

Internship Report:

The application of the ISO55000 improvement

loop & the improvement of maintenance

concepts at Strukton rail

Student: Ruizhou Fang (S1665863)

Msc Mechanical Engineering

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External supervisor: Marc de Wolf

Academic supervisor: A.J.J. Braaksma

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0. Background information overview -Strukton Rail

The rails in Netherlands can be divided into four types of rail: Main net , light rail, private rail and short line(The rail from factory to station site).

Prorail is the principal owner of the track in the Netherlands. However, Prorail do not do the maintenance by itself. The strategy is outsourcing the tasks to other companies. This is so-called the “output process contract”(OPC) or “performance based maintenance”(PBM) and makes Netherlands one of few countries where all the maintenance works, replacements and renewal projects on railways are outsourced.

Nedtrain, as a part of NS group, used to be mainly responsible for the maintenance work for the rolling stocks, since 2017, this job is taken over by NS Techniek. The track maintenance and overhaul and its supporting facilities are mainly taken over by 4 other service providers: Strukton Rail, Volker Rail, Bam Rail and Asset Rail. Strukton Rail used to own the largest market share in the past(50% in 2009, Prorail homepage). Now Strukton Rail and Volker Rail are the 2 biggest companies , Bam rail and Asset rail are smaller. Also, there could be some other contractors like Van Gelder Rail getting involved in overhaul tasks and of course the participation is limited. Due to the open market and 5 year contracts, this share of the market will vary.

In the past, the contracts between service provider and asset owner are in the form of OPC. The contractors are appointed in a contract area and the terms in a contract can be discussed. Normally, the more problems or defects in railways the service providers fixes , the more payment they get. Recent years, the OPC is taken over by PGO. The form of contractor selection is also renewed. The “reverse auction” is applied in particular. The lowest bid from 4 service providers in an auction wins after the discount for safety level and quality achieved in previous years. In this way, a better safety and quality level is encouraged, and also it brings more initiatives to service providers(The details will be discussed in chapter 2.2). The PGO contract named “De Wadden” has been won recently and it includes the main railway network in the province of Groningen and Friesland.

The development and implementation of a maintenance plan is more of a top-down process, but still there is some freedom to do adjustment from bottom-up, this is mainly caused by how process architecture designs(See figure 1) . The expert team in Maarsse is responsible for the basic direction of maintenance strategy , the inputs of their jobs could be the object behaviors and RAMS(Reliability, Availability, Maintainability, and Safety) requirements. The results from the expert team go to a contract area and the further details will be discussed in tactical and operational level. The KPI reports will go back to the expert team as feedback, which makes the whole process become a closed loop.(For details see chapter 1).

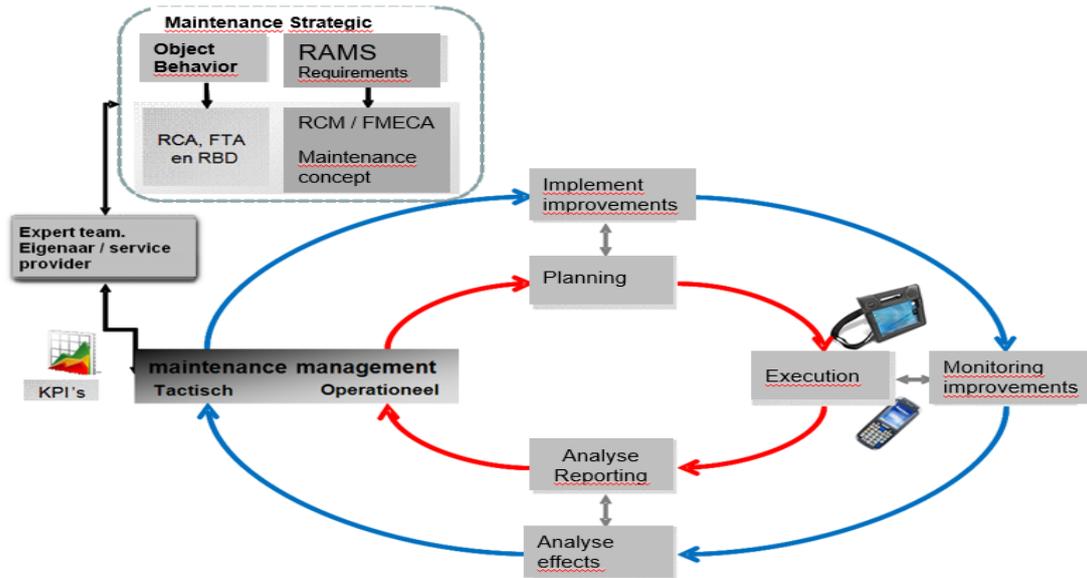


Figure 1 The process architecture designs (Source: Official Strukton slides)

At the start of each of the contract areas, the maintenance tasks are assigned according to 4 technical field :the track system, signaling system, electricity supply system, and bridge & tunnel system. Theoretically, each of these four system owns their specific planners, exporters ,and mechanics. One production manager is set as the supervisor of all the staffs in these 4 technical areas. However, this structure can be slightly different in different contract areas, because different production managers have their own way to do the maintenance work. In general, the work structure meets the criteria in ISO 55000 series. Multiple asset management plans are made for each asset class(the track, signaling, electricity supply, and bridge & tunnel system),thus making the maintenance plan more practical and easier to implement.

1.Describe the current generic-specific translation processes performed by Strukton Rail.

Asset management is a general term that is commonly utilized in finance, real estate, building space, resource allocation, and a host of other areas to mean maximizing utilization and return on assets, primarily financial. For a rail maintenance company, the concept of “physical asset management” is more appropriate and applicable. The definition of it is: “ A comprehensive, fully integrated strategic program directed to safely gaining and sustaining greatest lifetime value, utilization, productivity, effectiveness, value, profitability and return on assets from physical manufacturing, production, operating and infrastructure assets.” (J.S. Mitchel et al, 2013)

Strukton Rail puts some of knowledge in PAS 55(the former version of ISO 55000) into asset management. This is a smart action, but one obvious problem is that the PAS is designed for the organization or asset owner who execute tasks by themselves, therefore the enforcement of this theory can be different for Strukton Rail. (details see chapter 1.1 and 2.2). Now Strukton Rail expect the transition from PAS 55 to ISO 55000. Definitely there is a gap between these two forms, for example, the PDCA loop in PAS is used in different levels(strategic, tactical, and operational levels), there is not enough coordination among each level. The new model is recommended in ISO 55000 and somehow solves this problem. For Strukton Rail, it is not 100% certified and still will take some

time to complete this transition. In this chapter, the asset management process in Strukton Rail will be introduced in this chapter.

1.1 The different roles in asset management

In the asset management system, three separate roles are recognized: the asset owner, the asset manager and the service provider. (Van der Velde, Klatter & Bakker, 2012). The asset owner in theory is the party who ultimately uses the assets to execute tasks to achieve the organizational strategic plan. The asset managers are responsible for the execution of asset management. They translate the organizational plan into practical and detailed plans. The service providers execute actions that are put into motion by asset owner.

The “default setting” for any organization is that the owner of the asset will always be the asset user. The asset manager monitors the results of management actions and correct them if necessary. It only makes sense for service providers to exist when asset managers have a willing to outsource their work.

