# Valuing rail infrastructure performance in a multi actor context

*"Advising ProRail in making their maintenance policy decisions based on preferences of her external stakeholders"*

MSc-Thesis

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# PREFACE

This report is the result of a study conducted in the framework of SPM5910 'SEPAM Master Thesis Project'. This study is performed by order of ProRail's department of Infrastructure Management (IM) and carried out at the section Transport Policy and Logistics' Organization (TLO) of the faculty Technology, Policy and Management (TPA) of the Delft University of Technology (TUD). This study aims to gain insight in the preference behaviour of ProRail's external stakeholders with respect to the performance of the rail infrastructure. Hopefully, the results of this thesis will assist ProRail in managing and maintaining the infrastructure in a way that increases stakeholder value.

I would like to express my gratitude to Prof. Dr. Bert van Wee (TLO), Dr. Ir. Leon Hermans (Policy Analysis) for their advice and supervision during the project. In addition, I would like to thank Ir. Maarten Kroesen (TLO) for his pleasant guidance and sharp remarks. I would also like to thank Ir. Ted Luiten and Ing. Martijn van Noort (ProRail) for many interesting conversations on ProRail, my thesis and above all: on risk management. Lastly, I thank Ir. Randy Fischer (TLO/ProRail) for giving me the opportunity to assist in his PhD study. I enjoyed our conversations and cooperation, especially during the fieldwork. I have learned a lot and I hope that my thesis will be helpful in your PhD study. Good luck!

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# EXECUTIVE SUMMARY

The performance of the rail infrastructure system creates collective or public values for many of ProRail's external stakeholders. ProRail can affect the public values of the infrastructure through the use of maintenance, consisting of maintenance concepts (Gits, 1984, 1992). Safeguarding these public values in infrastructure sectors is difficult and complex but is at the same time an important aspect of safeguarding the overall infrastructure performance (Finger et al., 2005). In order to safeguard public values, one needs to be able to manage the trade-offs that can differ amongst different parties. And since ProRail wishes to increase stakeholder value, it is imperative that ProRail is able to manage the different trade-off decisions concerning elements that determine the (public) value of their stakeholders. To be able to do so, ProRail needs to obtain information on the trade-off behaviour of their external stakeholders. Only then can ProRail begin to think on how to manage these trade-offs.

Three main aspects are still lacking, restricting ProRail in being able to manage the different trade-off behaviour of their external stakeholders. Firstly, information on which performance indicators need to be included in that trade-off process is not complete. Secondly, the trade-off behaviour of ProRail's external stakeholders lacking. And thirdly, information is lacking on the impact of different infrastructure performances on stakeholders' satisfactions. Acquiring stakeholder preference information on these three aspects is the main focus of this study.

Next to analyzing relevant literature and policy documents, we interviewed eleven of ProRail's most relevant external stakeholders [1] and found that the most important infrastructure related performance indicators were related to: affordability (costs of using the infrastructure), availability (planned availability), reliability (unplanned availability) and safety (infrastructure's system safety). Stakeholders indicated that these four performances could substantially impact their company's objectives and preferences. Although there are trade-offs involved regarding these four performances, stakeholders do not perceive 'safety' a part of the trade-off process as safety needs to be guaranteed at all times.

On average, for all included stakeholders, <u>reliability</u> is considered the most important performance indicator (53%), followed by <u>affordability</u> (34%) and lastly, <u>availability</u> (13%) is considered to be least important. However, there are significant differences in the relative importance of the performance indicators amongst different stakeholders. Looking at the TOCs; NS Reizigers and the other three TOCs have substantial different perceptions on the relevance of the performance indicators relating to reliability and affordability. Furthermore, the TOCs and the public authorities have considerable different perceptions concerning the importance of the (planned) availability. Interestingly, the results indicated that the stakeholders are not satisfied about the current performance of the rail infrastructure system. We also found that it is very difficult to operationalize (or define) these performance indicators in the terminology that can be perfectly interpreted by all of ProRail's external stakeholders. Therefore we were not able to quantify the trade-off behaviour of ROVER.

1 We included passenger and cargo TOCS (NSR, NSHispeed, regional TOCs, ACTS, DB Schenker, ERS, Veolia), regional and national public authorities (DGMo, IVW, Province of Gelderland) and a consumer representative organization (ROVER).

By using the quantitative trade-off behaviour of ProRail's external stakeholders we were able to predict stakeholders' satisfactions in situations where the performance of the infrastructure varied, either by changing maintenance policy or implementing non-maintenance related policy measures. It was obvious that the effects of different maintenance concepts on stakeholders' satisfactions differed amongst stakeholders. Some stakeholders would be more positively or negatively affected than others. But in some cases the effect was conflicting; meaning that the implementation of some maintenance measures would positively affect some whilst negatively affecting others. These differing and even conflicting impacts make it difficult to determine a desirable strategy.
The desirability of such a (maintenance) strategy depends on the decision rule that ProRail uses concerning the relative importance of their external stakeholders. And as not every stakeholder would be evenly important for ProRail, it is unlikely that ProRail would take every stakeholder's preference in an even manner into account. The most desirable maintenance strategy proved to be highly dependent on which decision rule ProRail would choose to apply. ProRail should therefore be meticulous in determining the decision power of their external stakeholders.
The results of this study also indicated that policy measures that go beyond maintenance are required in order to realize a substantial impact on the satisfaction level of ProRail's external stakeholders.

Readers interested in a more detailed summary are referred to the next pages containing a more extended summary is presented that elaborates more on the research methodologies that were used to acquire these results. Furthermore, the last section of the extended summary will provide additional recommendations for ProRail.

# SUMMARY


## 1 Translating ProRail's problem into a research objective

As the national rail infrastructure manager (RIM) of the Dutch main rail network, ProRail's activities are extensive and diverse, and the impact of their policy is therefore far-reaching. Examples of ProRail's activities are: Infrastructure Management, Rail Development, Project Management, Capacity Management, Traffic Guidance. This study focuses on ProRail's policy on maintenance: "the total of activities aiming at retaining each part of a technical system in, or restoring it to, the operable state" (Gits, 1984). Purely focusing on maintaining the function of the physical rail infrastructure, which is the responsibility of ProRail's Infrastructure Management (IM)-department. The effects of for instance rail expansions or entirely new infrastructure; changing the function of the infrastructure, will not be considered.

Many actors are involved or affected by ProRail's policy decisions, otherwise referred to as 'stakeholders' or 'stakeholder organizations'. From a perspective of social responsibility, these stakeholders should be taken into account with respect to the formulation of the company strategy. Therefore, this study will focus on viewing ProRail's maintenance decisions from a multi-actor perspective, meaning that we look at stakeholders' interests and preferences with respect to maintenance policy.

In order to become the best infra-manager in Europe, IM first of all needs to become a good asset manager. For any asset manager, it is necessary to take stakeholders and their (often conflicting) objectives and preferences into account, since "it is essential that the asset management strategy has taken into account the views of all stakeholders, otherwise the organization might end up performing unnecessary or inappropriate tasks or failing to meet key business objectives" (IAM, 2004b).

ProRail uses 'maintenance concepts' in managing their maintenance activities. A maintenance concept consists of an ordered set of maintenance rules to a technical system, by prescribing *what* maintenance operation should be executed, and *when*. Maintenance rules can consist of: failure-, use- and condition-based maintenance (Gits, 1984, 1992). The effects of a maintenance concept applied to a rail section can be calculated by: first, specifying FMECAs and second, use a Monte Carlo simulation to predict the performance of that track section. Decisions regarding maintenance concepts have an effect on many involved stakeholders that are interested in the performance of the rail infrastructure system (RIS).

This study focuses on ProRail's external stakeholders; first of all on those stakeholders that use the rail infrastructure, the train operating companies (TOCs). Second of all, the study takes into account the public authorities, which are authorized to grant concessions to the TOCs: the Ministry of Transport and regional public authorities. European and national rules and regulations are considered a boundary condition.

Future growth in passenger and freight transport, accompanied by increasing competition of TOCs means an increased burden on the rail infrastructure in the future and all the more reason to 'optimize' the maintenance concepts for those involved.

As different groups perceive and value different consequences differently (Walker, 2000); the effects of different maintenance concepts will be differently valued by ProRail's stakeholders. The policy analysis framework of Walker (2000), presented in section 1.3, shows that the (main) goal of the maintenance policymaker of RIMs is to develop maintenance concepts, which allow RIS to perform to the satisfaction of stakeholders.

Safeguarding public values in infrastructure sectors is difficult and complex but is at the same time an important aspect of safeguarding the overall infrastructure performance (Finger et al., 2005). In order to safeguard public values, one needs to be able to manage the trade-offs that can differ amongst different parties. And since ProRail wishes to increase stakeholder value, it is imperative that ProRail is able to manage the different trade-off decisions concerning elements that determine the (public) value of their stakeholders. To be able to do so, ProRail needs to obtain information on the trade-off behaviour of their stakeholders. Only then can ProRail begin to think on how to manage these trade-offs.

Three main aspects are still lacking, which restricts ProRail in being able to manage the different trade-off behaviour of their external stakeholders. Firstly, the trade-off behaviour of ProRail's external stakeholders lacking. Secondly, information on which performance elements need to be included in that trade-off process is not complete. And thirdly, information is lacking on the impact of different RIS performances on stakeholders' satisfactions.

This study aims at understanding the preferences of ProRail's stakeholders with respect to the rail infrastructure's performance and how different maintenance strategies will affect these performances and thus their preferences, in order to be able to develop maintenance policy based on stakeholders' preferences. As a result, there is a need for information on which rail infrastructure related performance indicators are relevant to ProRail's stakeholders and how these performances determine their satisfaction.

The following research objective will have a central position in this study.

"Advising ProRail on the evaluation of rail infrastructure performance from a multi actor perspective in order to develop maintenance policy that is based on the preferences of all relevant stakeholders."

## 2 Specifying the research focus

The essence of this study can best be explained by the sub questions, which can best be summarized by the following main research question.

"Which maintenance concepts are preferred from the perspective of ProRail's external stakeholders?"

***Sub research questions***

1. "What are, from a perspective of ProRail's external stakeholders, the most relevant performance indicators that should be considered in evaluating different maintenance concepts?"

2. "How relatively important are the most relevant performance indicators (question 1) to each of the relevant external stakeholders?"

3. "How will the effects of different maintenance concepts affect the satisfaction of all relevant external stakeholders?"

## 3 How to answer the research questions?

The objective of this research consists of many different aspects. Information is required on actor perspectives, trade-off behaviour and impact of maintenance on actor satisfactions. Due to the complexity and diversity of the research focus an approach is required that crosses disciplines. We believe that the research questions can only be answered through using a multidisciplinary approach, combining the scientific fields of actor analysis, policy analysis and quantitative preference analysis.

For answering the first two research questions, we have used two different research methodologies. To answer the first research question we have interviewed several of ProRail's external stakeholders, consisting of: passenger and cargo TOCs, national and regional public authorities and a passenger representative organization. The results of the interviews will be translated into cognitive causal mappings, DANA models, which will be used to extract the most relevant performance indicators that will be used in the conjoint analysis. Next to these interviews, we have also analyzed several relevant policy documents[2] as they should contain criteria of initial importance concerning rail infrastructure performance.

To answer the second research question we will apply a conjoint analysis. More specifically, a rating based stated preference analysis where the attribute levels are based on the performance indicators from the answer on the first research question. The third research question will be answered by using the preference models for predicting stakeholders' preferences on the effects of maintenance concepts acquired by using the FMECA methodology and Monte Carlo simulation (Fischer et al., 2008).

## 4 Analyzing the actor perspectives

This section will summarize the results of the actor analysis in the third chapter of this report and will answer the first research question:

| |
|---|
| What are, from a perspective of ProRail's external stakeholders, the most relevant performance indicators that should be considered in evaluating different maintenance concepts? |

2 ProRail's management concession, Transport concession of the main railsystem, ProRail's Network Declaration, ProRail's Maintenance Plan and the Second Bill on railway safety.

Determining the most relevant performance indicators from a multi actor perspective required a selection of ProRail's external stakeholders to be included in this study. In order to acquire a comprehensive perspective on stakeholder preferences, it was deemed important to include stakeholder organizations that are both diverse and representative. The following stakeholder organizations were included:

- Passenger Train Operating Companies (TOCs): NS Reizigers, NS Hispeed, Regional TOCs[3].
- Cargo TOCs: ACTS, DB Schenker, ERS Railways and Veolia Cargo.
- Ministry of Transport: Directorate General Mobility and the Safety Inspectorate.
- Regional public authorities: Province of Gelderland
- Interest association for public transport passengers: ROVER.

Information on stakeholders' perspectives was acquired through qualitative interviews focusing on the desired performance of the rail infrastructure with respect to the goals and objectives of the organization. The interviewees were selected based on their capacity to answer such questions.
The interview reports were translated into causal diagrams representing each stakeholder's system perspective on how they perceive the performance of the rail infrastructure to be affected. These system perspectives are created by using the cognitive mapping methodology: Dynamic Actor Network Analysis (DANA) (Bots et al., 2000; Hermans, 2005). The actual interview reports and DANA models are presented in Appendix H and Brinkman and Fischer (2009).

The interview reports and corresponding DANA models show that the preferences of ProRail's external stakeholders can be influenced by more than just ProRail herself, and these factors which can be influenced by ProRail can be influenced by more than just maintenance policy. Due to the research focus on the effects of maintenance policy, we will discuss these aspects in section 6.5.
DANA analysis showed that, in the end, maintenance activities have an influence on four performance related clusters[4] on affordability, planned unavailability, safety and unplanned unavailability. These performance clusters in turn have an effect on the satisfaction levels of ProRail's external stakeholders. Improvements of the infrastructure could therefore better be aiming at improving one or more of these performances. For example, the results suggest that investments in improving the *comfort-level* or reducing *environmental damage*, that do not also positively affect on one of these four performances, could better be spent by improvements on affordability, unplanned and planned unavailability and/or safety.
Changing maintenance activities would result in developments that stakeholders would appreciate both positively and negatively. For example: increasing maintenance activities would on the one hand positively affect the safety level and unplanned unavailability of the infrastructure, but on the other hand would negatively affect the affordability and planned unavailability of the infrastructure. Clearly there are trade-offs involved and in order to appraise maintenance one needs to have information on the relative importance of performance criteria, which is the main concern of the next section.

3 Every interview was held with someone at the actual stakeholder organization, except for the regional TOCs. At ProRail's request we interviewed a ProRail expert: a senior employee for managing relations with regional TOCS.
4 Consisting of several factors relating to that specific performance type.

Based on the analysis on policy documents, the interview reports and DANA models we come to the conclusion that, from a multi actor perspective, the most relevant and maintenance related performance indicators are:

- **Affordability**: the affordability of the rail infrastructure.
- **Availability**: planned unavailability of the rail infrastructure.
- **Reliability**: unplanned unavailability of the rail infrastructure.
- **Safety**: the safety of the rail infrastructure.

These four performance indicators will provide the basis for the attribute selection in the conjoint analysis.

## 5 Analyzing stakeholder preference

This section will summarize the results of the conjoint analysis in the fourth chapter of this report and will answer the second research question:

| |
|---|
| How relatively important are the most relevant performance indicators (question 1) to each of the relevant external stakeholders? |

### Preceding the conjoint analysis

All four most important elements determining the stakeholders' trade-off behaviour should normally be included in the conjoint analysis. However, the aspect of safety is somewhat special and including 'safety' in the conjoint analysis introduces considerable risks, and therefore, 'safety' has been excluded as an attribute in the conjoint analysis.
Since 'safety' is the primary concern of the Safety Inspectorate IVW, this stakeholder was excluded for the conjoint analysis. Furthermore, one regional TOC was included, "Syntus", instead of ProRail's specialist. Therefore, ten stakeholder organizations were approached for participating in the conjoint analysis by sending a link to an internet questionnaire.

The conjoint analysis was applied using a rating based, stated preference approach where every respondent needed to rate a situation (profile) containing performance information on a section of the rail infrastructure on a scale of 1 to 10.
The profiles were created based on actual historical registry data (ProRail, 2009b), averaging three existing and intensively used corridors with an average length of 130 km: Rotterdam – Zevenaar border, Amsterdam – Eindhoven, and Amsterdam – Roosendaal border. In determining the values of the attribute levels concerning the affordability or "percentage change in usage rate", policy documents on the calculation of the financial usage tariffs have been used (ProRail, 2005d) to relate the maintenance costs to these rates. The attributes and their levels of the conjoint profiles are presented in table 1.

