this target is fixed and used in a performance contract. The next four years the targets set are less solid, and should be interpreted as in between targets and performance prognosis. It is the figure the asset manager aims for and which may be expected by the Netherlands Railways. But if different demands are made, these target values may change. In that way these values are a way to communicate what future performance may be expected, to allow tuning with other departments.

The targets are thus clearly multidisciplinary, and cover all the performance areas we had expected. However, all KPI targets only cover the short term (<5 years). It is only the general company ambitions and the life cycle strategies that may cover the long term. Here it is mainly the life cycle strategies that give direction. But as these are rather mind-sets – how do we manage the trains – than targets – what do we aim for – we may conclude that long term targets are less well-developed than the short term targets.

Information on the state of the target system and its environment

For the system to be controllable, one does not only need targets, but also a description of the performance. Table 3 shows what performance information is given in the ALCPs. From the table it becomes clear that the production and technical performance are covered in nearly all ALCPs. For the cost performance, numbers are sometimes missing, e.g. for the maintenance costs in the 2015 ALCPs. The commercial perspective is less developed, followed by operator satisfaction and sustainability.

The financial performance deserves some additional attention. The asset managers all agreed that cost control is currently relatively limited. This can be seen in the ALCPs, as hardly any control measures are listed in the cost chapters. This can partly be explained by the fact that NedTrain for a long time has been predominantly focused on the technical aspects of the management of the assets. A new accounting system has

recently been implemented to increase the insight in the financial performance. This will allow the asset managers to exert more control over the costs.

Regarding the time-perspective, performance prognoses cover the first five years into the future. Prognoses on the performance on the long term are scarce, and take the form of descriptions, such as a decrease in customer satisfaction with the ageing of the train.

Next to performance, the potential risks ranging from the environment are important to know about. The ALCPs written before 2015 all had a separate chapter on risks. In the latest review of the ALCP format, this chapter was taken out to reduce length as most (if not all) issues mentioned in this chapter were already covered in the ALCP. However, two of the asset managers stated not to be completely satisfied with this solution: “I kind of liked to have it in, as you had to think about the risks explicitly”. The role of risks in the ALCPs is still in development, and is one of the main priorities for the next years. Currently, no structured way of identifying risks is used, although all three asset managers showed to be aware of the importance of risk identification and showed how they had been pursuing this recently.

To conclude, information on the performance of the system is given for most of the perspectives. The long term performance is only treated marginally. Risks are mentioned in the ALCP, but not collected in a structured or regular way.

Control measures

In case differences are detected between the targets and the current or expected performance, control measures are taken. The asset managers generally stated to have three different control measures at their disposal: 1. changes in the quality of the maintenance execution; 2. changes in the maintenance concept; and 3. changes in the design of the train. The first is the easiest, takes the least time to implement, is used most often and is least expensive. Their impact on the performance of the train does however not necessarily follow the same pattern. This highly depends on the life cycle of the train series and the measures that already have been taken before. The manager of the intercity train series stated that for design changes in his train ‘all the low hanging fruit has already been picked’. For him, most impact could be made with changes in the maintenance concept. As his train is in the securing phase, the focus is on saving costs, and extending maintenance intervals is a good way to achieve this.

The life cycle phase of the train series also influences the control measures available to the asset manager. The shorter the remaining lifetime of the asset, the shorter the pay-back time on new investments. Hence the importance of design changes decreases over the lifetime of the train, limiting the margins within which influence can be exerted. Obsolescence of parts limits these margins even further.

Interestingly, two additional control measures were found. The first is changing the instructions for the operators of the trains. Only one of the asset managers mentioned this measure explicitly – even though the other two implicitly acknowledged it as well. The one asset manager explicitly aware of this type of control stated that “this is a large influencer”, which NedTrain has paid limited attention to thus far, as NedTrain had its primary focus on the technical aspects of the train. Hence “the exploitation of the physical side has gone very far, but now one has to turn to the side of the user to influence this [the performance]”. Interestingly, we see here how a limited model of the system – the train as a technical system excluding the human operator – limits the control over the system. A broader, albeit more complex, model may be worthwhile as this allows for additional control measures and performance improvements.