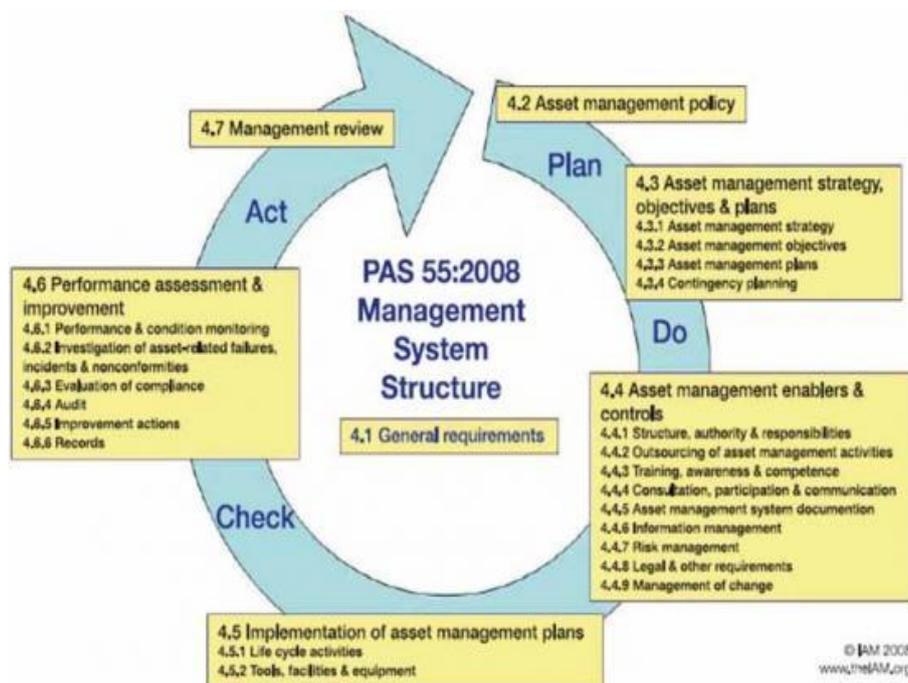


Figure 2 PAS 55:2008 Management system structure

In PAS 55 theory, a complete asset management involves 7 elements: 1. General requirements 2. Asset management policy 3. Asset management strategy/objectives/plans 4. Asset management enablers and controls 5. Implementation of asset management plans 6. performance assessment and improvement 7. Management review. Those elements are filled in PDCA loop and requirements for each phase of PDCA loop is clarified.

The next step is to determine the responsibilities of each role (see the figure 3). It should be noted that asset management roles are drawn from typical asset management theory and do not necessarily represent different organizations. In most of the cases, the asset owner is asset manager, so Prorail are more or less close to the asset owner and asset manager, Strukton Rail is more or less close to the service provider in the figure. However, in practice, those roles can be more complicated or intertwined, specific details will be discussed in chapter 2.2.

	Asset owner	Asset manager	Service provider
1. General requirements	█	█	█
2. Asset management policy	█		
3. Asset management strategy / objectives / plans		█	
4. Asset management enablers and controls		█	█
5. Implementation of asset management plans		█	█
6. Performance assessment and improvement	█	█	
7. Management review	█	█	

Figure 3 The responsibility of each role in theory (Source: Official Strukton slides)

1.2 The scope and asset management target

The organization shall determine the boundaries and applicability of the asset management to establish its scope (ISO 55001,chapter 4). The company should consider the external and internal issues, the needs of stakeholders and the interaction from other management system (if used), because all of them are beneficial and indispensable to achieve intended outcome.

The external and internal issues do not necessarily have to be specific problems, these items just give us an insight of the context of the organization. From this point of view, the external and internal issues are more of a limitation analysis.

The external issues for Strukton Rail could be the effect of the daily traffic of the train. The maintenance work occurs overnight , weekends or day-time, which may cause different results. For example, the work overnight can lead to an increase in cost due to overtime of staff is required. Sometimes the track has to shut down to do maintenance. All of this needs to be well arranged with railway operators. Another issue is the safety and security. Without doubt, additional costs are needed to protect the environment and guarantee the safety of the staff.

The internal issues could be the uncertainty in the budget calculation. The cost for certain rail or component is specific, but sometimes the budget still exceeds the expectation. This can be caused by factors like: weather or human resources. For example, at present, the challenge is that it is hard to determine the budget with precision. The good news is that the offers in reverse auction of 2017 show there are some changes on budget calculation compared with 2010,which means Strukton Rail somehow update the calculation model based on past experience or actual situations, but there is space for Strukton Rail to develop.

The needs of stakeholders derive from the needs of customers. In extreme condition, the customer's wishes are just simply business goals. For operational level, these needs are not applicable, so there should be a transformation process between business goals and key figures in the contract area. This can be indicates by figure 4.Asset owners are more on the strategic level, while service provider are

close to the operational level. To achieve the interactive management control and high alignment in each level, budget, KPI and a project management system can be applied in this transformation (Josep Bisbe, Josep Bisbe, 2004).

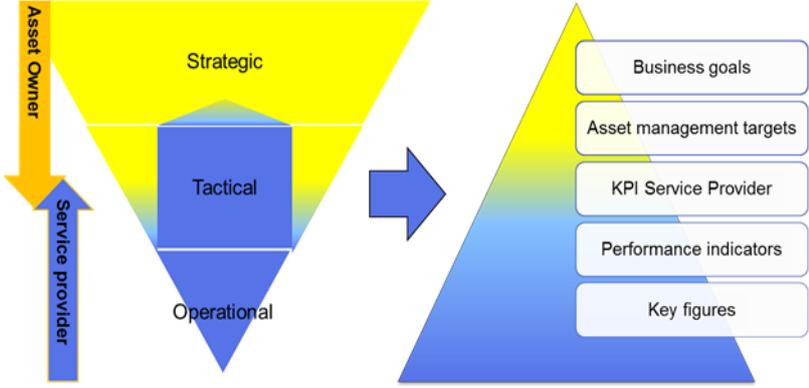


Figure 4 The need transformation process (source: Official Strukton Slides)

The scope of asset management can be divided into two categories: 1. All decision and activities relating to maintaining, renewing and enhancing the infrastructure. These extend from high level strategy for the railway infrastructure to the delivery of work and the provision of train paths. 2. In addition to including all aspects of maintaining renewing and enhancing the railway infrastructure, the scope of asset management includes the operation of the network, including capacity planning and timetabling(Justin Heubach,2014).

The long-term goals of the Strukton Rail are in 3 aspects: 1.International growth. A new department, Strukton Rail International department is established to expand oversea business. Now there are also projects in America, Australia, Sweden and Italy. 2. Innovation techniques. The research and development have already been a part of the daily work. A project named Smart maintenance is mainly responsible for collecting data from measurement and doing some analysis. This provides more information to Strukton Rail when they make maintenance plans. 3. Improve current process. Due to the complicated relationship between asset owner and service providers. The improvement in maintenance processes enable them to work more efficiently.

1.3 Strukton Rail PDCA loop

J. Heubach in Strukton Rail figured out the Strukton Rail PDCA loop(see figure 5) and inputs & outputs in each phase of PDCA loop(figure 6). It should be noted that Strukton Rail PDCA loop is not theoretical PAS 55 PDCA loop(figure 2), because in any situation, as a service provider, Strukton Rail is not responsible for all 7 elements mentioned in PAS 55 PDCA loop .

In PAS 55 theory, the organization work as a whole and the asset management target is clear and stable. In practice , there are a lot of parties like service providers, asset users, and asset managers involve in the asset management system and their interests might vary. This is also the reason why account management is valuable. The account management not only ensures that the customer gets delivered what has been agreed, but also manages the relationship with internal organization. is prior to all the maintenance work.