### Overall stakeholder preferences

Of the ten stakeholders that were approached for rating the conjoint profiles: five completed the questionnaire and one, ROVER, was not able to answer the questions as the operationalizations of the performance indicators did not match ROVER's state of mind. This will be dealt with further in chapter 7. Furthermore, one stakeholder, Province of Overijssel, participated while not being directly approached. In total, six individual preference models could be estimated, shown in Appendix R. The aggregated model results of these six stakeholders are presented in Table 1.

Table 1: The (aggregated) overall preference model, based on: NSR, NSHispeed, ERS, Veolia, Gelderland and Overijssel

| Aggregated overall preference model | | | | | | |
|---|---|---|---|---|---|---|
| | | Average rating | Part-worth utility | p-value | Range | Relevance |
| **Overall utility (constant)** | | 3.312 | | 0.000 | | |
| **% Hindered trains** | | | | | | |
| 11 | | 4.54 | 1.229 | 0.000 | 2.291 | 53% |
| 15 | | 3.54 | 0.229 | 0.070 | | |
| 19 | | 2.92 | -0.396 | 0.009 | | |
| 23 | | 2.25 | -1.062 | | | |
| **% Trains needing re-planning** | | | | | | |
| 5 | | 3.54 | 0.229 | 0.070 | 0.583 | 13% |
| 7 | | 3.54 | 0.229 | 0.070 | | |
| 9 | | 3.21 | -0.104 | 0.356 | | |
| 11 | | 2.96 | -0.354 | | | |
| **% Change in usage rate** | | | | | | |
| -5 | | 4.17 | 0.854 | 0.000 | 1.458 | 34% |
| 0 | | 3.50 | 0.187 | 0.122 | | |
| 5 | | 2.88 | -0.437 | 0.006 | | |
| 10 | | 2.71 | -0.604 | | | |
| | | | | | | **Check** |
| **R Square** | 0.981 | | **Total Range:** | | 4.332 | 100.0% |
| **Adjusted R Square** | 0.952 | | | | | |

The overall utility, or constant, is 3.312, which means that on average the profiles have been rated with a 3.312. Since the possible ratings of the profiles ranged between 1 and 10, one can conclude that, on average, all profiles were very unsatisfactory for the stakeholders.

Furthermore, the holdout profile was on average rated with a 3.83. And since the holdout profile was based on the actual rail infrastructure performance, it is likely that the stakeholders are not satisfied about the current performance of the rail infrastructure system[5]. The results suggest that substantial infrastructural improvements are required to realize a significant improvement in the overall satisfaction levels of ProRail's external stakeholders.

The part-worth utility of '11% hindered trains' is +1.229, which normally means that the stakeholders consider 11% trains hindered as 'positive'. However, as can be read from the first column, the inclusion of that attribute level in the profiles results in an average rating of 4.54, which should still be considered insufficient.

5 Based on the attribute levels in the profiles.

On average for all included stakeholders reliability is considered the most important attribute (53%), followed by affordability (34%) and lastly, availability (13%) is considered to be least important. Changes of the infrastructure performance would have a greater impact on stakeholder satisfactions when focusing on the most important performance criteria: improving the infrastructure's reliability would be more effective in increasing stakeholders' satisfactions than improving the availability. And vice versa; decreasing the reliability would be worse.

By analyzing the preference behaviour of each individual stakeholder, we found that there are differences in the relative importance of the performance indicators between stakeholders. Looking at the TOCs; NS Reizigers and the other three TOCs have substantial different perceptions on the relevance of the performance indicators relating to reliability and affordability. Furthermore, the TOCs and the public authorities have considerable different perceptions concerning the importance of the (planned) availability.

Lastly, the overall reliability and validation criteria give confidence in the conjoint preference models for both the aggregated and individual models. The relative importance of the performance indicators are considered to be reliable, however, one should be careful in the interpretation of the preference ratings as they appear to be somewhat low.

The conjoint analysis has shown that significant differences do exist between stakeholders with respect to the relative importance of these performance indicators. Eventually it is up to ProRail to decide on how to deal with these discrepancies, but the implications have been demonstrated in chapter 5 and will be summarized in section 6.

## 6 Predicting stakeholder preferences

This section will summarize the results of the application of the preference models in the fifth chapter of this report and will answer the third research question:

| |
|---|
| How will the effects of different maintenance concepts affect the satisfaction of all relevant external stakeholders? |

The application of the preference models is made by predicting the stakeholder satisfaction of the effects when different maintenance concepts or scenarios are applied. Fischer et al. (2008) have calculated the effects of three maintenance scenarios using the FMECA (Failure Mode, Effects, and Criticality Analysis) methodology as described in the American Military Standard 'MIL-STD-1629A' (1980) and Monte Carlo simulation. The simulation results from Fischer et al. (2008) are used to translate three maintenance scenarios into effects in terms of the PIs of the rail infrastructure corresponding with the attributes used in the conjoint analysis.

Based on the preference models, we have predicted the quantitative satisfaction for the stakeholders in each of the three scenarios. The predicted ratings for each of the three scenarios are shown in table 2.

Table 2: Predicted ratings for three scenarios

| *Stakeholder* | *Predicted ratings (1 to 10) of scenario:* Sc1: Present performance | Sc2: Low cost - Low performance | Sc3: High cost - High performance |
|---|---|---|---|
| ***All stakeholders***[6] | *3.38* | *3.49* | *3.06* |
| ***NS Reizigers*** | *2.10* | *2.05* | *2.46* |
| ***NS Hispeed*** | *4.22* | *4.41* | *3.92* |
| ***Veolia and ERS*** | *2.58* | *2.85* | *1.69* |
| ***Gelderland*** | *4.66* | *4.63* | *4.40* |
| ***Overijssel*** | *4.19* | *4.16* | *4.23* |

Looking at the overall aggregated model (all stakeholders), one can conclude that the scenario: Low cost-Low performance is preferred, followed by the present performance and lastly the High cost-High performance scenario. Note that the range of the effects relative to 'Sc1: present performance' is rather small: rating shifts of +0.11 and -0.32[7]. Analyzing from the present performance; a maintenance strategy towards scenario 3 is relatively worse than a strategy towards scenario 2 is better.

To demonstrate the applicability of the conjoint model results in further detail, we have determined the effects of different maintenance strategies on the individual stakeholders. Let us assume that ProRail is currently in the situation which resembles scenario 1: 'the present performance' and ProRail wishes to improve the satisfaction of its stakeholders and ProRail has two available maintenance strategies: scenario 2 and 3. Table 3, which is derived from table 5, shows how every individual stakeholder rating improves or worsens.

Table 3: Predicted changes of stakeholder rating for two scenarios

| **Stakeholder** | **Predicted rating-changes of scenario:** *Low cost - Low performance* | ***High cost - High performance*** |
|---|---|---|
| ***NS Reizigers*** | **-0.06** | **0.36** |
| ***NS Hispeed*** | **0.19** | **-0.30** |
| ***Veolia***[8] | **0.27** | **-0.89** |
| ***ERS*** | **0.27** | **-0.89** |
| ***Gelderland*** | **-0.04** | **-0.26** |
| ***Overijssel*** | **-0.03** | **0.05** |
| **Total** | **0.61** | **-1.93** |

Again, note that the impact of these maintenance concepts on stakeholders' satisfaction levels is relatively slim. The largest impact on a stakeholder satisfaction is a rating decrease of 0.89.

6 Based on the aggregated model of the six stakeholders.

7 This small range is due to the fact that conflicting preferences between the stakeholders are compensated as a scenario can be a positive change for one stakeholder, but a negative change for another.

8 The preference predictions of ERS and Veolia are based on the aggregated model and therefore, the values of these two stakeholders are similar.

The results of the predicted preferences in Tables 2 and 3 are based upon the effects of the maintenance concepts in Fischer et al. (2008). According to the authors, the effects of maintenance concepts on the rail infrastructure performance could be more extreme than the two scenarios that we used. Should one desire to predict the preferences of more extreme values of the attribute levels, one should be aware of the several limits of the model's predicting capabilities, described in section 5.4. In section 5.5 we have showed that more extreme performance levels[9] would result in substantially intensified preference ratings. This means that in order to considerably improve stakeholders' satisfactions, more excessive performance improvements are required than maintenance concepts could probably provide. Perhaps maintenance concepts could be further enhanced but performance improvements due to other policy measures seem necessary.

It is obvious that the effect of different maintenance concepts on stakeholders' satisfactions differs amongst stakeholders. Some stakeholders are more positively or negatively affected than others and in some cases the effect is conflicting; meaning that the implementation of some maintenance measures would positively affect some whilst negatively affecting others. These differing and even conflicting impacts make it difficult to determine a desirable strategy.
The desirability of such a (maintenance) strategy depends on the decision rule that ProRail uses concerning the relative importance of their external stakeholders. And as not every stakeholder would be evenly important for ProRail, it is unlikely that ProRail would take every stakeholder's preference in an even manner into account. The most desirable maintenance strategy proved to be highly dependent on which decision rule ProRail would choose to apply. ProRail should therefore be meticulous in determining the decision power of their external stakeholders

# 7 What can ProRail learn from this study?

This section is concerned with the implications specifically for ProRail and will present recommendations based on the results of this study. Implications and recommendations are given based on the analyses on stakeholder perspectives and preferences. Also some general recommendations will be provided on aspects that were not the primary focus of this study, but nonetheless would be of interest to ProRail. The following four recommendations are considered to be most important for ProRail. Additional recommendations are given in section 6.5.

**Do not consider every performance indicator evenly important, and realize that the relative importance of these PIs differ amongst stakeholders.**

According to all stakeholders[10] the ranking of the importance of the rail infrastructure related performance indicators are: 1: reliability, 2: affordability and 3: availability. However, there are (significant) differences between stakeholders, meaning that basing policy decisions on maximizing the overall stakeholder satisfaction involves disappointing some stakeholders.

9 More extreme than the effects of these three maintenance scenarios extracted from the Monte Carlo simulation.
10 Based on the aggregated preference model.

**Create a sense of urgency for negotiations, between ProRail and her relevant external stakeholders, on trade-offs regarding performance criteria, by demanding a hierarchical intervention by the Ministry.**

As De Bruijn and Dicke (2006) have discovered that a combination of the two safeguarding mechanisms *network* and *hierarchy* is very suitable for realizing a solution that is satisfactory for all involved stakeholders, we believe that intensive negotiations between ProRail and their external stakeholders could help ProRail in managing the infrastructure in a way that is satisfactory for all involved. Perhaps the results of this study could be used as a starting position, indicating that differences in infrastructure performance are differently valued amongst stakeholders. However, this negotiation process has little chance of succeeding without a hierarchical intervention by the Ministry as stakeholders could lack a sense of urgency to participate, which currently seems to be the case. This would certainly explain the lacking stakeholder response in this study with respect to the preference analysis. Therefore, ProRail should increase the stakeholders' sense of urgency by requesting[11] such a hierarchical intervention, obligating the entire rail sector (ProRail and external stakeholders) to participate in the process of dealing with the problem of differing trade-off behaviour with respect to the infrastructure's performance.

**Prioritize amongst external stakeholders with respect to decision power.**

Within the TOCs: NS Reizigers has substantial preference differences from ERS, Veolia and NS Hispeed. And overall: the regional authorities' preferences differ substantially from the TOCs. These diverging preferences make it imperative for ProRail to determine in what manner each stakeholder preference should be considered when evaluating their policy options. Based on the results of the conjoint analysis it is not possible to affect each stakeholder in a similar manner with one maintenance strategy. Prioritization is necessary.

**Jointly develop performance indicators with rail sector and improve communication on the status of these performances.**

Current PIs do not seem suitable. Stakeholders' responses with respect to some PIs were that these are hard to interpret and/or stakeholders were not certain whether these PIs were a good reflection of the actual performance. Stakeholders' perceptions on the current performance were very inconsistent and not well founded. Jointly[12] determining which PIs to apply and how to measure these PIs would make the performance evaluation more practically relevant. This approach would (more easily) reconcile the stakeholders' interests and result in a jointly satisfactory solution, according to the principles of Principled Negotiation (Fischer and Ury, 1983; Adler and Blue, 2002). Such PIs could provide a new basis for future performance agreements with TOCs as most TOCs are willing to invest in an increased performance of the rail infrastructure. It would then be imperative that ProRail informs the TOCs on how the performance will be improved for their organization. PIs based on the perspectives of TOCs could become (both communicatively and financially) beneficial for ProRail.

11 Or even demanding.

12 With ProRail's external stakeholders, more especially the TOCs, since DGMo expects the rail sector to create the PIs.

# TABLE OF CONTENTS

# List of Figures



# List of Tables

# 1 INTRODUCTION

*“Translating ProRail’s problem into a research objective”*

## 1.1 General introduction

As the Dutch rain infrastructure manager (RIM), ProRail operates within a multi actor environment where many external stakeholders are involved, each having their own objectives and preferences with respect to the performance of the rail infrastructure. Current performance criteria are mainly based upon the criteria specified by the Dutch government (top-down) and do not incorporate stakeholders’ preferences sufficiently (bottom-up). ProRail wants to incorporate stakeholders’ preferences into their policy decision-making process, however, information with respect to these preferences on the infrastructure’s performance is still lacking.

This chapter will explain ProRail’s problem in more detail by elaborating more on recent developments in the rail sector and on ProRail as a RIM. Furthermore we will combine several scientific areas to translate ProRail’s problem into a research objective.

### 1.1.1 Developments in the rail sector

Major changes have taken place in the Dutch main rail infrastructure over the last years. In 1995, a restructuring of the Dutch railway company, Nederlandse Spoorwegen (NS), has started. The first steps were the establishment of an ‘infrastructure services’ division, which functioned as an internal contractor for executing the maintenance work. The next steps were in 1997: the privatization of the engineering bureau of NS and the transfer of 3000 maintenance staffs to three private sector contractors. At that time the remaining maintenance staff, still part of the NS, had to redefine their role in the area of ‘infrastructure provision’.

Instead of performing the maintenance tasks themselves, they had, and still have, to manage the maintenance process by contract and tendering. These contracts needed to be tailored to meeting network wide performance targets.

This ‘contract management’ approach is entirely different from the relatively independent, operational way of working in the NS era, when technically skilled chiefs managed their own subsystem (Zoeteman, 2006).

In 2004, the Dutch parliament approved the new Railway Act, which created ProRail as the government commissioned RIM for the Dutch network. ProRail has to operate under a concession, lasting till 2015, and meet specified performance targets (VenW, 2005).

### 1.1.2 ProRail as a Rail Infrastructure Manager

The activities of ProRail are extensive and diverse, and the impact of their policy is therefore far-reaching. Examples of ProRail’s activities are: Infrastructure Management, Rail Development, Project Management, Capacity Management, Traffic Guidance. This study focuses on ProRail’s policy relating to maintenance: “the total of activities aiming at retaining each part of a technical system in, or restoring it to, the operable state” (Gits, 1984). Purely focusing on maintaining the function of the physical rail infrastructure, which is the responsibility of ProRail’s Infrastructure Management-department. The effects of rail expansions or entirely new infrastructure; changing the function of the infrastructure, will not be considered. Next to the rail infrastructure, ProRail is also responsible for the performance of the railway stations, being clean, safe and accessible. Maintenance operations regarding these stations will also not be considered in this study as the objectives for this type of maintenance is fundamentally different than it is for the rail infrastructure.

As the national RIM with the government owning 100% of the company shares, ProRail's key activities and responsibilities have an extensive social relevance. Many actors are involved or affected by ProRail's policy decisions, which we will also refer to as (external[13]) 'stakeholders' or 'stakeholder organizations'. From a perspective of social responsibility, these stakeholders should be taken into account with respect to the formulation of the company strategy. Therefore, this study will focus on viewing ProRail's maintenance decisions from a multi-actor perspective, meaning that we look at the interests and preferences of ProRail's external stakeholders with respect to maintenance policy.

With regard to ProRail's key performances, their mission has been translated into nine Key Performance Indicators (KPIs; see ProRail 2008b; Appendix O). These KPIs have a central position in the internal management of business processes and in the justification of their performance to ProRail's clients and the Ministry of Transport.