Goal adjustment can be regarded as a fifth control measure. As De Leeuw (2002) states, one way of making sure one reaches one’s goals is by adapting these. Interesting

is the fact that goal adjustment is part of the process of writing the ALCP. As already explained, the process starts with a kilometre production desired by the asset owner. It is then up to the asset manager to see if this production is feasible, and if so, at what price. Making this 'feasibility check' explicitly allows for a discussion between asset owner and service provider, as the manager of the ageing ICT shows: "then you get the discussion […] and in the end it has been decided to let it [the performance] decrease". This allows for deliberate decisions to be made and to adjust the goals if needed.

To conclude: many different control measures are at the disposal of the asset managers. However, their usability depends highly on the age of the asset. Including the operation explicitly in the model of the target system may make additional measures possible. Goal adjustment is already part of the asset management process, which prevents setting unfeasibly high targets resulting in unnecessary costs.

Capacity to process information

The final REC is the capacity to process information, and the ALCP is an important means in this. Writing the ALCP forces the asset manager to step back from the issues at hand and to focus on the future of the assets. The three asset managers all state that without an ALCP they would be firefighting all day, being overwhelmed by the daily business without the possibility to step back. In this way the ALCP is a means to allow the asset manager to think about the long(er) term and to take control over the asset.

Furthermore, the asset managers mentioned that the ALCP helps them to set an agenda for themselves and the entire organization. The ALCP can be seen as a 'priority list' for the coming years: "you receive questions all the time, and without an ALCP you cannot filter which question you should get down to and which are not that important". Not only does this help to keep the right focus, but it also helps to communicate this to the organization and to harmonize the different departments.

Table 3 showed that in a number of ALCPs at least some performance values are missing. The most recent example can be found in all three 2015 ALCPs. Here the data on the maintenance costs are lacking, due to a change in the accounting structure used. This shows a limit to information processing capacity.

Finally, an interesting remark was made by the asset manager of the ICT. He stated that for the current KPIs large improvements have been made which makes it hard to improve any further. By choosing different KPIs, new improvements could be made that would benefit the traveller even more. However, as the information collection is adapted to the current KPIs limited information is available on these issues. He and his team have meetings to dig into these issues, but these take a lot of time and effort and hence cannot be held frequently. This shows that the type of information that is received may strain the information processing capacity, which negatively influences the ability to exert control. In this way, choosing KPIs can be seen as a control measure in itself, as it increases the information on a particular issue which makes improvement more likely.

To conclude, the ALCP plays an important role in information processing, by giving focus on the long(er) term and setting priorities. However, not all information is readily available at the desired level of detail, which puts a limit to control.

Conclusion

This paper has set out to contribute to our understanding of the effective management of assets. To do this, a conceptual model of ALCM control has been introduced. Through a case study in rolling stock maintenance, this model has been put to practice. Only if all the requirements for effective control have been fulfilled both at the short and the long term, from a multidisciplinary perspective and including the identification of risks

effective ALCM control can be exerted. It has been found that the model may help us to research ALCM practices and to point at the limits to control faced by an asset manager.

The ALCM control framework as proposed in this paper does not just increase our understanding of the practice of ALCM, it leads to practical recommendations as well. For example, it asks whether multidisciplinary goals exist for the short and long term, if information on performance and risks are available and where control may be limited.

Discussion

This paper discussed the development and application of the ALCM control model. Even though this model seemed to work well in the study of ALCM at NedTrain, further study is needed to investigate whether it may be applicable in other contexts.

The case study covered in this paper has shown that even in an Asset Life Cycle Plan the emphasis on the long term was limited at NedTrain. The asset manager of the ICT explained that within five years so many things can happen that it would be a waste of time to spend too much time thinking about the long term. An interesting topic for further research would thus be how to deal with the long term – up to the end of the lifetime of the asset – in an efficient way. Adopting different mind-sets or strategies for different life cycle phases, such as NedTrain does, seems a promising way to go.

Finally, this study limited itself to risks, while the influence from the system's environment may be much larger, e.g. by changing demands and contexts over the lifetime of the asset. That may be an interesting topic for study as well.

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