In Strukton Rail, the strategic maintenance engineers will arrange a plan based on the experience, data analysis, and rules from Prorail. All the inputs will finally end up in progressive maintenance plans. These plans will go to the project sites and the details will be defined more specific, combining with experience of the practical situations. The check after the execution is needed, this is not only for data validation, but also a good method to do performance assessment. After that, the improvement analysis and translation deviations to actions will be done to make the whole processes a continuous development. Two grey blocks are major input for account management: A. Strukton Rail organization; the owner of Strukton Rail organization, which performs the acquisition of the asset management contract and offers the systems and historical data required to execute the maintenance contract. B. The contract partner, representing the asset owner or an asset manager, depending on the contract and asset management system. Strukton Rail has a contractual agreement with the contract partner to execute asset management (sub) activities.

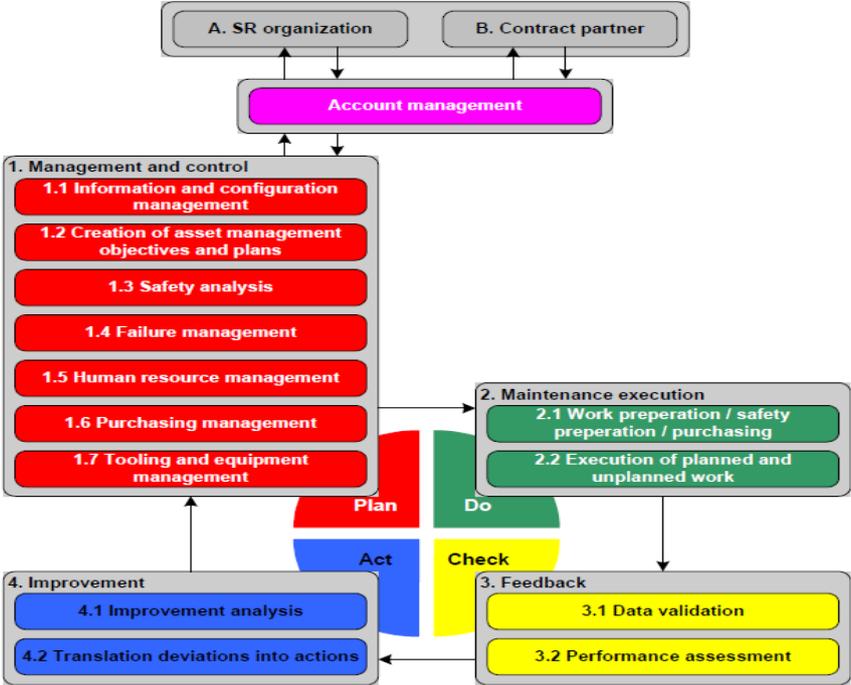


Figure 3.4: SR asset management structure

Figure 5 Strukton Rai PDCA loop (Source: Official Strukton slides)

The information flow can be in both top-down and bottom-up directions, this guarantees the exchange of information of their stakeholders, including service providers and asset owners. Obviously the account management is put at a core position and determines the direction of the

whole project.

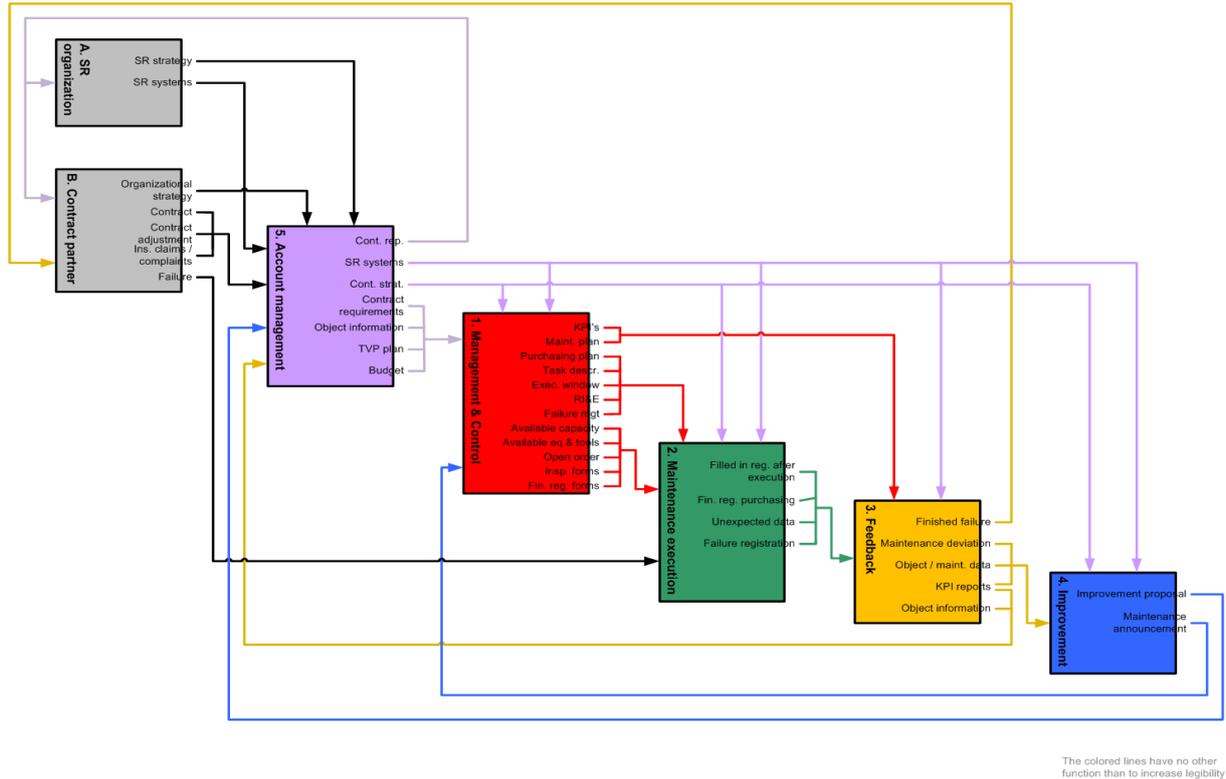


Figure 6 The inputs and outputs of asset management structure (Source: Official Strukton slides)

1.4 The limitations of Strukton PDCA loop

The Strukton Rail PDCA loop is an excellent tool, but this analysis has its limitations. Firstly, this PDCA loop is more on the details in operational level, it does not clearly indicates the coordination among headquarter and contract area. Secondly, the way to do check lack variety, other tools such as internal audits, management review should also be applied. The most important thing is that Strukton Rail now has not only one contract area, since the production manager in each contract area has its own way to execute maintenance tasks, there is not one standard for all the contract areas.

1.5 The maintenance decisions and plans

The maintenance plan will be generated in the Management & Control stage. In this stage, information and configuration management is the most technical process.

The technical demands are firstly analyzed in maintenance engineering. Normally, there are two methods to complete this analysis: one is modeling with historical data and failures. The Monte Carlo simulation and other statistical methods provide foundation for this modeling. The maintenance engineers always check the models with the calculation department and the executors in the field to make it roughly fit the facts. Another one is the use of knowledge in previous improvements. Take the maintenance work for switches in Netherlands as an example. In Strukton Rail, all the Prorail switches are divided into 2 grades- X switches and Y switches. Y switches refer to the switches with high load, while the load for X switches is relatively low. As a result, the number of inspections for Y switches is doubled compared with X switches to guarantee better performance.

Not only technical demands, the object database also plays a unique role in this process. The risk analysis on objects in asset management system are required, the asset standards are clear. For critical objects, the maintenance plan is directly linked to risk analysis.