In addition to the ProRail's key performances, the focus on client and the surrounding stakeholders are mentioned: "…key aspects are: listening to clients' wishes, working together on the best solutions possible, communicate the trade-offs, manage and monitor the decisions internally" (ProRail, 2008a), which emphasizes ProRail's desire to include their clients in the decision making process.

ProRail's department of Infra Management (IM) is responsible for maintaining and managing the physical infrastructure. IM's main objective is to become "the best Rail Infrastructure Manager in Europe" (ProRail, 2008e) and fulfils its role as an inframanager by (ProRail, 2007):

- Having attention for the day-to-day operational availability and performance of the rail infrastructure.
- Working together effectively with surrounding stakeholders, such as other departments, clients and the government.
- Making optimal trade-offs concerning RAMS (HE)[14]-performance and Life Cycle Costing decisions.

In order to become the best inframanager in Europe, IM first of all needs to become a good asset manager. An organization is considered to be an asset manager when physical assets are a key or critical factor in achieving its business objectives and in achieving effective service delivery (IAM, 2004a). The Institute of Asset Management has created a document that specifies which characteristics a good asset manager should have.

In this Publicly Available Specification, PAS 55, the objective of asset management is described as: "to ensure (and to be able to demonstrate) that the assets deliver the required function and level of performance in terms of service or production (output), in a sustainable manner, at an optimum whole-life cost without comprising health, safety, environmental performance, or the organizational reputation" (IAM, 2004a).

As we focus on the external stakeholders in ProRail's multi actor perspective, one should interpret 'stakeholder' or 'stakeholder organization' as belonging to ProRail's external environment.

14 RAMSHE is an abbreviation for Reliability, Availability, Maintainability, Safety, Health and Environment.

In PAS 55 is explained that the corporate policy should be deduced from the organization's strategic plan. In the policy of an asset manager, the corporate strategy should deal with the conflicting expectations of the stakeholders (IAM, 2004b). Concerning the long term strategy of an asset manager, the PAS 55 states: "It shall identify and consider the requirements of all other relevant stakeholders including health, safety, sustainability and environmental performance requirements."

For any asset manager, the necessity of taking into account the stakeholders and their (often conflicting) objectives and preferences can be derived from the following: "It is essential that the asset management strategy has taken into account the views of all stakeholders, otherwise the organization might end up performing unnecessary or inappropriate tasks or failing to meet key business objectives" (IAM, 2004b).

This study will focus on ProRail's maintenance policy decision making on the physical rail infrastructure, from a multi actor perspective. Therefore, the following section will elaborate on both aspects and will explain why stakeholder information is required to evaluate the effects of ProRail's maintenance policy properly.

## 1.2 Identifying ProRail's problem

### 1.2.1 ProRail's maintenance process

ProRail uses maintenance in managing their maintenance operations. A 'maintenance concept' is defined by Gits (1984) as: "the ordered set of maintenance rules connected to a technical system (TS)", and a 'maintenance rule' is: "a directive prescribing a collection of maintenance operations and "when" this collection should be carried out." A maintenance concept can be regarded as an instrument for realizing maintenance policy.

A method suitable for analyzing a technical system is the FMECA (Failure Mode, Effects, and Criticality Analysis) methodology as described in the American Military Standard 'MIL-STD-1629A (1980). The FMECA details all the anticipated failure modes associated with a technical system, and includes a consideration of the effect of the failure on the system. Some basic steps in performing a FMECA are: identifying the functions of a technical system, identifying failure modes of a technical system, identifying failure causes and conditions of the failure modes, and quantifying Mean Time Between Failures (MTBFs). ProRail determines the effects of failure as a measure of consequences on their company objectives (ProRail, 2005).

The rationale of maintenance lies in reduction of failure consequences. With respect to the objective to be reached by maintenance, operations can be divided into the following two categories (Gits, 1984):

- Corrective Maintenance (CM): maintenance with the objective to *restore* a part of a TS to the operable state.
- Preventive maintenance (PM): maintenance with the objective to *retain* a part of a TS in the operable state.

With respect to maintenance activation, the following three categories of maintenance rules can be distinguished (Gits, 1984, 1992):

- Failure based maintenance (FBM): maintenance prescribed to be activated by the event of failure only. FBM consists of corrective maintenance and is effective in any case.
- Use based Maintenance (UBM): maintenance prescribed to be activated by the event of a TS reaching a specified number of units of use, or by the event of failure, if failure occurs early.

UBM can be categorized as corrective and preventive maintenance and UBM is effective in case of an increasing failure rate.

- Condition based maintenance (CBM): maintenance prescribed to be activated by the event of a failure prediction property reaching a control norm, or by the event of failure. CBM can be categorized as corrective and preventive maintenance and CBM is effective if a failure prediction property is known.

Important aspects relating to maintenance are “reliability” and “availability”. According to the Dutch normalisation institute in a specification on rail applications (NEN-EN 50126-1, 1999) “reliability” can be defined as: “the probability that an item can perform a requiredfunction under given conditions for a given time interval”. And “availability” is defined as “the ability of a product to be in a state to perform a required function under given conditions at a given instant of time or over a given time interval assuming that the required external resources are provided”.

ProRail’s maintenance policy is specified in maintenance documents (In Dutch: “instandhoudingsdocumenten”, see also appendix F). The types of information in these maintenance documents are comparable to the FMECA methodology and contain information on technical systems and its components regarding: the function of a component or system, failure modes, failure cause, condition of the failure mode, maintenance rule (FBM, UBM or CBM), maintenance activity and maintenance interval. Appendix F shows a page in the maintenance document concerning the technical system: rail. For more detailed information we refer to ProRail (2005b, 2005c).

ProRail’s maintenance documents provide no information on the failure *behaviour* of the components in a technical system, which is necessary to simulate the performance of a rail infrastructure system over a time period. Ideally, the failure behaviour of a technical system is based on reliable statistical information, but since there is a lack of adequate failure data; ‘expert elicitation’ is required, where experts have to estimate failure distribution functions and their corresponding MTBFs.

The FMECA methodology provides a basis for determining maintenance concepts, which is done in the study by Fischer et al. (2008), where the following data was gathered per failure mode: maintenance rules, description of the maintenance rule, costs and frequency. Table 4 shows a part of the generated FMECAs and corresponding maintenance rules in that study. The FMECA displays one of the possible failure modes of the chosen technical systems, namely “Incorrect ‘Track occupied’ indication”. One of the failure causes of this failure mode is ‘Insulated joint causes short-circuit’, with Wear, Vandalism, and Pollution as three of the underlying failure mechanisms.

Table 4: Example of FMECAs, adopted from Fischer et al. (2008)

| Failure Mode | Failure Cause | Failure mechanism | MTTF/ MTBF | Distribution | Maintenance rule | Description | Costs [€] | Yearly frequency |
|---|---|---|---|---|---|---|---|---|
| Incorrect 'Track occupied' indication | Insulated joint causes short-circuit | Wear | 10 Years | Normal | Condition based maintenance | Continuity test of insulated joint | 150 | 2 |
| Incorrect 'Track occupied' indication | Insulated joint causes short-circuit | Vandalism | 50 Years | Exponential | Failure based maintenance | Remove cause of short-circuit | 100 | - |
| Incorrect 'Track occupied' indication | Insulated joint causes short-circuit | Litter | 2 Years | Normal | Failure Based Maintenance | Remove litter | 100 | - |

Using analytical solutions to acquire information on the track performance based on a sequence of numerous of failure distribution functions would be very complex and a Monte Carlo simulation is taken as a more suitable approach. Monte Carlo techniques are used to simulate the operational life of the chosen track, each run using different values of the distributed parameters. The selection of parameter values is made randomly, but with probabilities governed by the relevant distribution functions. ProRail uses the software tool 'Optimizer+' to perform several Monte Carlo simulations to predict the performance of track sections (Roost et al., 2003).

Fischer et al. (2008) simulated different scenarios of maintenance concepts and have determined the effects on 'costs' and 'unplanned downtime'. It is no surprise that the implementation of different maintenance concepts to a specific track section, results in varying effects. But are there additional effects of importance? And if so, which? Waeyenbergh and Pintelon (2004) foresee in the future that a multi criteria decision methodology will be used in order to assist in the maintenance policy decision making. The question then remains: "which criteria should one use to evaluate the effects maintenance concepts?"

ProRail's current use of performance evaluation criteria in evaluation methods is described in Appendix A, where it has become apparent that these criteria are somewhat lacking and applied inconsistently. The apparent performance indicators are often different or defined in a different manner, resulting in evaluation methods that lack uniformity.

Furthermore, these criteria should reflect the Key Performance Indicators, mentioned and specified in the management concession of the main rail infrastructure (VenW, 2005; ProRail, 2006, 2007b, 2008f). But Appendix O shows that the government specifies criteria merely in general terms, such as "the reliability and availability of the rail infrastructure", instead of specifying concrete and measurable indicators. This means that the Key Performance Indicators, specified by the government, do not provide sufficient detail for ProRail to specify proper criteria for evaluating the effects of maintenance concepts.

ProRail's maintenance policy decisions have an effect on many involved stakeholders that are interested in the quality of the physical rail infrastructure. Using the right performance criteria requires not only internal consistent use of these criteria, but also requires understanding of the

stakeholders. 'What are and aren't they interested in?' is an important question that needs answering to be able to acquire a complete picture of how stakeholders are affected by ProRail's maintenance policy.
Section 1.2.2 will illustrate the environment of ProRail in order to give a perspective on how ProRail's stakeholders are connected to their (maintenance) policy.

### 1.2.2 ProRail's multi-actor environment

Although ProRail is a monopolist in maintaining and managing the main rail infrastructure, their environment takes an important position in the formulation of their policy. The company plan of ProRail describes how ProRail views these surrounding influences. Five main categories are recognized by ProRail and are displayed in Figure 1 (ProRail, 2008a).

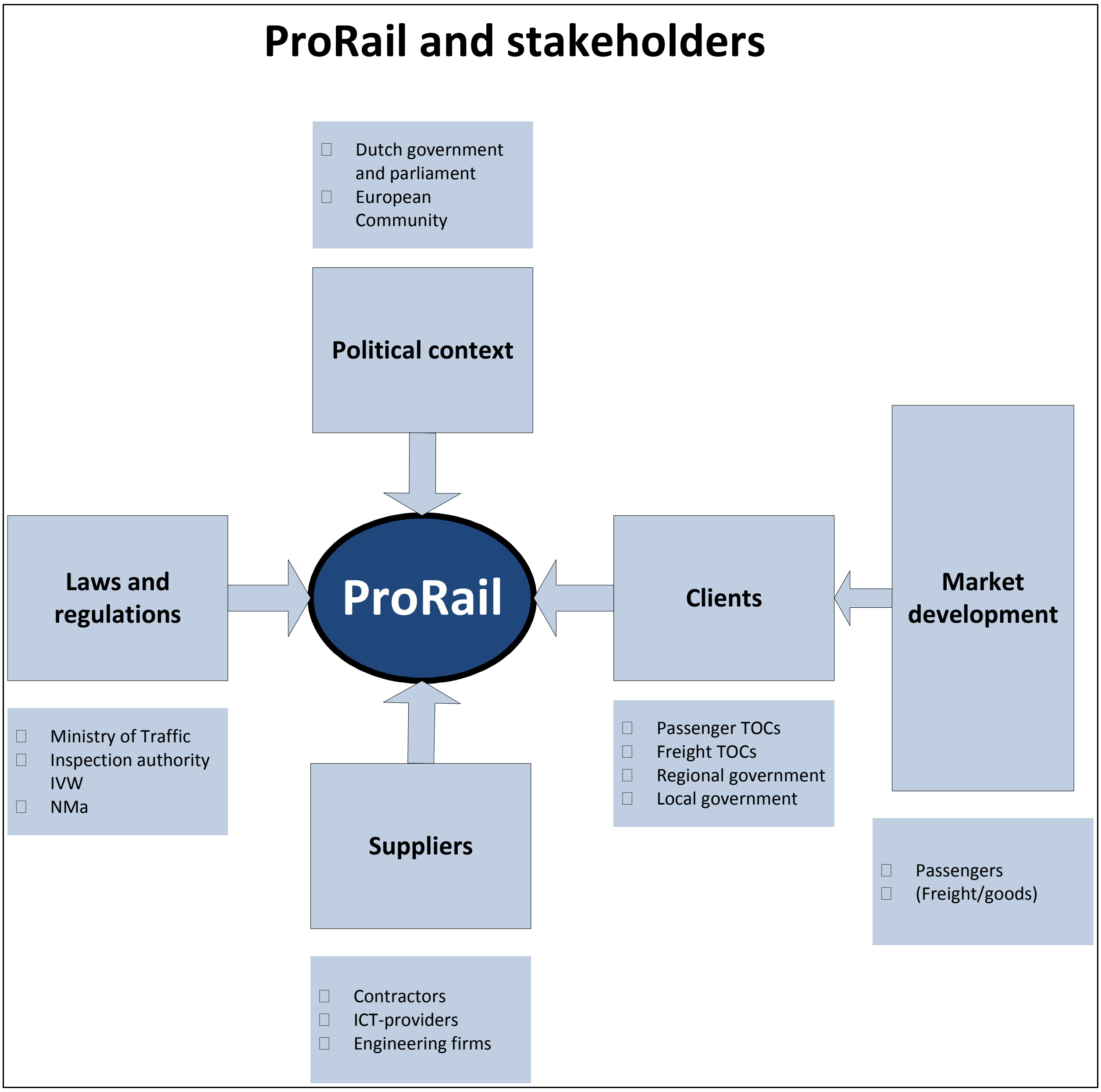


Figure 1: ProRail and the surrounding stakeholders

Firstly, the development of the market is of influence. The development of the number of passengers on the one hand and the freight transport on the other, determine the demand for rail infrastructure capacity. For the next twelve years, a passenger growth of approximately 21% is expected. The expected growth percentage of the volume of freight transport is somewhere between 96% and 186%[15] (ProRail, 2008a). These growth percentages will increase the burden of the rail network and therefore increase the need for a higher rail capacity and improved capacity management. The growing burden on the rail network will further increase need for a well performing physical rail infrastructure. ProRail's maintenance policy decisions are of great influence to this.

Secondly, ProRail's clients are an important stakeholder category. The clients can be divided into two types of stakeholders: the Train Operating Companies (TOCs) and public partners. At the moment ProRail has 37[16] different passenger and cargo TOCs, which pay an allowance based on the use of the infrastructure (ProRail, 2006). Public partners have been developing, on both a regional and local level, to large financiers and are therefore considered to be important clients for ProRail.

Thirdly, ProRail needs to have regard for the political context, where central aspects are: (1) the Dutch government (Ministry of Transport), with whom is decided that the focus of managing the company needs to become output oriented; (2) legislation, where ProRail needs to keep operating within the guidelines of the Railway Act and Concession Act; (3) the decentralization of maintenance and management, where ProRail's task on regional lines have become subject for debate; and (4) the relationship with Brussels, where the European interoperability is an important aspect of interest.

Fourthly, ProRail has to deal with its suppliers. To these stakeholders, ProRail acts as a principal for contractors, ICT-service providers and engineering firms.

Finally, control or supervision on laws and legislations are of importance for ProRail. Laws and regulations concerning safety of labour, external safety and environment are stringent and result in limitations. Supervision on compliance with these rules is the responsibility of the inspection service IVW, the competition authority NMa and the Ministry of Transport.

Looking at ProRail's (external) multi actor environment, it can be concluded that ProRail has to deal with many different stakeholders, each having their own objectives, interests, responsibilities and preferences, which can be conflicting. Information on stakeholder interests with respect to ProRail's maintenance operations is however still lacking. One example of this lacking has been illustrated in box 1 of Appendix A, where 'comfort' could be of interest to one or more stakeholders, however is not used as a criterion in maintenance policy decisions.

A stakeholder's system perspective, representing an actor's point of view in an organized manner, should provide important insights for ProRail and help in creating proper stakeholder-based performance criteria. Having information on the stakeholders' system views regarding their interests on ProRail's maintenance activities, could and should prevent the exclusion of significant criteria. Furthermore, having a system's view at one's disposal is of importance for ProRail as it can be used to justify their maintenance focus to the stakeholders.

15 Although it is highly likely that the economic crisis of 2009 would negatively affect these growth predictions.

16 According to an internal news message on the ProRail intranet site on 16 December 2008, by ProRail's division of Capacity Management. In 2008, 37 TOCs were operating on the rail infrastructure. For 2009, the number of TOCs will be 36 due to 'Rail4Chem Benelux BV' taking over 'Rail4Chem GmbH'.

## 1.3 Stakeholder involvement in maintenance policy decision making

In order to understand the process of policymaking better, we need to investigate the area of policy analysis in the public sector. Problems and implications for the policymaking process in the public sector are well described by Walker (2000). The author gives many explanations as to why policymaking can be so complicated. Policymakers are faced with policy alternatives that are often numerous, diverse and produce multiple consequences that are far-reaching and difficult to anticipate, let alone predict (Walker, 2000), which is no different from ProRail's situation where several maintenance concepts are optional. Furthermore different groups perceive and value different consequences differently (Walker, 2000), which confirms that the effects of different maintenance concepts will be differently valued by ProRail's stakeholders. However, information on exactly how these effects are valued is not known.

Policy analysis has its roots in operations research. In the beginning, operations research techniques were applied to problems in which there were few parameters and a clearly defined objective function to be optimized. Gradually, the problems being analyzed became broader and the contexts more complex. Single objectives (cost minimization or performance maximization for example) were replaced by the need to consider trade-offs among multiple (and conflicting) objectives (Walker, 2000).

Optimization was replaced by 'satisficing'. Simon (1969) defined 'satisficing' to mean finding an acceptable or satisfactory solution to a problem instead of an optimal solution. In a multi-actor or multi-objective context, there are hardly any optimal solutions. 'Optimal' is dependent on the perspective in which one views a problem. When multiple stakeholders are involved, the optimal solution for the one could be very harmful for the other. A satisfactory solution therefore requires a trade-off between the differing preferences of the stakeholders. The essence of a satisfactory solution is that it is at least *acceptable* for those involved.

Public policy analysis is a rational, systematic approach to making policy choices in the public sector. Its purpose is to assist policymakers in choosing a course of action among complex alternatives under uncertain conditions (Walker, 2000). Policy analysis is to be considered as a 'tool' and is not meant to replace the judgment of policymakers. "It is a way of solving a specific problem, but is a general approach to problem solving. It is not a specific methodology, but it makes use of a variety of methodologies (including multi-criteria analysis) in the context of a general framework. Most important, it is a process, each step of which is critical to the success of a study and must be linked to the policymakers, to other stakeholders and to the policymaking process" (Walker, 2000).

Figure 2 gives an overview of the elements of the policy analysis framework of Walker (2000) translated to the context of a RIM. The framework should be interpreted as a process diagram (instead of a system diagram) reflecting an iterative process where the elements are constantly influencing one another.

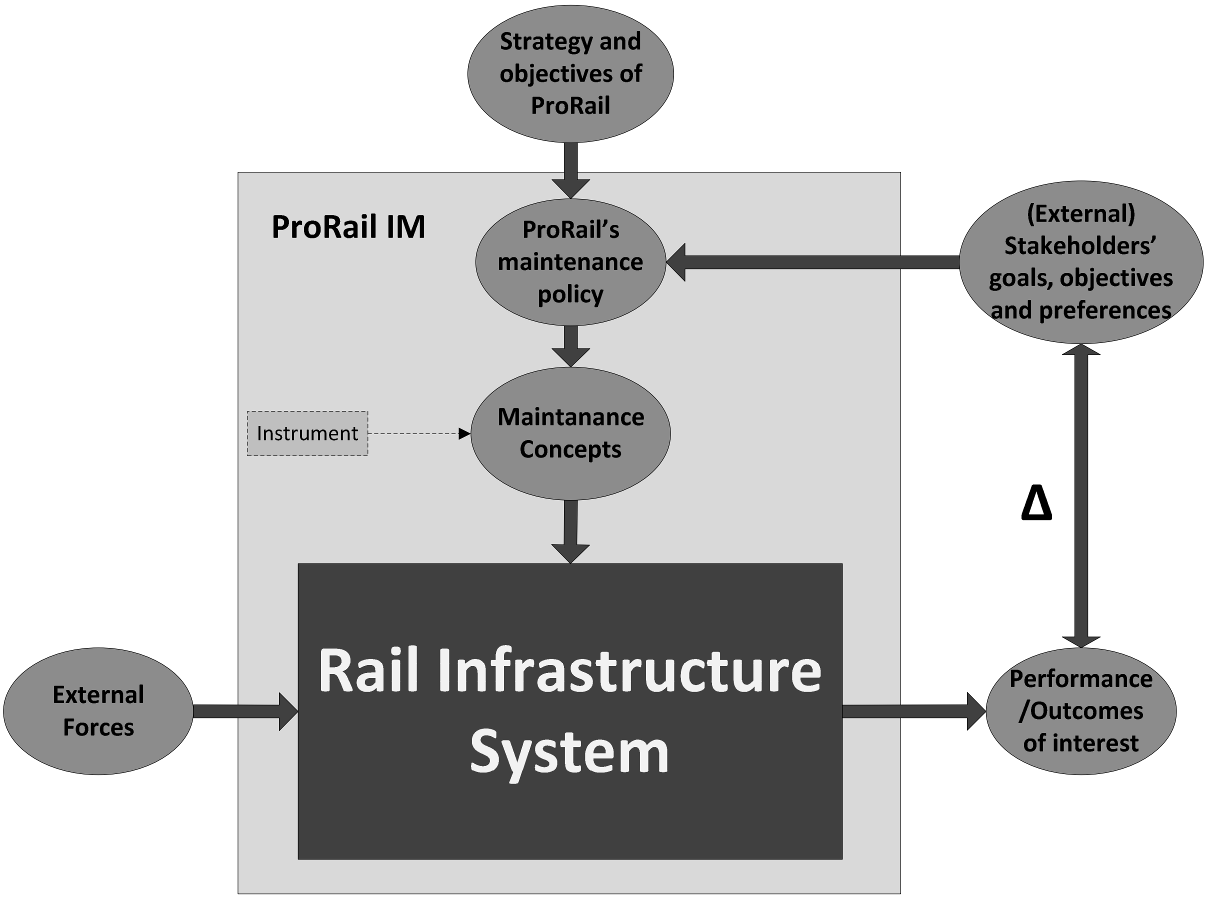


**Figure 2: Process diagram of the elements of the policy analysis framework translated to the context of a RIM (adopted from Fischer et al., 2008)**

Figure 2 confirms the importance of involving the stakeholders, as specified in PAS 55. The outcomes of the Rail Infrastructure System (RIS), which are related to the policy goals and objectives, are called *outcomes of interest.* The collection of outcomes of interests is called *performance* of the RIS. An actor who can be affected by the performance is called a *stakeholder*. Examples are national and regional governments, TOCs, and municipalities. Their *goals, objectives, and preferences* are reflected in the *value system,* indicating the desirability of a certain performance level of the RIS. *External forces* are developments outside the system that can affect the structure of the system significantly, and therefore its performance; unfortunately, they are not controllable by the policymakers. Maintenance concepts are conceived as one of the outcomes of the policymaking process of Rail Infrastructure Managers (RIMs). The main goal of the maintenance policymaker of RIMs is to develop a maintenance policy, consisting of maintenance concepts, which allows the RIS to perform to the satisfaction of stakeholders. Consequently, they pursue a minimum difference between the preferred performance and the actual performance (Fischer et al., 2008).
This is supported by Walker (2000) as "policy choices, therefore, depend not only on measuring the outcomes of interest relative to the policy goals and objectives, but identifying the *preferences* of the various stakeholders and identifying trade-offs among the outcomes of interest given these various sets of preferences."
ProRail determines the effects of maintenance concepts as a measure of consequences on their company objectives (ProRail, 2005) and according to Figure 2; these objectives should take stakeholders into account. At the moment it is not clear whether the objectives or selection criteria,

which are used in the realization of ProRail's maintenance policy, correspond with the objectives and interests of the stakeholders. Fischer et al. (2008) have identified that Rail Infrastructure Managers (RIMs) managers "experience difficulties in effectuating a commonly accepted performance of the rail infrastructure that satisfies the needs of several external stakeholders." One of the explanations for these difficulties is: "competition on track between Train Operating Companies means that more stakeholders have divergent objectives and preferences regarding the performance of the rail infrastructure, therefore, the RIMs struggle with the question: How can all these different stakeholders be satisfied?"

Thomas and Palfrey (1996) have stated that: "different stakeholders in the evaluation enterprise are likely to adopt criteria that differ from (or attract different weightings from) those that other stakeholders might choose to apply." Furthermore, the authors have reviewed the repertoire of evaluation criteria and have suggested that the intended (main) beneficiaries of public sector services (the "clients") have potentially an important role to play in evaluation.

## 1.4 Infrastructure performance: how to safeguard public values?

"Infrastructures are very complex technical, economic and political systems that provide essential services to society" (Finger et al., 2005). According to the authors, technical performance of single elements and individual economic behaviour are not arbitrary but need to be synchronized in order to safeguard the proper functioning of the network and therefore deliver the desired performance. Finger et al. (2005) have distinguished three categories of infrastructure performance, which all need to be safeguarded in order to safeguard the overall infrastructure performance. The categories focus on the safeguarding of *economic performance, technical integrity,* and *public values*. The latter, public values, is most important due to the study's research focus.

Based on explanations in literature we can regard the rail infrastructure as a public value, as the infrastructure provides a *collective* value for many stakeholders, instead of benefitting merely *private* interests. And safeguarding these public values can be realized by managing the infrastructure correctly.

Another important observation is that the protection of public values always requires a trade-off between their own values and the values of efficiency. The fact that public values compete and always require a trade-off (on some occasions between different public values, but on other occasions even within one and the same public value) implies that the judgement about this trade-off tends to be subjective. Different parties (for example, governments, private companies, citizens, network managers, service providers) may choose different trade-offs (De Bruijn and Dicke, 2006).

Literature has indicated that in order to safeguard public values, one needs to be able to manage the trade-offs that can differ amongst different parties. And since ProRail wishes to increase stakeholder value, it is imperative that ProRail is able to manage the different trade-off decisions concerning elements that determine the (public) value of their stakeholders. Obviously to do so, ProRail needs to obtain information on the trade-off <u>behaviour</u> of their stakeholders. Only then can ProRail begin to think on how to manage these trade-offs. Next to information on trade-off behaviour, information is required on <u>which</u> elements need to be included in the trade-off process. Although many of these elements (related to infrastructure performance) can be found in literature and policy documents, literature also shows the extent of (possible) differences in stakeholder preferences. This introduces a possibility that these elements from literature and policy documents provide an incorrect picture

on the most important elements determining the public value[17]. And according to literature on Principled Negotiation[18] (PN) (Fischer and Ury, 1983); having perfect knowledge on the stakeholders' sets of criteria would be desirable as a jointly acceptable solution is realized in a faster and more direct manner (Adler and Blue, 2005). It would therefore be preferable to acquire information, for each of ProRail's external stakeholders, on their preferred set of performance criteria.
According to Bruijn and Dicke (2006) "Public values are inherently relative. It is difficult, if not impossible, to define them unambiguously: trade-offs are required between public values and efficiency and between public values mutually and these trade-offs can change with time." According to the authors the inherently relative nature of public values has instrumental consequences. In order to cope with the relative nature of public values, some sort of institutional safeguarding mechanism is required. De Bruijn and Dicke distinguish three different types of safeguarding mechanisms:

- Hierarchy: imposing public values, for example by regulation
- Network: interacting about public values
- Market: competing on public values

The authors have made "smart combinations of safeguarding mechanisms" in order to 'blend in' hierarchy. In a similar situation that ProRail is currently in[19] they have discovered that a combination of the mechanisms *network* and *hierarchy* is very suitable for realizing a solution that is satisfactory for all involved stakeholders. The essence of this *hybrid* construction is that both hierarchical and network-like mechanisms are used to protect public interests. Regarding the network-like mechanism, negotiations between all stakeholders proved to be beneficial; corresponding with the Ministry of Transport's desire to let the rail sector come up with appropriate performance criteria. But with respect to the hierarchical safeguarding mechanism, hierarchical interventions proved to be *crucial* to the success of these negotiations in three ways (De Bruijn and Dicke, 2006):

- Intervention by the Ministry was used as an incentive to start these negotiations: a sense of urgency was created.
- The shadow of hierarchy boosted the progress of the negotiations. Although the Ministry was not involved in these negotiations, it was present at the background; being able to threaten with hierarchical intervention.
- Hierarchy was combined with room to manoeuvre or 'negotiating space'; which implied the prospect of gain for the involved stakeholders.

In combination with network-like mechanisms, hierarchy serves to incentivize and facilitate negotiations on public values rather than to determine what public values are and how they should be safeguarded (De Bruijn and Dicke, 2006). The current mechanism for safeguarding the collective value of the infrastructure's performance appears to be largely network-like, as the Ministry of Transport wants the development of performance evaluation to be dealt with by the rail sector herself (ProRail, 2008g), and not that hierarchical; which introduces the risk of a lacking sense of urgency for stakeholders to participate. Should we encounter a lacking sense of urgency through

17 Where 'public' relates to ProRail's external stakeholders.
18 Where the objective of PN is for the parties involved to reconcile their interests to obtain a jointly satisfactory solution.
19 That particular case involved the Dutch rail, the Ministry of Transport and consumer organizations on a conflict on the measurement of several 'quality of service' criteria.

deficient cooperation by stakeholders, the cause could be that the degree of hierarchy is rather limited.

## 1.5 Summarizing the problem

ProRail uses 'maintenance concepts' in managing their maintenance activities. A maintenance concept consists of an ordered set of maintenance rules to a technical system, by prescribing *what* maintenance operation should be executed, and *when*. Maintenance rules can consist of: failure-, use- and condition-based maintenance (Gits, 1984, 1992). The effects of a maintenance concept applied to a (rail) track section can be calculated by: first, specifying FMECAs and second, use a Monte Carlo simulation to predict the performance of that track section. Decisions regarding maintenance concepts have an effect on many involved stakeholders that are interested in the performance of the RIS.

This study focuses on the effects of maintenance policy on ProRail's external environment; first of all on those stakeholders that use the rail infrastructure, the train operating companies (TOCs). Second of all, the study takes into account the public authorities which are authorized to grant concessions to the TOCs: the Ministry of Transport and regional public authorities. European and national rules and regulations are considered a boundary condition. Future growth in passenger and freight transport, accompanied by increasing competition of TOCs means an increased burden on the rail infrastructure in the future and all the more reason to 'optimize' the maintenance concepts for those involved.

As different groups perceive and value different consequences differently (Walker, 2000); the effects of different maintenance concepts will be differently valued by ProRail's stakeholders. The policy analysis framework of Walker (2000), translated to the context of RIMs by Fischer et al. (2008) shows that the (main) goal of the maintenance policymaker of RIMs is to develop maintenance concepts, which allow RIS to perform to the satisfaction of stakeholders. This corresponds with the desired characteristics of a good asset manager explained in the first chapter, as it is essential that the asset management strategy has taken into account the views of all stakeholders, otherwise the organization might end up performing unnecessary or inappropriate tasks or failing to meet key business objectives (IAM, 2004b).

Safeguarding public values in infrastructure sectors is difficult and complex but is at the same time an important aspect of safeguarding the overall infrastructure performance (Finger et al., 2005). In order to safeguard public values, one needs to be able to manage the trade-offs that can differ amongst different parties. And since ProRail wishes to increase stakeholder value, it is imperative that ProRail is able to manage the different trade-off decisions concerning elements that determine the (public) value of their stakeholders. To be able to do so, ProRail needs to obtain information on the trade-off behaviour of their stakeholders. Only then can ProRail begin to think on how to manage these trade-offs.

Three main aspects are still lacking, which restricts ProRail in being able to manage the different trade-off behaviour of their external stakeholders. Firstly, the trade-off behaviour of ProRail's external stakeholders lacking. Secondly, information on which performance elements need to be included in that trade-off process is not complete. And thirdly, information is lacking on the impact of different RIS performances on stakeholders' satisfactions.