One thing that I have to mention is the decision when to do maintenance, because it directly determines the workload. Normally, Strukton Rail defines the time when critical condition occurs as a failure, that is to say, before the components completely functionally fail, the maintenance work has already performed. The relationship between MTTC and MTF can be indicated in the figure below:

• **MTTF, MTTC en Leadtime (P-F Interval)**

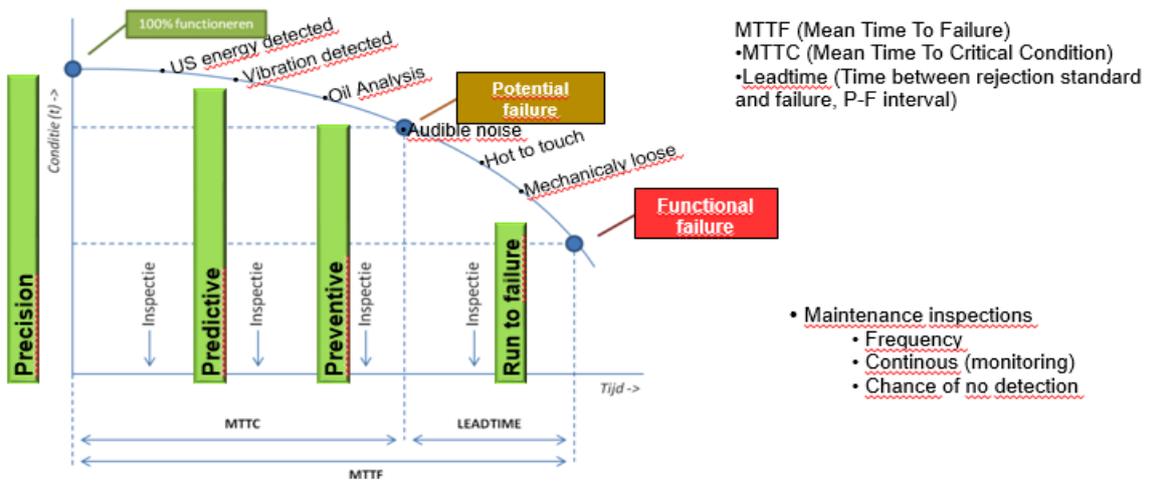


Figure 7 The MTTF, MTTC and Leadtime (P-F Interval) (Source: Official Strukton slides)

Combing object data with the technical demands and the execution window agreed upon between Strukton Rail and Prorail, the maintenance plan is then generated.(see figure 8). This analysis is logical to approach the maintenance plans, but equally important is that the feedback from the operational level and policy from asset owner has a significant impact on technical demands. The object database is always up to date, the maintenance plan still need to be improved using PDCA loop. As a result, it is closer to the ideal maintenance plan generation model.

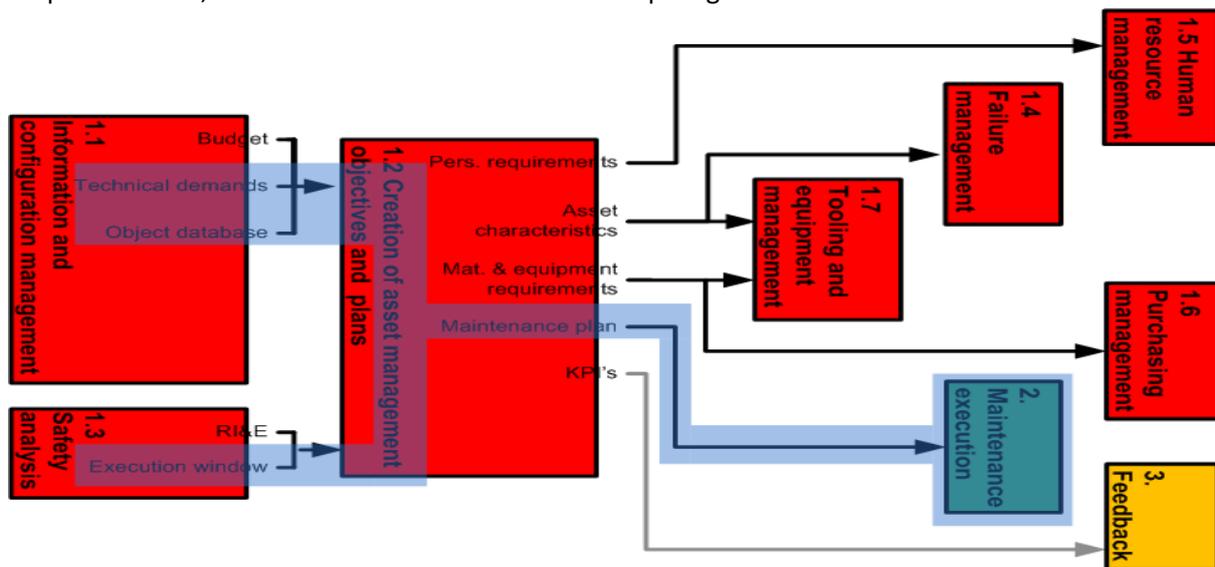


Figure 8 The maintenance plan generation process (Source: Official Strukton slides)

The information flow in maintenance planning and execution is shown below (figure 9). Relatics, SAP and Mobile Quality Management (MQM) are three software packages Strukton Rail uses in the Management & Control stage. Relatics is a system where all maintenance plans gather. The inputs of it could be what is done by Strukton Rail and what is agreed up on what Strukton Rail should do. The strategic maintenance engineers here will consider all the tasks together and rearrange the plans. All the tasks are in Relatics, so based on these tasks, the calculation department can do cost calculation and put this information back to Relatics. The output of Relatics goes to SAP, which is a procedure translating work order to execution plan. In this stage, the specific maintenance plans such as annual tamping plans, and machining plans generate. This can be done only after knowing the number of objects in a certain area from GIS (Geographic information system) system and the tasks to do in Relatics. The output of SAP is PO plan (progressive maintenance plan), which tells planners in field what to do at a certain time. In the execution stage, MQM will collect the information at working site. The executors or planners are required to fill in inspection forms in MQM for continuously planning work, after that, this information goes back to SAP and new work order may generate again.