A stakeholder's perspective should help ProRail in understanding exactly which infrastructure related performance criteria are of interest to the stakeholders. To determine how different maintenance concepts influence the RIS performance and with that, influence the satisfaction of the relevant stakeholders, information is required on:

- The outcomes or criteria of interest for the relevant stakeholders, with respect to the performance of the RIS: the elements that determine the public value.
- The relative importance of these criteria.
- The effects of maintenance concepts on the RIS performance.
- Stakeholders' valuations (satisfaction) of different RIS performances.

## 1.6 Research objective

This study aims at understanding the preferences of ProRail's stakeholders with respect to ProRail's maintenance policy and how different maintenance strategies will affect these preferences, in order to be able to develop maintenance policy based on stakeholders' preferences. As a result, there is a need for information on which rail infrastructure related performance indicators are relevant to ProRail's stakeholders and how these performances determine their satisfaction.

The following research objective will have a central position in this study and will be further specified in the next section.

"Advising ProRail on the evaluation of rail infrastructure performance from a multi actor perspective in order to develop maintenance policy that is based on the preferences of all relevant external stakeholders."

## 1.7 Specifying the research focus

The essence of this study can best be explained by the sub questions, which can best be summarized by the following main research question.

"Which maintenance concepts are preferred from the perspective of ProRail's external stakeholders?"

The main research question can be divided into three more specific sub questions:

***Sub research questions***

1. "What are, from a perspective of ProRail's external stakeholders, the most relevant performance indicators that should be considered in evaluating different maintenance concepts?"

2. "How relatively important are the most relevant performance indicators (question 1) to each of the relevant external stakeholders?"

3. "How will the effects of different maintenance concepts affect the satisfaction of all relevant external stakeholders?"

The objective of this research consists of many different aspects. Information is required on actor perspectives, trade-off behaviour and impact of maintenance on actor satisfactions. Due to the complexity and diversity of the research focus an approach is required that crosses disciplines. We believe that the research questions can only be answered through using a multidisciplinary approach, combining the scientific fields of actor analysis, policy analysis and quantitative preference analysis.The following chapter, and the complementary appendices B-E, are concerned with the selection process and description of the actual research methods.

Figure 3 gives an overview of the different chapters, with their contents and their relations. Chapter 2 deals with the research methodologies. Chapter 3 will present the results of the actor analysis where the most relevant performance indicators will provide a basis for the conjoint analysis of which the results are presented in chapter 4. Chapter 5 will deal wilt the practical application of the preference models. The conclusions and recommendations will be given in chapter 6, followed by some reflective remarks in chapter 7.

# OVERVIEW OF RESEARCH REPORT

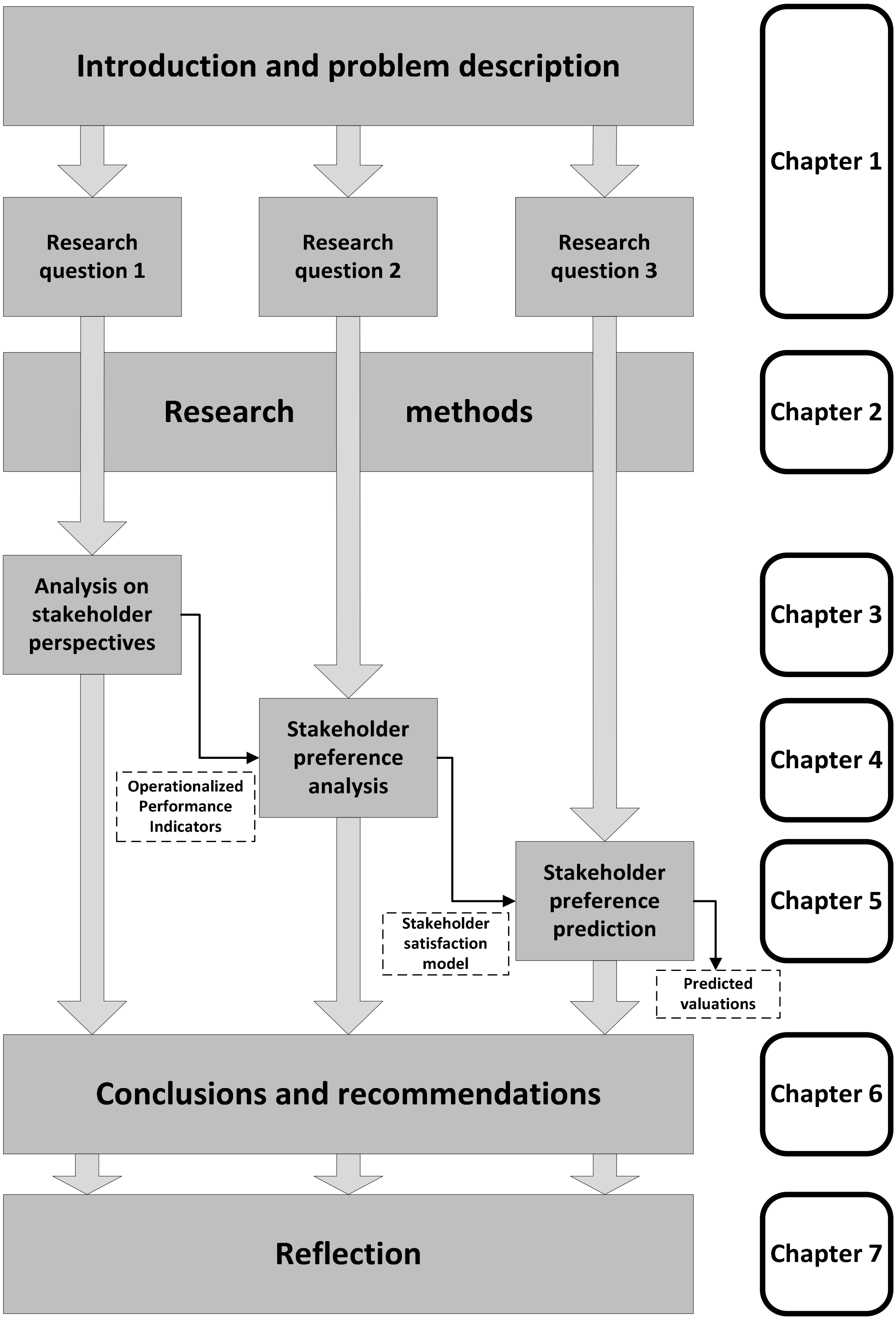


Figure 3: Schematic overview of study report

# 2 RESEARCH METHODOLOGIES

*"How to answer the research questions?"*

## 2.1 Introduction

The second chapter is concerned with the research methodologies that are used in this study. Section 2.2 will elaborate on the analysis on stakeholder perspectives, where it is explained how DANA is used, how the interviews are taken, along with the limitations of the DANA method and how it is dealt with. Section 2.3 deals with conjoint analysis and describes how a rating based stated preference analysis is used, including the steps that need to be taken in a conjoint analysis such as deciding on the attributes and determining their range. This section will also describe how the data is collected and what limitations of conjoint analysis should be understood. And lastly, section 2.4 will give a summary of the main conclusions.

## 2.2 How to analyse actor perspectives?

Appendix B and C are concerned with the trade-off and selection process of several actor analysis methods, where it has been decided that a qualitative DANA method is most suitable in this study, mainly because DANA is able to grasp an actor's point of view into a causal map that contains factors which are useful as input for the conjoint analysis. This section will give a description of the DANA methodology, which organizations are included, how DANA is used and its implications and limitations.

### 2.2.1 Dynamic Actor Network Analysis

#### *Cognitive Mapping*

Cognitive mapping methods are models with a focus on the perceptions of individual actors (or a group of actors with similar perspectives, such as one organization) that are based on the idea that the behaviour of actors is driven by their perception of the situation they find themselves in. Analysts may consider these perceptions to be incomplete or incorrect, but in policy problems, these perceptions are the reality with which analysts have to deal with (Bots et al., 2000). Cognitive mapping methods are an attempt to capture the perceptions of actors in causal relation diagrams, where the most important factors and their relations are modelled (Hermans, 2005). Hermans et al. (2008) have divided the cognitive mapping methods into "comparing causal maps"-methods and the Dynamic Actor Network Analysis-method (DANA). According to Hermans (2005) a method like DANA might be more useful when diverging actor perceptions make it hard to merge these perceptions into one strategic map. With regard to this study: it is not the intention to merge all different perspectives into one map in order to arrive at an *agreement* between these perceptions. Actually, we are interested in *all* their objectives and preferences, including the conflicting ones. However, in the end we *are* interested in combining different stakeholder perspectives to be able to identify the most important aspects relating to the rail infrastructure performance.

### *Dynamic Actor Network Analysis*

DANA is an approach that has been developed at TU Delft (Bots et al., 2000). The perceptions of actors are modelled in causal relations diagrams that show the factors and instruments that actors find to be of relevance, together with the causal relations they assume between those elements. These diagrams can be constructed with supporting DANA software, which is linked to a database that supports further analysis (Bots et al., 2000b; Hermans, 2004).

One of the benefits of using DANA is that it yields insights into the actors' perceptions on the importance of specific problems, the underlying factors causing these problems, instruments to address problems and actors that control these instruments. Based on this, one can also obtain an indication of the level of agreement or conflict between actors, relations of dependency and sensitive issues (Bots et al., 2000). "This information can be used in organizing actor involvement in policy development and in designing and evaluating alternative policy measures. An additional benefit is that the constructed diagrams provide a visual representation of actor perceptions that may serve as an organizational memory and as a basis for discussion amongst analysts and decision makers" (Hermans, 2004). For ProRail this means that the causal diagrams can provide as justification to public authorities and the TOCs on their maintenance policy focus. According to Bots et al. (2000), the process of modelling and analysis is also a means to better understanding a situation.

DANA focuses specifically on the actors' perceptions, objectives, instruments, causality and the main factors; which corresponds with what we are interested in when trying to answer the first research question. DANA can do more than is necessary than is required for this study, but depending on how DANA is used, does not require too much effort.

DANA is originally developed in a university project EPSILON as a method for creating a "quick scan" of the relevant stakeholders (Bots et al., 2000b). In a quick scan process, "because of the stakeholder involvement in the generation of alternatives and screening criteria, a social basis for the problem and proposed solutions can be expected" (Enserink, 2000). Reflecting on this study; quick scans can provide a social basis for the decisions made by ProRail concerning their maintenance policy.

As mentioned before, the DANA method is supported with a software package that is able to model causal relations diagrams of factors and instruments that the stakeholders consider to be important. However, DANA is more than just a software package as it also includes the process of creating the causal maps of the stakeholders. Once the factors, instruments and their causal relations are specified for each stakeholder, DANA software can be used for further analysis.

The focus of the DANA analysis within this study will, first of all, be on acquiring stakeholder information in order to create these system perspectives. The next step, the quantitative analysis in the software program, can provide interesting data. However, the primary objective of the DANA analysis is to extract the right factors and relations.

DANA will be used to acquire information on: the factors, objectives, instruments and their causal relations that are of significance with respect to maintenance in the RIS. This information should provide insights into similarities and differences between stakeholders concerning perceived causal relations, goals, prospects, interests and satisfaction.

### 2.2.2 Stakeholder involvement

The diversity of ProRail's stakeholders can be explained in two ways. Firstly ProRail has to deal with their external environment, which is explained in 1.2.2 But secondly, ProRail's internal departments can also be regarded as stakeholders since each department is responsible for a different area of expertise and will therefore have different objectives and preferences.

To be able to decide on which stakeholders to include in the study, we need to look at the reason why stakeholders should be involved in this policy making process. With respect to maintenance on the RIS, there is a trade-off between the need for *using* the RIS on the one hand and the need for *maintenance* on the other. Somehow a balance between the two should be found.

This study aims to finding the balance between these preferences: when is maintenance preferred, and when should the RIS be available? This type of preference information can be acquired by focusing on both external users as well as internal stakeholders.

The users of the RIS are external stakeholders consisting of TOCs and their clients (passengers and 'cargo shipping agents'). ProRail's internal stakeholders, each of the six main departments, are responsible for aspects that are of interest to ProRail's external environment. The need for maintenance versus the need for infrastructure availability is somehow translated to objectives and KPI's for each department. However, these objectives will always be an indirect representation of the users of the RIS and therefore, this study will first mainly focus on ProRail's <u>external</u> stakeholders.

There are many external stakeholders somehow involved or affected by ProRail's maintenance activities. Looking back at Figure 1: suppliers, clients, governments, and law and regulation related organizations; all are connected to the maintenance policy of ProRail.

The inclusion of the type of external stakeholder needs to be decided. In order to be able to decide on what type of stakeholder to consider, we need to look at the question: "which effects of ProRail's maintenance policy are relevant?" Are we interested in satisfying the need of the contractors, where ProRail acts as a principal? Or are we interested in ProRail's clients or customers, where ProRail acts as a service-oriented organization?

Defining the stakeholder focus can be explained and founded by introducing a layered model of the traffic- and transport-system, translated to the context of a RIS in Figure 4 (Van de Riet and Egeter, 1998):

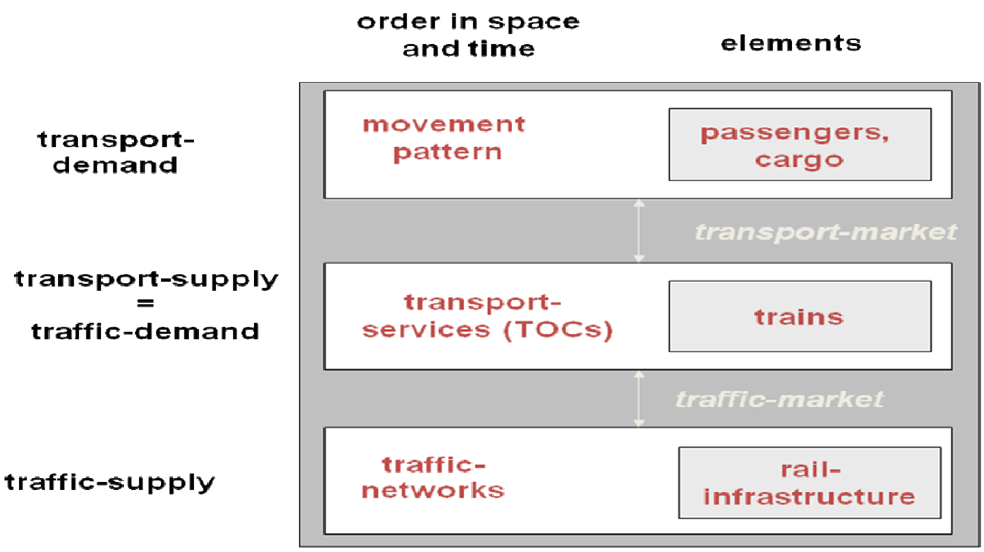


Figure 4: The structure of the traffic and transportation system

As a RIM, ProRail operates within the *traffic-market*. The actual technical 'tuning' between the *traffic-infrastructure (rail infrastructure)* and the *transport-modes (trains)*, occurs on the level of the physical infrastructure (Schoemaker, 2002). The transport services on the rail network are strongly connected to and highly influenced by ProRail's policy concerning the rail infrastructure. Therefore, the **train operating companies (TOCs)** will be taken into account in this study. ProRail's contractors will not be considered.

The end users, passengers and cargo (shipping agents), existing at the end of the supply chain, have an indirect relation with the actual RIS. We will not directly include these end users in this study and should therefore assume that the TOCs are able to properly represent the desires and preferences of their clients. Unfortunately this introduces a risk as there is a (real) possibility of the preferences of the TOCs being different from their clients' preferences. But it is not realistic for ProRail, and all the more in this study, to analyze every type of stakeholder thoroughly. The problem of the passenger TOCs not being able to reflect the preferences of their clients is dealt with by including the passengers in a limited manner in the study; by means of including a **passenger representative association**. Clients of cargo TOCs will not be incorporated in this study for mainly two reasons: (1) time limitations, and (2) lacking key performance indicators for satisfaction of cargo TOCs' clients, in contrary to KPIs for passenger satisfaction (Appendix O).

TOCs have to operate under a concession granted by public authorities on a national level (Ministry of Transport, DG Mobility) or on a regional level (Province, Urban region or local authority[20]) depending on the geographical radius of the rail infrastructure (Wp2000). These public authorities enforce conditions in the concessions that TOCs need to comply with. Because a TOC's ability to comply with these conditions depends much on the performance of the rail infrastructure, the **Ministry of Transport's** and the **Regional public authorities'** interests in the RIS are also considered in this study. There are two main bodies within the Ministry of Transport, concerned with supervising ProRail's ability to meet the conditions in the Railway Act and the concession for maintaining the main rail infrastructure: the **Dutch Safety Inspectorate (IVW)** and the **Directorate General of Mobility (DGMo)**. These supervising authorities will both be included in this study.

Although general information on the governmental interests are documented (VenW, 2004, 2005; and Appendix H), specific information regarding their problem perception is of interest.

### *Excluded stakeholders*

The NMa will deliberately not be involved in this study due to the fact that the NMa, in contrast to the IVW and DGMo, has little responsibility concerning the performance of the physical rail infrastructure as its interests are more on economical and competition aspects.

Furthermore, the clients of freight TOCs and their shipping agents are excluded from this study. The benefit of including these stakeholders does not outweigh the extra efforts[21].

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20 In Dutch: Provincie (Gedeputeerde Staten), Stadsgewest en gemeente. The regional public authority responsible for the regional transport concession is not necessarily one actor. Depending on the geographical area of the regional rail infrastructure, and which boundaries it crosses, the responsible authorities for granting the concession and its conditions can be determined.

21 There is no representative organization is is the case with the clients of passenger TOCs, meaning that individual organizations of clients of cargo TOCs should then be included. This would require a lot of time. Furthermore, ProRail has not indicated a desire to incorporate the perceptions of these stakeholders. "When does the line of responsibility

Lastly, the actual end users, the passengers, are not directly taken into account in this study. However, to be able to investigate ProRail's influence on train passengers, it is assumed that a representative organization is sufficiently able to reflect passengers' preferences with respect to the performance of the RIS.

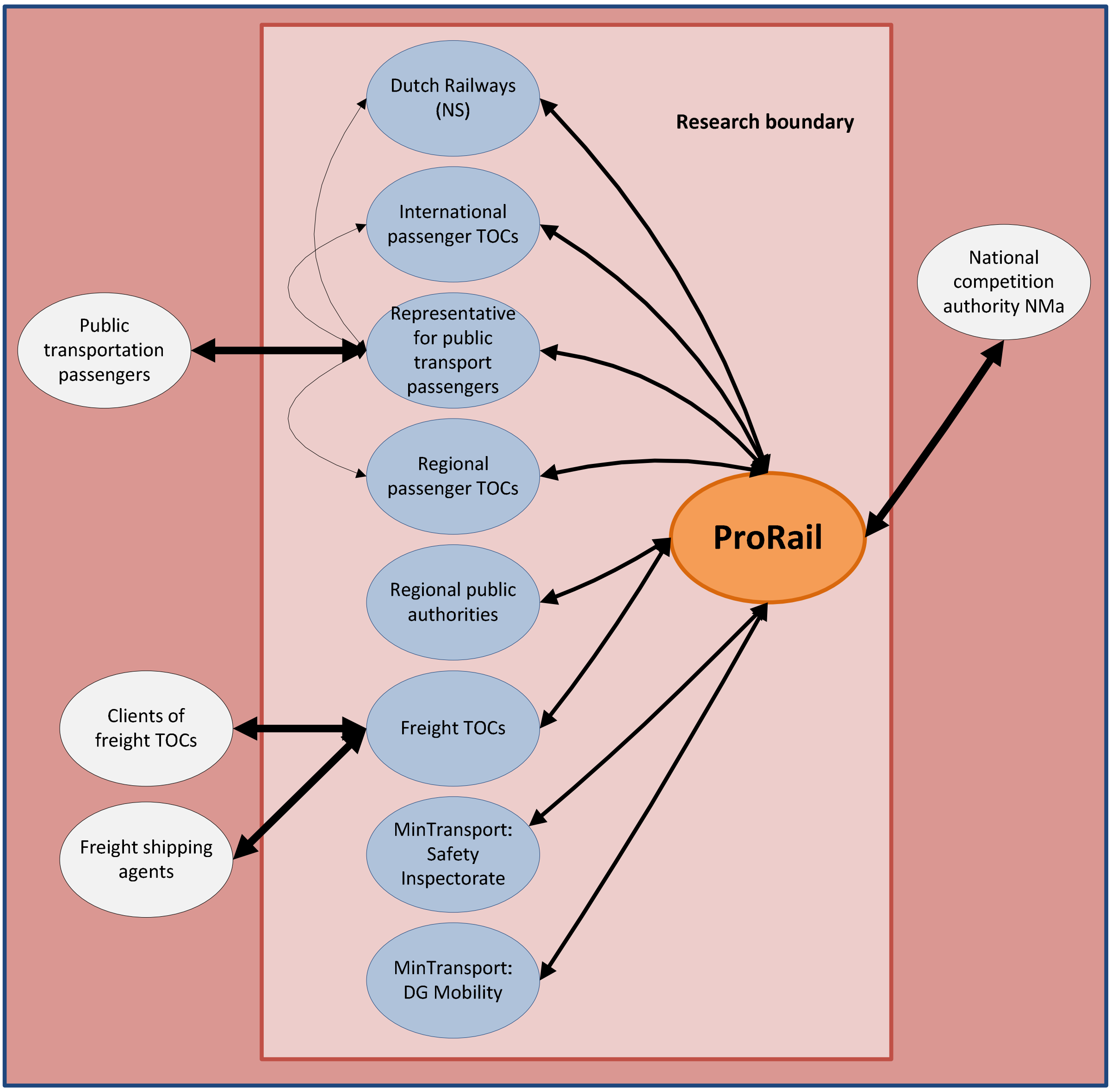


**Figure 5: Overview of ProRail's in- and excluded external stakeholders**

Figure 5 visualizes which main stakeholders are included (ellipses inside the boundary circle) and which are excluded (dark ellipses outside the circle). There are 37[22] TOCs and approximately a dozen regional concession granting authorities. Including all these actors would not be preferable due to time constraints in this study, nor will it be necessary as it is not expected that there are large

end?" (T. Luiten on May 26 of 2009). The benefits of having such information are therefore not expected to be very beneficial.

22 According to an internal news message on the ProRail intranet site on 16 December 2008, by ProRail's division of Capacity Management. In 2008, 37 TOCs were operating on the rail infrastructure. For 2009, the number of TOCs will be 36 due to 'Rail4Chem Benelux BV' taking over 'Rail4Chem GmbH'.

differences between the organizations within the same stakeholder group. Next to DGMo and IVW, the following are selected to be included in this study.

### *Passenger TOCs*

The selection of passenger TOCs is based on maximizing diversity of preferences of all passenger TOCs, in order to acquire a broad perspective on these differences. The diversity of passenger TOCs is created by including three different groups TOCs, which differ from one another on their geographical area of operation: national, regional and international. We included:

- The Dutch Railways (NS Reizigers), the single passenger TOC that is operating on the national rail network.
- Regional TOCs, especially Syntus[23], a regional TOC, providing train service in Gelderland.
- The Highspeed Alliance, also known as NSHispeed, which is a collection of Thalys, ICE, Eurostar, TGV, IC Berlin, Intercity Brussel and City Nightline, originated from alliances between Nederlandse Spoorwegen (NS), Nationale Maatschappij der Belgische Spoorwegen (NMBS), Société Nationale des Chemins de Fer Français (SNCF) and DB Bahn (DB) (NSHispeed, 2009)

### *Freight TOCs*

Although there many freight TOCs active on the Dutch rail infrastructure, the four largest TOCs are responsible for approximately 98% of the gross ton-kilometres (ProRail, 2007c). The four freight TOCs responsible for most of the freight transport are:

- ACTS
- DB Schenker: formerly known as Railion
- ERS Railways
- Veolia Cargo (including Rail4Chem, since February 2008)

### *Regional governments*

The regional governments are responsible for granting concessions for the regional TOCs. The regional governments are concerned with creating specific conditions, including the performance indicators (PIs) that the regional TOCs need to comply with. Because Syntus is included in this study, we have selected the accompanying regional public authority, which is the Province of Gelderland.

### *Representative organization for public transport passengers*

There are several associations representing the preferences of public transport passengers, such as ROVER and other members of the LOCOV and ROCOV[24].

ROVER is an eminent and consumer interest association within (exclusively) the public transport sector and is therefore included in this study. Practically, ROVER is the link between the passengers on the one hand and the TOCs on the other.

23 Acquiring preference information on regional TOCs was done by interviewing an expert in this area; however, during the next stage of analysis, Syntus is included because the company is actively involved in subjects relating to this study. More detail will be provided in chapters 3 and 4.

24 In Dutch: Landelijk en Regionaal Overleg Consumentenbelangen Openbaar Vervoer. National and regional consultation establishment, consisting of e.g. the "Consumentenbond", the ANWB, the council for the chronically ill and disabled, elderly organizations and the student union (LOCOV (2009), www.locov.nl, →informatie→deelnemers).

### 2.2.3 Data collection: interviews and selection of respondents

The input data for the analysis have been obtained through interviews with selected actors of ProRail's (external) environment, allowing them to express their view of the performance of the RIS. Next to interviews, there are other options able to extract preference information from the stakeholders. Workshop or GDR[25]-sessions, where more people are simultaneously involved, could also been used. An advantage of involving more people simultaneously over individual interviews is that flawed or incomplete information is more likely to be corrected. However, involving several people in a single session would be more difficult to realise with respect to time planning issues. Due to limited time availability for this study (and interviewees), individual interviews are considered to be more suitable for this particular study. Moreover, qualitative interviews and judgements have proven to be suitable for developing criteria on public values that are satisfactory for all stakeholder organizations (De Bruijn and Dicke, 2006, pp. 728).

To minimize flawed or incomplete information, the final interview reports and the corresponding DANA diagrams have been sent back to the interviewees, who were asked to review the report and supplement it or make adjustments where they find it to be necessary.

The interviews are prepared along the lines of a 'probing interview'. The purpose of a probing interview is "to get relevant and timely information as accurately and completely as possible in the shortest amount of time" (Stewart and Cash, 2008). There is no typical way of conducting a probing interview as "they are as varied as the conversations we have and the people we talk to" (Eric Nalder, 1994). The most important preparations consist of determining the purpose of the interview, researching the topic and structuring the interview (Stewart and Cash, 2008). See 3.3.1 for elaboration on these aspects.

Next to these interviews, we will also analyse several relevant policy documents as they should contain criteria of initial importance concerning rail infrastructure performance (see section 3.2).

### 2.2.4 Limitations of the used approach

This subsection will deal with certain limitations of the chosen actor analysis method, partly extracted from Hermans[26] (2005).

#### *Representation of actors by interview respondents*

The approach used for the actor analysis is believed to yield results that provide answers to the first research question, but in interpreting these results, one has to be aware of certain limitations. Firstly, the primary source for the actor analysis is the information collected through interviews, which of course only reflects the opinions of the interviewed actor representatives. Other persons within an organization could have other opinions and other views. To deal with this limitation, mainly representatives with management responsibilities have been interviewed, as it was assumed that these should be able to express an opinion that would be representative for their organization as the probability for knowledge deficiency is relatively low and it is more likely that an individual who is higher-up in the chain of command has preference knowledge crossing departments.

25 Group Decision Room

26 The information is extracted from a draft report from 13 September 2002: "Actor Analysis for the Büyük Menderes River Basin Management Plan: Report for the Implementation of the Water Framework Directive in Turkey", which is the basis for chapter 8 of the reference mentioned in the main text.

### *Issues left unsaid*

Another limitation that should be mentioned here is related to what has *not* been said during the interviews. The analysis is based on different diagrams that each should reflect the views of one single actor. This means that the analyst cannot make assumptions on what respondents probably will have meant, but that only the information that has been discussed can be used in these diagrams. Some issues have not been addressed by certain respondents, which does not necessarily has to mean that they do not find these issues important. There can be different reasons why a respondent did not mentioned certain issues: he/she can find it unnecessary to raise issues as he/she considers them to be obvious, he/she can just have forgotten to mention them, or he/she did not want to discuss certain issues for strategic reasons.

### *Changing perceptions over time*

The analysis is based on the views of actors, which of course will change over time. This means that the analysis can only serve as snapshot of a certain moment; it does not necessarily reflect the situation over a longer period of time.

### *Validation of analysis results*

As said, the interview results have been transformed into diagrams that formed the main basis for the actor analysis. In order to increase the validity of the analysis results, these diagrams and the transcripts have been handed back to the respondents and were checked. Furthermore, the interview results will also be validated by comparing them with the analysis of existing policy documents.

## 2.3 How to analyse actor preferences?

Appendix D and E are concerned with the trade-off and selection process of several preference elicitation methods, where it has been decided that a stated preference analysis is most suitable in this study; mainly because a conjoint analysis is able to quantify the relative importance of several (performance related) characteristics in a reliable[27] manner. Furthermore, conjoint analysis is suitable to incorporate the most relevant performance indicators from DANA into the attributes in the conjoint profiles. This section will give a description of stated preference analysis, how the data is collected and several assumptions and limitations.

### 2.3.1 Stated Preference Analysis

Conjoint analysis is a multivariate data collection technique used specifically to understand how respondents develop preferences for products or services. It is based on the simple premise that consumers evaluate the value of a product/service/idea (real of hypothetical) by combining separate amounts of value provided by each attribute (Hair et al., 1998, pp.392). The flexibility of conjoint analysis gives rise to its application in almost any area in which decisions are studies (Hair et al., 1998, pp.398). Conjoint analysis is mostly used in marketing research, where the decision behaviour of customers is analyzed. Another application of this method is in transportation studies; see for example Ben-Akiva and Lerman (1985) and Molin (1999). The application of conjoint analysis for understanding preferences of stakeholders and organizations that can be used in a multi objective

27 Meaning not directly asking for a ranking of the importance of several characteristics, but doing so indirectly by letting the respondent make implicit trade-offs.

decision making process seems rather innovative. Applying conjoint analysis for these purposes will test its practical applicability of the attribute-related value information created during the analysis.
Conjoint analysis assumes that any set of objects (e.g., brands, companies, maintenance activities…) or concepts is evaluated as a bundle of attributes (Hair et al., 1998, pp.398). The criteria, developed by answering the first research question, are suitable to be used as attributes. The result of a conjoint analysis is concerned with the relative importance of these attributes. Conjoint analysis uses the comparison of multiple, if not all, attributes and their levels simultaneously in the decision making process, as a result of which the respondent really needs to focus on the trade-offs involved. Furthermore, the importance of a criterion is highly dependent on the value-range of that criterion.

### 2.3.2 Steps in a conjoint analysis experiment

Central to conjoint analysis is the use of experimental designs to examine the preference functions of decision makers. In these experiments, decision makers are asked to express their overall preferences for integral descriptions of hypothetical choice alternatives. These descriptions or "profiles" are combinations of the most relevant attributes (criteria), and are created according to the principles underlying the design of statistical experiments. The respondents' responses to these profiles are used to estimate preference or choice models (Molin, 1999). The following steps need to be followed in a conjoint analysis and will explain how this method is used in this study.

#### Step 1: Selection of attributes

The attributes that are used in the conjoint analysis will follow from answering the first research question and will reflect the most important criteria regarding ProRail's maintenance policy. Section 4.2 will deal with the actual attribute selection process.

#### Step 2: Determination of attribute levels and range

Decisions have to be made on the number of attribute levels and on the range of their values. The number of levels is dependent on the assumptions one is willing to make about the relationship between the attribute values and the derived utility. The number of levels is usually limited to 2-4. If one assumes that the part-worth utility linearly increases or decreases with increasing attribute values, only two attribute values are required. If one assumes that an optimum or minimum level exists, one needs to select at least three levels. Finally, four levels are required when one assumes that utility increases with increased attribute values, but is indifferent with respect to middle values (Molin, 1999). Depending on the selected attributes in step 1, the levels can be chosen.
The range of the attribute levels can best be chosen in a way that they span the range observed in current or planned choice alternatives. The determination process of the levels and range is presented in section 4.2.

#### Step 3: Selection of experimental design

When for instance 5 attributes and three levels are used, it is possible to create $3^9$ = 243 different profiles. This is called a "full factorial" design, where every main and interaction effects can be measured. It would be "unpractical" for one respondent to evaluate 243 different performance related situations. Another possibility is to use a "fractional factorial design", which only measures the main effects and assumes that the interaction effects among the attributes are not statistically significant. It should be possible for one[28] respondent to evaluate the *entire* set of profiles, because only then can a model be estimated.