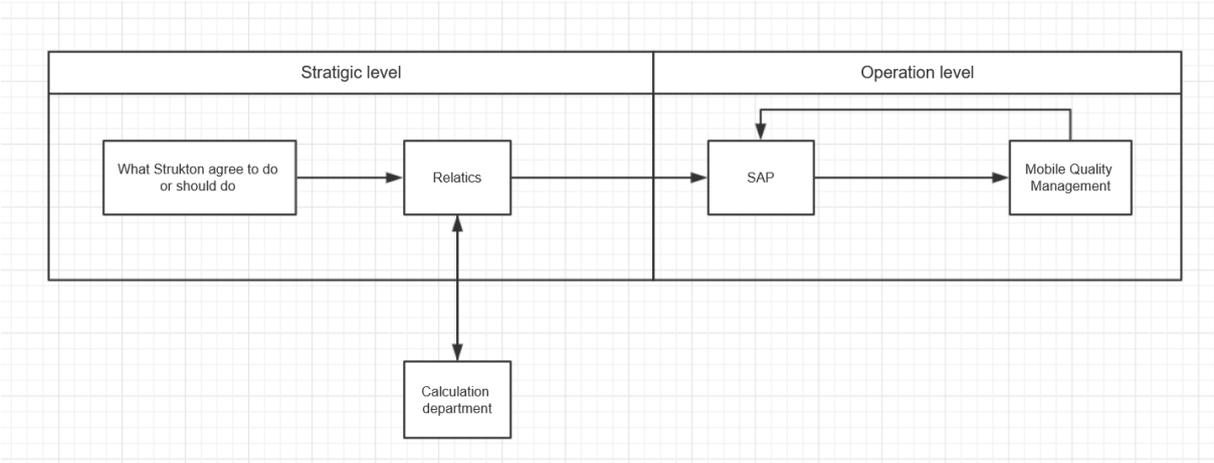


Figure 9 The maintenance information flow

The usage of these software package make the “do” phase become the most mature part in PDCA loop. Let us choose some cases as the embodiment of high-efficient work in Strukton Rail. The UMT (ultrasonic measurement train type 1) does the inspections twice a year and it gives an insight of rolling contact fatigue defects; The UMF (ultrasonic measurement train type 2) looks for geometry problems in the track and the frequency is also twice a year. The VST (video surveillance train) does the inspections every 4 weeks looking for the geometry problem of the track especially for switches. In those two cases, the advanced technology are used and all the information are accessible in software, not only that, a control center in Maarsse is in charge of all these distant inspections and sends useful information in time to the support centers in different contract areas no matter how planners and executors think about it (Some planners may think repeat reporting the same defects is annoying, but it is rigorous behaviors, since feedback does not always occur).

1.6 The risk control

The risk metrics (see figure 10 & 11), as a good way of risk analysis, provides the basis for the FMECA.

The influence of the failure is classified by the severity and occurrence. The red blocks refer to undesired scenarios and this is caused by unacceptable severity and high frequency. The green blocks are acceptable scenarios. The upper number in each of the blocks show the scenario without any

maintenance work, and the lower number comes from the simulation in a software named Optimizer and gives us the insights after maintenance work(The sum of upper number in same rowing equals to the sum of lower ones). If the maintenance plan works, some of the number should shift from the right side to the left side in simulation scenarios. The contents of events could be the effect on railway shutdown (reliability matrix), the damage to people or asset(safety matrix), the system functioning state time (Availability) and the opportunities to maintain or repair the asset (Maintainability).

On the one hand, this chart is dynamic, the number will change if the maintenance strategy changes. On the other hand, this tool also has a large effect on the maintenance strategy. Too many numbers in the red blocks might suggest not enough or incorrect maintenance work.

If too much number are put in red blocks, then it suggests maintenance work might be incorrect or not enough. Normally, there are four methods to achieve better maintenance work. 1) Asset modification. The update of the materials or parts are always the effective tools to make the railways more reliable. 2) Change of design. It is possible to change the design of devices to avoid the defects. 3) Increase the inspection frequency, this allows maintenance team gain more chances to identify and mitigate risks. 4) Change of regime. Sometimes if failure based or time based maintenance does not work well , the regime may have to switch to condition based maintenance, because it directly gives insight into how defects propagate in its lifetime and is able to reminders engineers to do maintenance when the need arises.

Risico Matrix		Classificatie (MTTF)				
		> 10 Jaar	5 Jaar < X <= 10 Jaar	1 Jaar < X <= 5 Jaar	1 Maand < X <= 1 Jaar	0 Uur < X <= 1 Maand
Classificatie						
B	> 5 dagen geen vervoer van reizigers mogelijk/Catastrofe door bv ontsporing met ernstig beschadigde infrastructuur. Wegslepen onmogelijk, kraan noodzakelijk.	0 0	0 0	0 0	0 0	0 0
	< 5 dagen geen vervoer van reizigers mogelijk/> 1 week verstoorde dienstregeling	31 50	7 0	12 0	0 0	0 0
	< een dag geen vervoer van reizigers mogelijk/< 1 week verstoorde dienstregeling	141 397	106 2	153 1	0 0	0 0
	< 2 uur geen vervoer van reizigers mogelijk/< 1 dag verstoorde dienstregeling	83 144	35 0	26 0	0 0	0 0
	1 tram valt uit/< 2 uur vervoer (max. 32 ritten > 3 min te laat) van reizigers niet volgens (geplande) dienstregeling	90 210	47 0	73 0	0 0	0 0

Figure 10 The reliability matrix for risk analysis (Source: Official Strukton slides)

Risico Matrix		Classificatie (MTTF)				
		> 10 Jaar	5 Jaar < X ≤ 10 Jaar	1 Jaar < X ≤ 5 Jaar	1 Maand < X ≤ 1 Jaar	0 Uur < X ≤ 1 Maand
Classificatie						
v	1 of meer dodelijke slachtoffer(s)	0	0	0	0	0
	Zwaargewonden (>2)	23	7	10	0	0
	Zwaargewonde (1 a 2)/Lichtgewonden (>3)	21	9	52	0	0
	Lichtgewonde (1 a 2)	97	81	153	0	0
	Geen letsel	204	98	49	0	0
		348	2	1	0	0

Figure 11 The safety matrix for risk analysis (Source: Official Strukton slides)

1.7 the support

As described in ISO 55000, the organization shall determine and provide the resources needed for meeting asset management objectives and implementing the activities specified in asset management plan. In Strukton Rail, a X-21 week plan is designed for work preparation before execution. This activity provides planners and work preparers with opportunities to take advantage of all the available resources. During this period, the planners and work preparers will try to combine the tasks together to achieve high work efficiency and make sure there is no conflict among all the stakeholders. Safety and budget will also be checked in this period. Although this plan is called “the 21 week plan”, this does not mean all the preparation work takes 21 weeks, it is more of a reminder to do preparation. The time schedule is rather flexible, if the activities are familiar or relatively simple to planners/ work preparers, it could even be shortened to about 12 or 13 weeks.

Strukton Rail equips with various kinds of software in order to achieve high efficient communication. Another benefit of doing so is that all the users can speak same “language” in same digital platforms. The GIS (geographical information system) and IRISYS (rail information) collect data in contract areas and gives engineers an overall picture of all the assets. The Relatics and SAP share the information needed to make maintenance and execution plans. The MQM enables the planners to check on-site if repairs are being carried out as planned and also give feedback to maintenance engineers in the office. Of course using such kinds of software is not always an advantage, the drawbacks will be analyzed in chapter 3.3.

All the knowledge, awareness, skills and experience needed to fulfill the asset management roles and responsibilities is also clearly determined in Strukton Rail. The strategy taken by Strukton Rail for training is to get senior specialists with over 40 years of on-track experience who cooperate with our highly educated engineers and specialists involved in all technical fields throughout our company. This ensures that persons are competent when performing their tasks. The winter school is another way to raise competition ability of employees. This kind of training courses usually starts from January because it is the time period with lowest workload in entire year. At the same time, some staffs still remain at contract area to guarantee the quick response to the failure or accidents in railways.

2. Compare this process with the elements of effective control for maintenance concepts.

2.1 The comparison between common PDCA (plan-do-check-act) processes and Strukton Rail's PDCA processes

Implementing an asset management system must include establishing infrastructure that supports the plan-do-check-act methodology of the ISO standard. The elements of effective control for maintenance concepts in the ISO 55001 standard are also distributed in this loop, this is indicated by the figure below (Slides from Woodhouse partnership Ltd, 2014). This loop is based on the understanding of the objectives of the organization, and as an important element of the theory, support is reflected in each of the 4 phases in the PDCA. This loop has no end, so it improves continuously.