As a fractional factorial design will require a lot less choice alternatives and is therefore considered to be appropriate for this study. The actual choice for a type of experimental design is made and described in section 4.3. It is important that (1) the main effects are estimated independently from the other main effects and (2) the results of the attribute levels are equal, and therefore an experimental design that is both 'orthogonal and balanced', is most desirable.

#### Step 4: Choice of measurement task

Three different measurement tasks can be distinguished: ranking, rating and choice tasks (Molin, 1999). The *ranking* based measurement task has become rare and has the disadvantage of lacking the availability of an error theory, which enables one to test various model specifications (Molin, 1999).

We need a measurement task that is able to estimate a model based on relatively little data, because each stakeholder organization will be represented by merely one or a few experts. A *rating* based measurement task is able to estimate a model based on one respondent's responses, which makes the rating-based stated preference method very suitable for segmentation purposes. The *choice* based task requires at least 30 respondents for estimating a model, which is simply not realistic in this study[29]. Therefore, the rating based task is used in this study.

#### Step 5: Choice of estimation procedure

A rating based conjoint model can and will be estimated by applying a multiple regression technique to estimate the preference functions of each stakeholder, as this method is suitable for the estimation of the part-worths for each level (Hair et al., 1998, p420).

#### Step 6: Simulation of choices

The prediction of the preferences for a combination of attribute levels varied in the experimental design will be done through answering the third research question. Realistic choice alternatives will be generated by using a model of the technical system that contains a deterioration model of physical elements and is able to translate maintenance concepts to the effects on the RIS and thereby a choice alternative. Subsequently, all stakeholders' preferences can be estimated based on the individual stated preference models. With that, the effects of ProRail's maintenance policy decisions on stakeholders' satisfactions can be estimated. Chapter 5 will further deal with the prediction of stakeholder preferences.

### 2.3.4 Assumptions and limitations of conjoint analysis

Conjoint analysis involves several assumptions and limitations. In reference with any other multivariate technique, conjoint analysis has the least restrictive set of assumptions. However,

28 It would also be possible to split-up the set of profiles, which would require more than one respondent per stakeholder organization to be able to estimate an individual stakeholder model. However, being able to estimate a model for every respondent has two advantages: (1) internal differences can become apparent more easily, and (2) less respondents are necessary for model estimation. The second advantage is decisive due to the time efficiency and the possibility for lacking respondents that are able or willing to evaluate the performance related situations.

29 The respondents need to be able to have knowledge and feeling on how different performance indicators affect their company objectives and preferences. It would be difficult if not impossible to find at least 30 respondents that posses such knowledge and experience.

conjoint analysis is very theory driven in its design, estimation and interpretation (Hair et al., 1998, p418).
In a rating based conjoint analysis, one has to assume that ratings data can satisfy interval (cardinal) measurement properties under experimental and task conditions. Despite of much argument on this assumption in the past, it now seems to be more acceptable to assume that ratings data do satisfy these properties (Louviere, 1988b).
In order to forecast choices from conjoint ratings data one must assume that either (a) highest predicted ratings equals first choice, or (b) predicted ratings values satisfy MNL or other choice model scale properties (Louviere, 1988 and 1988b).
Conjoint analysis is based on the assumption that consumers' purchasing behaviour follows the compensative value model. This means that the utility from product's benefits and costs can be simply summed together (as higher performance of one attribute compensates for low performance of another). This is also sometimes considered as a limitation to conjoint method, because the purchasing decision may also follow, for example, an exclusion or magnified compensative model. However, Green and Srinivasan (1990) have concluded that conjoint analysis' predictive validity is quite high even when the consumer actually follows different decision rules other than compensative.

Another shortcoming of conjoint method (especially the full concept approach) is the small number of product attributes that can be effectively analyzed. To overcome it, a bridging technique can be used (Dahan et al., 2002). To put it simply, bridging means creating several concept card sets, which analyze different attributes, but share a common "anchor attribute" in every set that makes the results and utility functions comparable. Oppewal and Vriens (2000) talk about a successful example where even 28 product attributes were included to conjoint analysis in four card sets.
According to Malhotra et al. (2000); conjoint analysis assumes that the important attributes of a product can be identified. It also assumes that consumers evaluate the choice alternatives in terms of these attributes and make trade-offs. The explorative interviews with the stakeholders should minimize the risks of these assumptions.
Limitations of conjoint analysis are that the trade-off model may not be a good representation of the choice process. Another limitation is that data collection may be complex, particularly if a large number of attributes are involved and the model must be estimated at the individual level (Malhotra et al., 2000).
In a rating based conjoint analysis one assumes that every stakeholder rates a profile in the same manner. However, one can never be sure if one specific rating has the same meaning of importance to all stakeholders.

Overall, many of these assumptions and limitations are technical in nature, but do demonstrate the need for caution in making consequential business recommendations from conjoint research.

## 2.4 Conclusion

For the answering of the first two research questions, we will use two different research methodologies. To answer the *first* research question: "what are, from a perspective of ProRail's external stakeholders, the most relevant performance indicators that should be considered in evaluating different maintenance concepts?", we shall interview several of ProRail's external stakeholders consisting of: passenger and cargo TOCs, national and regional public authorities and a passenger representative organization. The results of the interviews will be translated into cognitive causal mappings, DANA models, which will be used to extract the most relevant performance indicators which will be used in the conjoint analysis. Next to these interviews, we have also analyzed several relevant policy documents as they should contain criteria of initial importance concerning rail infrastructure performance.

To answer the *second* research question: “how relatively important are the most relevant performance indicators (question 1) to each of the relevant external stakeholders?”, we will apply a conjoint analysis. More specifically, a rating based stated preference analysis where the attribute levels are based on the performance indicators from answering the first research question.

The *third* research question, “how will the effects of different maintenance concepts affect the satisfaction of all relevant external stakeholders?”, will be answered by using the conjoint models for predicting stakeholders’ preferences on the effects of maintenance concepts or scenarios acquired by using the FMECA methodology and the Monte Carlo method (Fischer et al., 2008), simulating the failures of technical components based on their deterioration behaviour and applied maintenance activities. This study does not focus on the failure behaviour of technical components according to different maintenance scenarios, but on the main effects of these scenarios. Therefore, the FMECA methodology and Monte Carlo simulation is not explained in this chapter, but will be briefly elaborated on in chapter five.

# 3 ANALYZING STAKEHOLDER PERSPECTIVES

*“Which are relevant performance indicators?”*

## 3.1 Introduction

This chapter will provide the results of the actor analysis, where people from eleven stakeholder organizations are interviewed to acquire a comprehensive perspective on stakeholders’ preferences with respect to the performance of the rail infrastructure. In the section 3.2 several (policy) documents are analyzed, focusing on the presence and definition of the performance indicators. The third section will summarize the interviews and describes how each stakeholder perceives the rail infrastructure performance in relation to their company objectives. The fourth section will also deal with stakeholder perspectives, but more specifically focusing on how the performance of the physical rail infrastructure can affect stakeholders’ interests. Then, section 3.5 will deal with the validation of the results of the actor analysis. And lastly, section 3.6 will summarize the main conclusions.

## 3.2 Analysis of existing documents on performance indicators in the rail sector

The stakeholders that are considered in this study are passenger and freight TOCs, public authorities: Directorate General of Mobility (DGMo), the inspection authority (IVW) and the regional government and ROVER. Before these stakeholders are interviewed for extracting preference information it is useful to investigate existing policy documents as they should reflect aspects of initial importance. In this section several of these policy documents will be analyzed with respect to rail infrastructure related performance indicators, relevant for this study.

### 3.2.1 Analyzing the policy documents

The government has a public responsibility for ensuring proper functioning of the rail infrastructure itself as well as the transport taking place on that infrastructure. National laws concerning *maintaining* the rail infrastructure are laid down in the Railway Act, which describes the use of one or more concessions (Railway Act, 2003, article 16). Article 17 of the Railway Act states that this concession should contain regulations, such as: performance indicators to guarantee the quality of the rail network.

National laws concerning rail *transport* are laid down in the Act Passenger Transport 2000 (Wet personenvervoer 2000, Wp2000). Article 20 of the Wp2000 describes the use of concessions containing regulations that need to be met by passenger transportation companies. No concessions are required for freight transportation to encourage competition on the rail network.

To determine the aspects of importance for the Dutch government concerning the rail sector, two concessions are analyzed, searching for relevant performance indicators:

<u>Management concession main rail infrastructure</u>[30]: containing regulations according to the Railway Act. The regulations in this concession should reflect the aspects of importance and preferences of the Ministry of Transport concerning the management and maintenance of the rail network, for which ProRail is responsible (V&W, 2005).

30 In Dutch: Beheerconcessie hoofspoorweginfrastructuur

Transport-concession main rail network[31]: containing regulations according to the Wp2000. The regulations in this concession should reflect the aspects of importance and preferences of the Dutch government (Ministry of Transport and Regional public authorities[32]) concerning passenger transportation by train. It also should reflect aspects of importance for the NS; the TOC for the main rail network, as there is a risk of losing the concession rights when these regulations are not met (V&W, 2004).

Furthermore, in order to acquire a full perspective on existing rail infrastructure related performance indicators, we will, next to these two concessions, also analyze ProRail's Network Declaration (ProRail, 2009), ProRail's Maintenance Plan (ProRail, 2009g) and the Second Bill on railway safety[33](VenW, 2004b).

### *Management concession main rail infrastructure*

The analysis of the management concession is displayed in Table 5; showing the performance criteria ProRail should meet according to the Ministry of Transport (V&W, 2005).

**Table 5: Performance Indicators in maintenance concession**

| Main performance indicator | Definition or elaboration on performance indicator |
|---|---|
| Punctuality | Not defined |
| Availability and reliability | Planned unavailability (for maintenance activities) |
| | Unplanned unavailability (disruptions or system failure) |
| | Reliability rail track (for a disruption-free train path) |
| Transfer | Cleanness of stations |
| | Social safety of passengers and personnel |
| | Accessibility for people with functional limitations |
| Re-directing | Effectiveness of coping with disruptions |
| Dividing rail capacity | Customer judgment of capacity division |
| Safety and Environment | Noise hindrance |
| | System safety |
| Efficiency | Costs versus performance (measured and rated by international benchmarks) |

### *Transport-concession main rail network*

The analysis of the transport-concession is displayed in Table 6; showing the performance criteria the NS should meet according to the Ministry of Transport (V&W, 2004). Concessions for regional rail transport, granted by regional public authorities, are not expected to differ significantly from the regulations for the main rail network. The performance indicators in table 6 should therefore reflect the aspects of interest of both national and regional passenger transport companies.

31 In Dutch: Vervoerconcessie hoofdrailnet
32 In Dutch: Gedeputeerde Staten
33 In Dutch: Tweede Kadernota Railveiligheid

Table 6: Performance Indicators in transport-concession

| Main performance indicator | Definition or elaboration on performance indicator |
|---|---|
| Accessibility of the service | Accessibility of large cities and economically important areas |
| | Accessibility of all county-areas |
| | Accessibility during rush-hours |
| Physical accessibility | For everyone, including people with physical limitations |
| Service-level | Clean trains |
| | Clean stations |
| | Quality information service for passengers |
| Punctuality | Punctuality of arrival |
| Availability of seating | Reasonable chance for a passenger to have a train-seat |
| Safety | Safety for passengers |
| | Safety for personnel |
| Financial tariffs | Costs of exploiting the train service should reflect the tariffs charged to the passengers. These tariffs are therefore a reflection of exploitation costs. |

### *ProRail's Maintenance plan*

The performance indicators in Table 7 are included in the ProRail's Maintenance Plan of 2009.

Table 7: Performance Indicators in Maintenance Plan

| Main performance indicator | Definition or elaboration on performance indicator |
|---|---|
| Customer satisfaction | Satisfaction for TOCs |
| | Satisfaction public authorities |
| | Satisfaction passengers |
| Traffic guidance | Re-directing conform arrangements |
| | Number of irregularities on rail sections |
| | Trainpath: showing percentage of delivered trainpaths in reference with the number of requested trainpaths by TOCs, including causes when a trainpath could not be delivered |
| | Recovery capacity: alternative offered trainpaths |
| Reliability and availability of the rail infrastructure | Punctuality: relating to train delays in minutes |
| | Availability (unplanned and planned) |
| | Realization of infraprojects: measuring the progress |
| Transfer facilities | Passenger satisfaction on cleanness |
| | Passenger satisfaction on social safety |
| | Accessibility of transfer |
| In compliance with legal regulations on safety and environment | Safety: number of train-train collisions |
| | Safety: number of derailments |
| | Safety: number of work related incidents |
| Efficiency | Costs per train kilometre |
| | Costs per ton kilometre |

### *ProRail's Network Declaration*

The performance indicators in Table 8 are included in the ProRail's Network Declaration of 2010[34].

**Table 8: Performance Indicators in Network Declaration**

| Main performance indicator | Definition or elaboration on performance indicator |
|---|---|
| Reliability and availability | ProRail's KPI Availability focusing on the planned and unplanned unavailability of the rail infrastructure |
| Maintainability | Minimizing the hindrance for rail users/-traffic during maintenance activities |
| Safety | Safe, safe to use and safe accessible work environment |
| Health | Healthy environment for ProRail's own employees and personnel working along the rail infrastructure |
| Environment | Managing and reducing hindrance and pollution, taking into account the corresponding legal specifications |

### *Second Bill on Railway Safety*

The performance indicators in Table 9 are included in the Second Bill on Railway Safety, created by the Dutch Ministry of Transport, the DG Passenger-transport and the Rail Committee.

**Table 9: Performance Indicators in Second Bill on Railway Safety**

| Main performance indicator | Definition or elaboration on performance indicator |
|---|---|
| Railway Safety | Rail infrastructure related malfunctions (rail fraction, cracks or kinks) |
| | Red light passings |
| | Defects to rolling stock (broken wheels or axes) |
| | Technical safety (ATB-system and level-crossings) |
| | Accidents, incidents and almost-accidents |
| | Vandalism |

### 3.2.2 Conclusions on document analysis

Based on the main performance indicators included in these five policy documents we can draw several conclusions:

- Many performance criteria are not related to maintenance concepts concerning the physical infrastructure, and therefore fall outside the scope of this study: transfer, re-directing, dividing rail capacity, physical accessibility, service-level, seating-availability, traffic guidance, transfer facilities and health.
- Performance criteria that do fall within the scope of this study are: accessibility, safety, financial tarrifs, customer satisfaction, reliability and availability, compliance, efficiency, maintainability, environment and railway safety.
- There appear to be some inconsistencies as the definitions or operationalizations of these performance indicators are not uniform in these policy documents; measuring the performance of a similar criterion can have different outcomes. See for instance the different definitions of 'efficiency' (table 5-7) and 'safety' (table 5, 6, 8, 9).

34 The network declaration of 2010 is released in 2009.

- Although the range of performance indicators is broad and diverse, it does not appear to be complete as for instance no criterion for "comfort" is included.
- Although the included performance indicators are in many cases further explained, detailed operationalizations are missing. For instance, the planned or unplanned unavailability does not explain how to express these performances. The infrastructure's (un)availability could be for instance measured in percentages in time, number and length of occurrences of unavailability, number of trains hindered due to the unavailability, number of passengers hindered due to the unavailability, length of resulting time delays.

The performance indicators/criteria in tables 5-9 consist of aspects of importance for the government, ProRail and the NS. They help understanding the position of these stakeholders and their preferences, but are inconsistent and do not fully reflect all stakeholders' preferences with respect to ProRail's maintenance policy. And next to that, information is lacking on stakeholders' preferences with respect to operationalizing these performance criteria. Interviewing the actual stakeholders should provide a more comprehensive picture of these preferences, and by transferring this information in DANA; should provide insights which criteria (factors) can be influenced by maintenance activities and how (causality).

The conditions in the regional concession are determined by a regional authority, and can differ amongst different regions. However there are main performance criteria that regional TOCs should meet, which are presented in Appendix L.