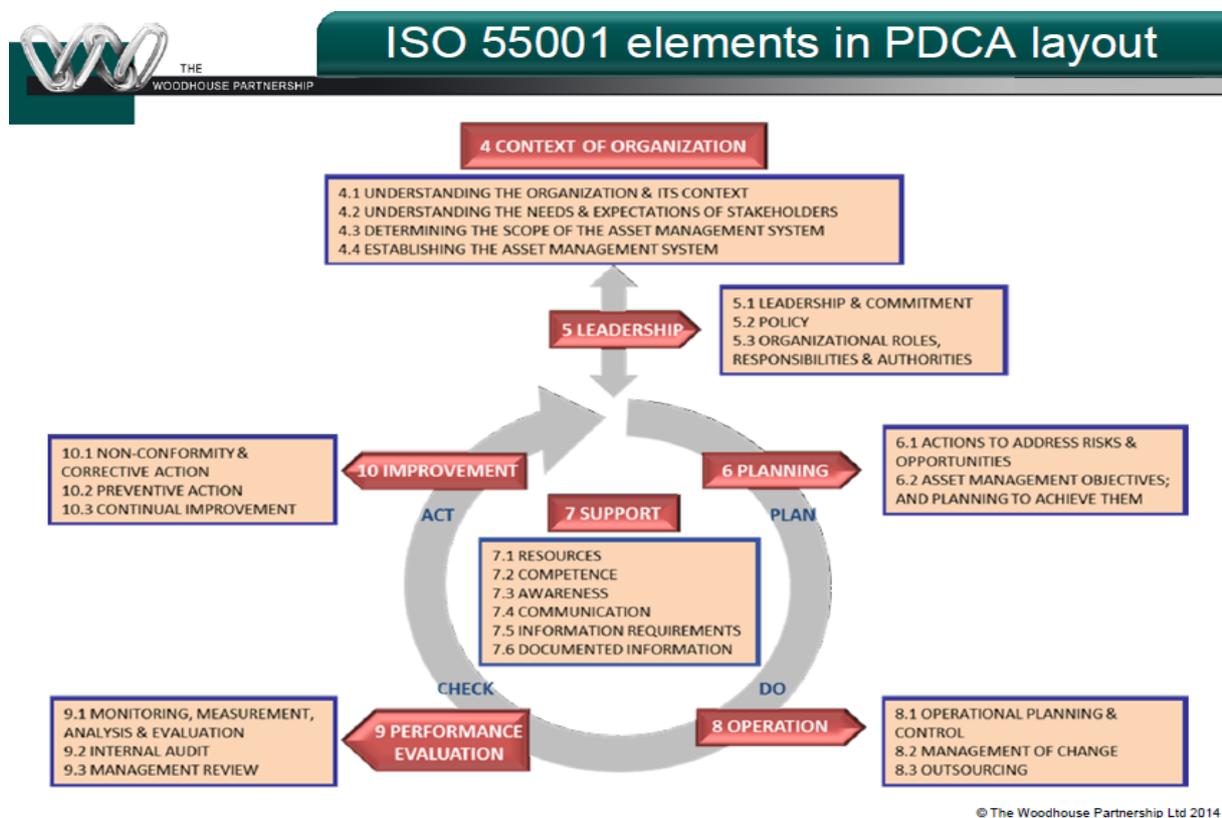


Figure 12 The placement of elements of asset management in PDCA loop (Source: Woodhouse, J., 2014)

The application of PDCA loop in chapter 1.3 (figure 3.2) is local, or in other words, it concentrates more on operational level, while this PDCA loop with ISO 55001 elements make the collaboration among each level (strategic, tactical, and operational levels) closer. The context of organization, leadership and support undoubtedly enhances the cooperation among different department and reduces the unnecessary work.

To facilitate the transition from PAS 55 to ISO 55000, the similarities and differences in different phases of PDCA loop are analyzed by comparing the ISO 55000 theory with actual conditions. (See appendix 2 for results)

2.2 The comparison about the role of asset management between that in ISO 55000 and Strukton Rail

In chapter 1.1, the typical asset management roles are introduced, now the analysis focuses on the special situation in Strukton Rail (the “green part” represents what service providers do in conventional sense).

In the past, when OPC was applied, Strukton Rail operate as a service provider, because from a ISO 55000 point of review, Strukton Rail fills in one of the requirements: the implementation of asset management plans. Also, Strukton Rail showed it is possible to make contribution to asset management as an enablers by training personnel, managing information and executing part of the risk analysis management. In addition, Strukton Rail performs inspections and monitoring of the assets, so a part of performance and improvement is filled in. This can be also shown in the “yellow part” yellow part in the figure 13 below.

The switch from OPC to PGO puts higher demand on and increased the freedom for Strukton Rail. Since technical and practical knowledge is available, Strukton Rail start to evolves in the asset management strategy-making, and is expected to complete more controls of asset management, assessment and continual improvement tasks. At this moment, Strukton Rail made a progress on the road to a new role. For example, if a new technique is adopted by Strukton Rail, it only takes time to revise procedures in software packages (Relatics, SAP), while Strukton Rail had to get dozens of permits to achieve that in the past.

The requirements for Strukton Rail now (PBC situation) can be indicated by the “red part” in the figure below, this is also the desired position for Strukton Rail. Unfortunately Strukton Rail do not fully meet all these requirements, the improvement projects in contract area still highly depends on the customers.

In order to explain Strukton Rail’s tasks in the asset management system more clearly, the responsibilities & products are specified and correspond to figure (See appendix 2). This is from the results of maintenance engineers in Strukton Rail.

The advantages of PGO are obvious. In the past, based upon the OPC from main client Prorail, both the initial contract is managed as well as the contract adjustments which are made during the contract. If the details such as the number of inspections per year changes, the payment may also changes. In fact, Strukton Rail does not have much decision-making power. The new PGO contract brings more subjective initiative for Strukton Rail, they can meet availability and safety target using their own methods, Prorail only set minimum technical requirements. The better performance is, the more rewards Strukton Rail can get. The research findings from development engineers in Strukton Rail are easier to translate into certain operation plan. Engineers can put it in Relatics and generate maintenance plans in SAP. This process was complicated in the past, because Strukton Rail have to get approval from Prorail if they want to change operation plans. Even though PGO may lead to fierce competition among contractors and thus causing tight budget in some contract areas, the advantages of PGO outweigh its disadvantages.

	Asset owner	Asset manager	Service provider	SR IST	SR SOLL
1. General requirements					
2. Asset management policy					
3. Asset management strategy / objectives / plans					
4. Asset management enablers and controls					
5. Implementation of asset management plans					
6. Performance assessment and improvement					
7. Management review					

Figure 13 The responsibilities of each role (updated version) (Source: Official Strukton slides)

In addition, it is important to note that the definition of asset owner in ISO 55000 is the party which ultimately uses the assets to execute its tasks. However, in the Dutch infrastructure business, ProRail represents the owner of assets, the NS (Nederlandse Spoorwegen) or other small parties use the asset to transport passengers and goods. The owner of the local infrastructure is not the party which uses them to fulfil their organizational goals. In this way, the conflicts can be caused by life-cycle activities, it is important to make the proper agreement among different parties.

3. Where are bottlenecks or improvement potential for Strukton Rail such that it continuously improves?

3.1 The bottlenecks caused by external reasons.

The composition of a maintenance team is dynamic in order to adapt to the PGO contract. One problem is that almost all the teams in different technical field are facing with personnel loss , this loss can even go up to 50%(for signaling system in “De Wadden”).This becomes a big challenge to the team and may lead to a time delay in their work.

Another problem is that some technical fields are relatively independent for technical reasons. Take the bridge system as an example. There are no same two bridges in “De Wadden” contract area, so there is no single “model” for bridges. Some components are customized for certain bridges , the training for mechanics always last for the whole year. More importantly, these bridges staffs have a large impact on maintenance plan making. The knowledge is there and they are able to decide maintenance intervals themselves because there is no average data available from strategic maintenance engineers. As a result, the PDCA loop is more at operation level and the continuous improvement is relatively difficult.

After having interviews with planners in track system, I realized the causes of some failure sometimes might be complicated. For example, other contractors (Volker rail or other service

providers) may cause defect because of overhaul activities, since each individual overhaul project is also reverse auctioned. However, it is still unknown for planners whether they get paid from these companies or not after they fixed these problems. This might not be a serious issue for Strukton Rail, but there is definitely improvement potential to specify the communication processes with other contractors and make the financial data more in control. The information management and communication are also regarded as two important elements in ISO 55000.

3.2 The bottlenecks caused by internal reasons

Another problem is that there is no specialized project improvement team in contract area the “Wadden”. Basically, the planners and executors there are responsible for these plans. These improvement plans could be the new measurement method for hydraulic devices in bridges or the updating the heating device in switches, which lead to more work load.

Some maintenance intervals can also be not logical or reasonable, the execution plan in SAP might be based on average data. In “the De Wadden” contract area, the frequency of inspections for signaling devices in EBI switches is once a year and this is regarded as not enough for some switches. This because there are a lot of sensors and other components in EBI-switches which brings technical difficulties, compared to NSE switches.

The traceability of components is required in asset management, this is also a good way to document information. However, in the field ,when purchasing components from suppliers, only financial data is collected. For some components from these suppliers, there are no configuration number or track number, especially for customized components required in bridge maintenance. As a result, not all the needed information are documented in proper way.

The internal and external audits could be helpful to meet legal, regulatory and contractual requirements and the organization’s own requirements. However, the procedures of those audits are relatively simple. Either internal or external audits from Prorail only require employees in fields to fill in digital forms. To some extent, maintenance behaviors and the reasons for failures have not been analyzed.

In the field, Strukton Rail outsources part of the job to other companies. For example, the installation of hydraulic devices in bridges is taken over by another company, and this is long-term cooperation. The work procedures for this part is not that clear. Some details should be refined to prevent operation errors due to suppliers’ actions.

3.3 Other bottlenecks: communication, improvement project

The communication is also a part of the support plan. However, this is not always clear within Strukton Rail:

- 1) The strategic engineers do not always go to field to see if there is any practical problem. For some improvement project , the guidance can be obtained from HQ(headquarter), but the details has to be determined by support centers themselves.
- 2) The MQM is generally performed after a shutdown of the tracks, missing the opportunity to provide analysis of how much time maintenance takes, this may lead to a less comprehensive evaluation.
- 3) There is not enough communication among planners in each contract area. For planners in track system, this is not a problem, the planners from different contract areas gather to

discuss about the annual plan at a certain time period of the year(November), however this is not case for bridge and track system. The results could be less reliable budget in tendering and most likely a profit loss.

- 4) The feedback from the field is rather simple. The evaluation of renewal projects is essential, but it is not the same for maintenance work. Only digital inspection forms are required after they do their maintenance work (if some problems cannot be fixed immediately, they will do maintenance at another time and fill in the digital inspection form again), this is somehow not very robust as feedback.

The reasons are complicated, the objective reasons are: 1) the dynamic work structure of Strukton Rail due to the change of contract every five years. In the investigation, the team in Groningen are facing personnel losses and they are always paying attention to figure out the job responsibility changes. 2) Geographically speaking, the support center in each contract area is far away from the management department in Maarssen. These two reasons bring difficulties to the communication. The subjective reasons are:1) There are no enough internal audits towards the maintenance work itself. The engineers in the office may lack knowledge of actual maintenance. 2) The company should provide more opportunities to do interactions with each other. If there are more inter-contractual meetings among planners in different contract areas or other companies, it will be a good supplement to the communications.

The improvement projects team are the most complicated part. In Strukton Rail, the research & development team are responsible for providing new technology or management methods in order to improve maintenance performance. The good things are: 1) all the projects are data driven and derived from customer, which provides the foundation for knowing the actual needs. 2)The R&D team prioritize the projects according to amount of benefits. The high priority projects will be followed more frequently, which somehow guarantee the implementation of projects. However, the R&D team is only responsible for developing a new product, while engineering is responsible for evaluation. They only evaluate the improvement projects themselves and hardly get feedback from the operation level, not to mention result evaluation . In ISO 55000, the key point is that the improvement should come from the operation level. In the contract area, it is known that executors and planners are also responsible for some improvement projects, but the truth is that most of them, such as asset modifications, are from customers or asset owners. Although it is not true to say there is no feedback to R&D team, there are still a lot of things to do to combine the R&D and actual conditions together.

4.What principles or ideas can be used for this improvement?

4.1 Appropriate feedback and project improvement team

Obviously, the internal communication is the biggest obstacle for Strukton Rail, the feedback loop is rather simple(see chapter 3.3). In the short run, the possible solutions for Strukton Rail is updating the internal audit procedures. The digital inspection form itself is not able to find all the problems, more powerful internal audits towards the evaluation of maintenance should be designed. For example, those questions might be the points of interest for the company when designing the questionnaire for internal audits: Do they finish the job in time? How about the customer satisfaction? Are there enough procedures to guarantee the quality of maintenance? A presentation with a variety of charts to management department will also be helpful to this situation. The appropriate feedback is also what ISO 55000 series asking for.

In the investigation, we find the planners or executors in the field are also responsible for some bottom-up improvement projects, for example, the use of voltage measurement for bridges. It is true that it brings benefits to the technology development, but the workload for them also rises. If budget is allowed, the best solution is to create a project improvement team in the field. They would take over the development projects in the field. Their daily job is collecting and analyzing the technical data and doing evaluation towards the maintenance work. In addition, Every month they should report their work progress to the company. This is different from development engineer in Maarsse, because they have the right to ask planners/executors for cooperation, they focus on the evaluation of the performance and also applications of new technology. This is based on the consideration of Lean management theory, also the project improvement team can make a contribution to the feedback loop because they are also familiar with daily work in the field.

Apart from these most important points above, there are other points of interest: Traceability, Root cause analysis, and economic analysis of maintenance strategy.

4.2 The Traceability

The traceability is another place can be improved, the similar regulation could be also found in ISO 55001. It helps the company avoid quality and acceptance problems, and enables further improvement of the product and maintenance. In fact, both Strukton Rail and its suppliers do not follow this regulation strictly. Strukton Rail should request suppliers to number their components and document it in proper way. Besides, Strukton Rail also should give internal number to all the components needed including the components from supplier (regardless of whether they are numbered or not). The number should contain the information like batch number, the producer information and the system name and so on. However, for the bridge & tunnel technical field, the number of suppliers are limited, high demand may lead to no suppliers, the appropriate implementation of traceability deserves further discussion.

4.3 The root cause analysis(RCA) and corrective actions

The performance of the executions are directly linked to the rules in PGO contract, that is the reason why the evaluations of the work becomes so important. Sometimes if some operation errors occurs, the root cause analysis and corrective actions are required. The production managers should fill in the chart to do root cause analysis and give effective corrective actions to prevent similar problems. The root causes analysis is a method of problem solving used for identifying the root causes of faults or problems. The root causes should be sufficient and insightful. Also, there should be a due date to check the whole process. Luckily, Strukton Rail realized the problem and now are doing RCA training. Some analytical methods such as using event map to seek for the reasons and cost of events have been known by the engineers, but some details like threshold to implement RCA and the participants list are still being discussed. It is believed RCA will be soon be put into use in the near future. RCA is also an element of Lean management theory. However, Strukton Rail is transitioning towards a failure registration system from Prorail, of which the effectiveness is currently unclear.

4.4 The economic analysis of the maintenance strategy

The risk analysis is evolved in maintenance strategy making, but if the economic factor can be taken into account, the decision-making criteria will be more comprehensive. As a certain kind of strategy

(either time-based or condition-based maintenance strategy) is adopted, the cost or Net Present Value (NPV) of different plans should be taken into account. For example, the model in chapter 5 provides the possibilities for finding the optimal minimum preventive maintenance intervals when time-based maintenance strategy is used, thus saving the cost. Also for objects using condition-based maintenance strategy, it is worthy to discuss about the cost of different kinds of inspections. The need for such an analysis is high because the professional knowledge is needed. Probably this is not doable for now, but this can be set as a long-term target for Strukton Rail.

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Appendix 1: The similarities and differences in different phases of PDCA loop (Comparing ISO 55000 theory with actual condition)

	Similarities	Differences
Account management	<p>In the PDCA loop in ISO 55000, the understanding of the organization itself, the needs of stakeholders, the establishing of management system are regarded as the prerequisites of PDCA loop. In the Strukton, the account management is such a similar process. The needs and expectation are translated from contract, adjustment or complain from Prorail. The external and internal problems like: budget, company structure, object information determines the scope of the asset management and give a general picture of the organization. From here, the continuous improvement processes starts, which is a good presentation of the program.</p> <p>The contents about leadership can be demonstrated by following processes:</p> <ol style="list-style-type: none"> 1. FMECA is used to set priorities for objects or tasks. 2. The use of software Relatics, SAP, MQM ensures the reasonable allocation of resources and the support of continuous improvement. 3. The related team is established in this stage. 	<p>The SAMP (strategic asset management policy) in ISO 55000 is defined as a framework to achieve organization objectives and more like figured out by organization itself. In Strukton, this is given by contract partner Prorail directly. For example, the availability and related technical regulations are in the contract.</p> <p>Another difference is that ISO 55000 requires the organization using asset management related decision-making criteria for capital expenditures and other decisions, but Strukton have to do budget calculation before tendering and can cause a difference between actual expenditures and predicted due to "reverse auctions"</p>
Plan	<p>In this stage, 1. The risk matrix may be used as part of actions to address risks, and the FMECA analyzes the potential event and its causes.</p> <p>2. The specific, measurable, achievable, realistic and time-bound asset management objectives such as purchasing plans, maintenance plans, tooling & equipment management plan are determined in this stage.</p> <p>3. The performance assessment is also executed in this stage, inspection forms and finance & regulation forms are required by company.</p> <p>4. In ISO 55000, the multiple plan for each asset class (rail, track, infrastructure) is an typical example for asset management.</p> <p>5. Since Strukton Rail is a maintenance company, the life-cycle of asset is always taken into consideration.</p>	<ol style="list-style-type: none"> 1. For asset management, Strukton do not always pay attention to some of financial data (such as net present value or return on capital employed) at "plan" phase. Some other important factors like customer satisfaction scores and environment factors are not very obviously reflected at this phase. 2. In chapter 6.2.2.2, ISO 55002, the persons who are responsible for continual improvement should be specified. In Strukton, this is more like a "common project" for every participant. It is integrated with other department. Another finding in "De Wadden" is the most of improvement projects highly depends on Prorail's idea. It would be better to establish a project improvement team.
Do	<p>In Strukton, the X-21 week plan and the use of software SAP guarantee the good work preparation and sufficient time to response to the changes. The safety is put into a very important position, safety persons are set for each of the phases.</p>	<p>In ISO 55000, the organization should achieve the governance of outsourced activities. However, some work such as the installation of the devices for bridge & tunnels are outsourced to other companies, the control is somehow not efficient.</p>
Check	<p>The use of software MQM or data validation is the direct method to evaluate asset performance. The KPI report in Strukton can be also regarded as a methods of management review. The executors in the field are required to fill in the digital inspection forms.</p>	<p>In ISO 55000, there are many specific requirements in monitoring & evaluation, internal audit, management review. The evaluation or audit should be based on the full scope of the asset management system. The effectiveness of maintenance work, the benefits of technologies, financial linkage to the work, the completeness of the procedures, all of these factors should be taken into account. Single audit do not necessarily cover entire system, but all these factors above should be investigated in several audits. In "De Wadden project", the evaluation is not powerful due to its singularity.</p>
Act	<ol style="list-style-type: none"> 1. The training about RCA (root cause analysis) is now ongoing, if it is effective and can be put into use, then it will be a good way to solve nonconformity and incident. 2. The external audit is given by Prorail, this is a reflect of continuous improvement. 3. The risk metric is dynamic processes, if the results are not acceptable, then the new maintenance strategy will be made and the analysis will repeat until it is acceptable. 	<ol style="list-style-type: none"> 1. In chapter 10.3, ISO 55002, opportunities for improvement should be identified, assessed and implemented across the organization through a combination of corrective actions and asset management system. However, the R&D team only concentrates on the value of improvement projects themselves, somehow lose the feedback from contract areas. Strukton now only uses a single pilot to evaluate innovations, however the starting situation can be different for each area. 2. The preventive actions are also required by ISO 55000, but for Strukton, my advice will be firstly establishing efficient corrective actions, then figure out how to prevent failures in reality and transform it into procedures.
Support	<ol style="list-style-type: none"> 1. The calculation department focus on the budget calculation and gap analysis. 2. The training towards the executors and planners are held at the beginning of every year. The experienced supervisors will also teach staffs to complete their jobs. 3. The employees are aware of the importance of the asset management. 4. The digital software are used to improve the communication efficiency and it is also provides easy access to all the departments. 5. The control of documented information is appropriate. The records of video surveillance are kept adequately. 	<ol style="list-style-type: none"> 1. The information requirements are emphasized in ISO 55000. The communication is not clear with Strukton Rail, see chapter 3.3 2. Some information of purchased-part is not documented in proper way. Only financial data are available in "De Wadden" project, some other information like configuration, manufacturer should be documented.

Appendix 2: Asset management responsibilities and products(source: Justin Heubach, 2014)

# AM requirement	# SR - responsibilities	SR - Related products
1 General requirements	1 Management of object information 2 Management of performance information 3 Review against PAS55 standards	object information performance data
2 Asset management policy	-	
3 Asset management strategy / objectives / plans	4 Creation of asset management objectives 5 Creation of asset management plan (maintenance)	Asset management policy Organizational strategic plan Object / maintenance information Handbook failure management Maintenance plan Maintenance requirements Asset standards Task descriptions SR strategy
4 Asset management enablers and controls	6 Safety analysis 7 Configuration management 8 Information management 9 Risk analysis 10 Training of competences and awareness 11 Failure management 12 Purchasing management 13 Human resource management	Maintenance requirements Task description Inspection Financial registration forms Handbook failure management Materials / equipment / tooling plan HRM plan Execution window Object / maintenance information Safety boundaries SR strategy
5 Implementation of asset management plans	14 Preparation of work execution 15 Safety preparation 16 Execution of planned work 17 Failure management execution 18 Purchasing 19 Data validation 20 Management of tools, facilities and equipment	Open work order Task description Inspection form Filled in inspection Registration form Filled in registration Execution windows Safety boundaries Failures Finished failures
6 Performance assessment and improvement	21 Improvement analysis 22 Translation registration / inspection into maintenance action 23 Performance assessment	Improvement proposal Object information Filled in inspection Filled in registration Maintenance announcement Asset condition Asset standards Performance reports
7 Management review	24 Improvement of the asset management system 25 Improvement of the SR organization	Performance reports Improvement proposal