## 3.3 The perspective of a stakeholder

An overview of the interviewees and related information is presented in Appendix K. The actual interview reports can be found in Brinkman and Fischer (2009), along with a translation in schematic causal models in Appendix H. As this information needed to be returned to the interviewees for feedback, the text is in Dutch. This section will discuss the individual perspectives of the interviewees, representing their organizations objectives and preferences. Especially with respect to Appendix H, showing the individual causal mappings, it is possible that some factors or causal links are not logical or not as expected. We have tried to keep the interview reports and the translations into causal mappings as direct as possible, meaning minimizing our own interpretation level. Section 3.5 will deal with the actual interpretation of the raw interview data.

### 3.3.1 Interview questions

The interviews are primarily meant for acquiring information on performance related characteristics of the rail infrastructure with respect to the goals and objectives of their stakeholder organization. The list of interview questions can be found in Appendix G. The interviews were taken between January and March of 2009.

The interview questions are first of all focusing on which performance indicators are of interest, to be able to create clusters of similar[35] factors in the DANA diagrams. Furthermore, we are interested in how the stakeholders measure or operationalize these performance indicators[36], because we have noticed that performance indicators can be expressed in many ways. The interview questions also

35 Relating to the same performance characteristic.
36 As these operationalizations are useful for operationalizing the attributes in the conjoint analysis.

focus on financial value of performance and willingness to pay for increased performance, as financial information and willingness to pay could be helpful in validating the results of the conjoint analysis. The last focus of the research questions is aimed at understanding on what performance indicators their[37] clients would evaluate their performance, meant for checking whether the preferences of ProRail's stakeholders incorporate the preferences of their clients.
As some stakeholders are different in nature, not every interview contained similar questions. For instance, a question related to the financial value of unavailability of the rail infrastructure has no significance for IVW. Most important is that every interview had a similar focus: aiming at increasing the understanding which performance indicators are relevant for that specific stakeholder and why these are important.

### 3.3.2 Stakeholder perspectives

In this subsection the results of the interviews will be summarized, by discussing the perspective of each stakeholder group separately on their similarities and differences. Readers interested in the full interview reports and corresponding causal mappings are referred to Brinkman and Fischer (2009) and Appendix H.

#### Perspective of TOCs

*Similarities*

All of the interviewed TOCs have mentioned the following elements to be of importance to their company.

- The satisfaction of their customers. Although being different in nature between passenger and cargo TOCs, their customers or clients determine part if not all of their success and survival.
- Punctuality is highly important. It determines their capability to timely transport passengers or freight. Unplanned malfunctions resulting in unavailability or speed limitations results in financial damage, hindrance for passengers and clients and damage to their image.
- Availability. The planned availability, or the time length that the rail infrastructure is available for use to TOCs, influences all TOCs. The availability influences the daily time range and frequency of train traffic.
- Safety is a must, and needs to be guaranteed. However, TOCs do not feel responsible for the system safety of the rail infrastructure as this is ProRail's responsibility, under the supervision of the Safety Inspectorate.

*Differences*

- Passenger TOCs are concerned with meeting the conditions in their transport-concession (VenW, 2004; Kennisplatvorm Verkeer&Vervoer, 2004-2007; Provincie Gelderland, 2000; MuConsult, 2009; ROVER, 2009; Probit, 2008). Cargo TOCs however, do not have to meet such conditions. Because cargo TOCs operate in a competitive market they are forced to meet the conditions of their clients, which are more diverse than the conditions for passenger TOCs.

37 The clients of ProRail's stakeholders.

- Although availability is an important aspect for all TOCs, the quality of availability is perceived differently as passenger TOCs have an interest in relatively high operating speeds and cargo TOCs are satisfied with an operating speed of 80 km/h.
- NS Reizigers is the only TOC that has mentioned the aspect of comfort in relation with the quality of the physical rail infrastructure. Although not being mentioned, this does not necessarily have to mean that comfort is not of importance to other TOCs.
- Unplanned delays could lead to slot times not being met. The effects of not making slot times differ amongst the TOCs. Missing one slot could result in missing several slots, as they need to wait for another opening. In extreme cases a delay of 3 minutes is translated into a delay of several hours. A TOC such as NS Reizigers operates according to a rigid timetable. Not meeting a time slot can affect the time table and cause delays, but not as extreme as for international TOCs as NSR would often have the next time slots available for their trains.
- Some cargo TOCs indicated that the Dutch rail system is too sophisticated for their needs and feel having to pay for services which they do not use. Many switches, advanced safety systems and high operating speeds are obsolete characteristics.
- NS Hispeed and cargo TOCs perceive the Dutch rail system of lacking international character. Examples of characteristics that cause problems relating to this are: different time slots and lack of clustered maintenance activities with adjacent countries[38]. More cooperation and communication between cross-border infraproviders is needed.
- The affordability of using the rail infrastructure is not specifically mentioned by NS Reizigers. The other TOCs did indicate that the affordability is of significance to the performance of their company.

### Perspective of National Public Authorities

*Similarities*

- The Directorate General Mobility (DGMo) is concerned with a broad perspective of performance indicators, one of which is safety, which is the primary concern of the Safety Inspectorate IVW. Although they are both concerned with safety, IVW is expected to supervise in more detail on the matter as it is their sole responsibility.
- Both DGMo and IVW operate under the principle of supervising distantly. DGMO and IVW want to leave most aspects with respect to the content up to ProRail and the rail sector: such as developing boundary specifications. The supervision and evaluation by IVW and DGMo is mostly done by comparing ProRail's performance with performance conditions that are created by ProRail and the rail sector. The idea is to not interfere with their core business; do not tell ProRail exactly what to do when the rail sector is better capable of doing so.
- Safety is a broad characteristic consisting of: safety of personnel, red-light passings, safety of rail infrastructure, physical quality, possibility for unsafe situations, derailment, exceeding safety standards, human injury and loss of life.
- The performance of ProRail needs to be continuously improving every year.

38 When planned maintenance activities on a similar track section that crosses borders are not simultaneously executed, but chronologically after one another (as was the case with the Betuweroute, according to Veolia Cargo). An international TOC cannot operate on that track when there are maintenance activities being performed in the neighboring country.

*Differences*

- The main difference is that DGMo is responsible for more than just safety related aspects, which can result in conflicting issues. For example, safety can be increased by doing maintenance only when there is no train traffic. This negatively influences the planned availability of the rail infrastructure. In practice, this could lead to conflicts between the two public authorities as DGMo prefers a high availability and does not always believe that it is necessary to prohibit train traffic during maintenance while the IVW would demand total prohibition.
- For other of DGMo's relevant performance indicators besides safety, see table 10.

### Perspective of Regional Public Authority

The following elements are perceived to be important for the Province of Gelderland, according to the interview and the regional transportation concession (Provincie Gelderland, 2000) with corresponding studies on customer satisfactions (Probit, 2008; ROVER, 2008; and MuConsult, 2009).

- Reliability and punctuality: measured in delays of arrival and departure times.
- Information provision for the passengers.
- The quality of the train material.
- The growth of the number of passenger.
- The satisfaction of the passenger, both subjective and objective.
- Safety, not safety of the rail infrastructure which is secured by law.
- Comfort-level
- Price of the train ticket
- Syntus' ability to cover their costs
- Quality of the connections when passengers need to change to another public transport modality.

### Perspective of ROVER

- The main objective of ROVER is to increase the satisfaction public transport passengers and make sure that the "voice" of the passengers is heard by the parties that can affect their satisfaction.
- With respect to the rail sector, ROVER's main factors of interest are: availability, affordability, reliability, frequency, ease of use, speed, accessibility, safety, quality of connection and hospitality.
- Many of these factors of interest can be influenced by ProRail, however ROVER believes that passenger TOCs have the largest effect on consumer satisfaction. ROVER is not only interested in the physical rail infrastructure, but also the transfer stations and the systems for guiding the train traffic.
- ROVER is most of all concerned with the relation between quality and price.
- Different ratios concerning price/quality can and are preferred to exist, as there are different passenger markets.
- ROVER prefers safety to be as high as reasonably achievable.
- A reliable service is more than just increased punctuality, as it concerns predictability of the *entire* journey, including transfer connections. When delays occur, accurate information should be presented to the passengers in a timely manner.

- In the nineties, the reliability of the rail infrastructure was decreasing rapidly, which became noticeable in more malfunctions and increased impact or hindrance of these malfunctions.
- Measures for improvement are in process and ROVER is noticing these improvements increasingly, however, ROVER is not yet satisfied with the current performance of the rail infrastructure due to maintaining malfunctions in switches, signalling and electricity supply.
- The capacity is becoming an increased bottleneck. And capacity is more than just the frequency of train traffic, as it concerns the system's ability for facilitating the most desirable time table in terms of train types, frequency, travelling times, connections and reliability.
- Problems concerning the availability of the rail infrastructure are, according to ROVER, related to an increased demand for capacity on the one hand, and the need for maintenance in "train free paths" (In Dutch: TVPs, Trein Vrije Perioden), where many maintenance activities can only be executed when no trains are operating in that track-zone[39].

### 3.3.3 Additional aspects of interest

The perception of the performance of the rail infrastructure is diverse amongst the stakeholders. Most stakeholders' perceptions vary substantially on the former performance, the current performance and the development in between. Interestingly, these statements are hardly based on reliable registry data, but are more a general feeling of what they experience in practice.

Another interesting aspect involves the availability of the rail infrastructure. When stakeholders understand the difference between unplanned unavailability and planned unavailability they all, especially TOCs, point out that unplanned unavailability has more extensive negative effects for their organization than the planned variant would have. These indications can be used to validate the results of the conjoint analysis.

## 3.4 How rail infrastructure performance affects stakeholders' interests

From the interviews explained in the previous section, and moreover in the interview reports and DANA models of each stakeholder[40], it becomes apparent that the preferences of ProRail's external stakeholders can be influenced by more than just ProRail herself. And the factors of importance for the stakeholders that can be influenced by ProRail are broader than the factors of which maintenance has an influence. Although focusing on how stakeholders influence each other's preferences can lead to interesting insights, we need to focus more on how ProRail's maintenance policy can affect stakeholders' objectives and preferences. This paragraph deals with just that; taking ProRail's maintenance activities as a starting point and, through using and interpreting the interview information, drawing the one general system perspective of how ProRail's maintenance policy can affect the satisfaction levels of her external environment. This "analyst view" is presented in Figure 6 on the next page. The system perspective in Figure 6 is meant to show the combined individual stakeholder views in terms of factors and influences, the actual or quantitative strength of influence or objectives are not relevant here. For information on how to interpret the causal model, see Appendix H.

39 In Dutch: spoorzone
40 As 3.3.2 is more concerned with performance criteria relating to the rail infrastructure. An example of this is the impact of passenger TOCs on the preferences of ROVER with respect to the quality of information and capabilities for changing trains.

The “analyst view” was created by: (1) merging factors with similar meaning across all stakeholders, (2) focusing solely in maintenance related factors and (3) linking these factors in a logical and plausible manner to each stakeholder’s satisfaction level, based on the interview results where stakeholders indicated (1) how rail infrastructure performance was affected and (2) how this performance could affect their company’s objectives.

The analyst view is to be considered as one perspective *combining* the different perspectives of the individual stakeholders into one map. The map is not to be regarded as one uniform point of view of all stakeholders, because one uniform perspective does not exist as explained in the previous section.

When looking at the factors relating to the satisfaction, one can observe that not every satisfaction is influenced in a similar manner. However, the analyst view does contain many factors that, eventually, influence the company’s objectives and preferences of all stakeholders and thereby their satisfaction level.

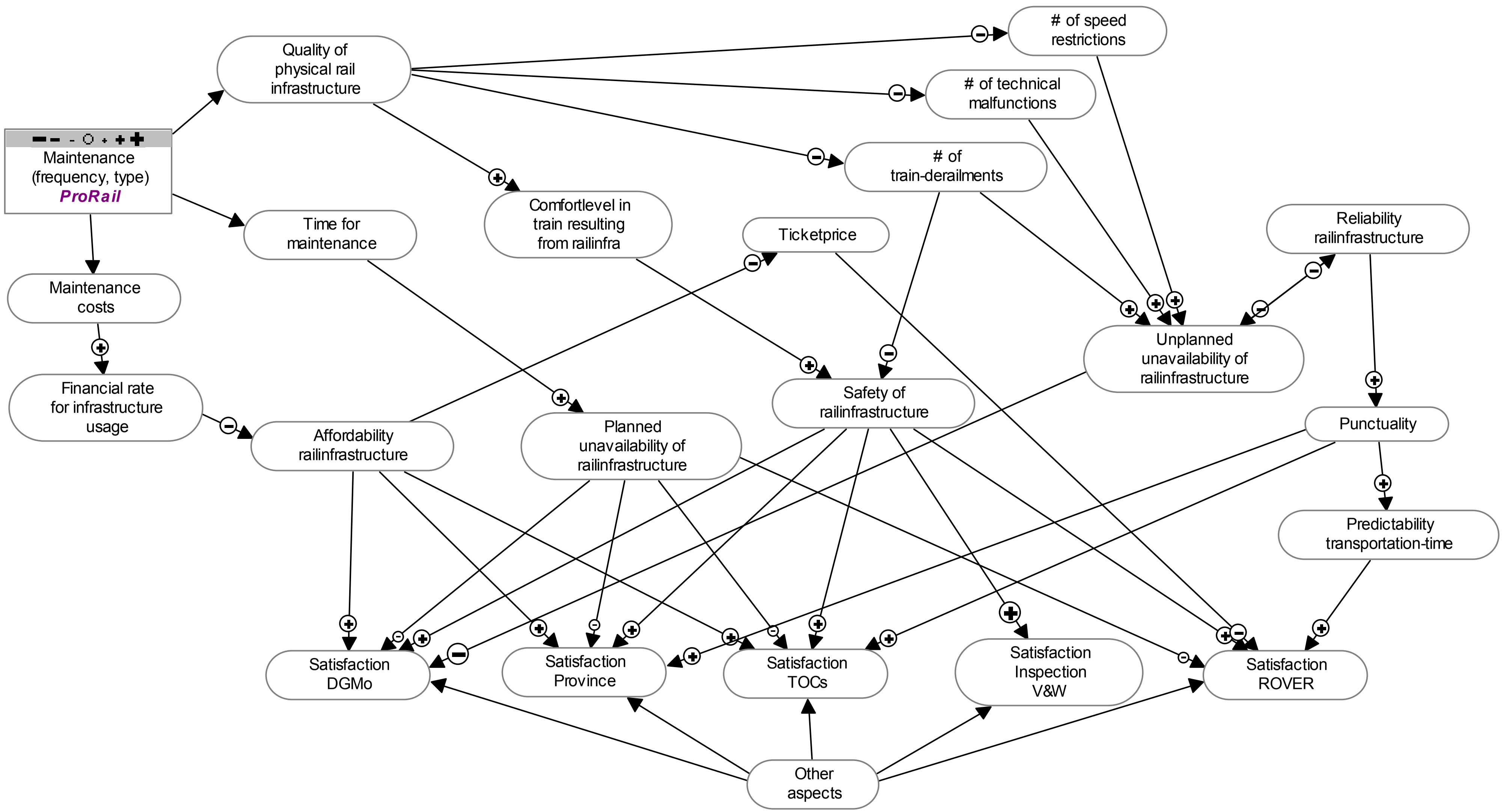


Figure 6: Analyst view of effect performance rail infrastructure on stakeholder satisfactions

Figure 6 shows the general perspective of the included stakeholders on how the maintenance-related performance of the infrastructure affects their company's objectives and preferences. Figure 6 shows that ProRail's maintenance activities have an influence on three factors that eventually affect the satisfaction level of their external stakeholders.

The first factor that maintenance affects is the quality of the physical rail infrastructure, which influences two performance "clusters": the *safety-cluster*[41] and the *unplanned-unavailability-cluster*[42]. An improved quality of the rail infrastructure will eventually improve the satisfaction of the stakeholders by improving the safety level and decreasing the time that the infrastructure is (unplanned) unavailable.

The second factor that maintenance affects is the time required for maintenance, which directly influences the *planned unavailability*. Increasing maintenance activities will require more time to perform these activities and since many maintenance activities can only be performed during train-free periods; the planned unavailability will also increase.

Lastly, maintenance also influences the *affordability-cluster*. Increasing maintenance activities will increase maintenance costs and since the usage rates are influenced by these costs, these rates will also increase. Therefore the affordability will decrease.

In the end, maintenance activities have an influence on four performance related clusters[43] on affordability, planned unavailability, safety and unplanned unavailability, which have an effect on the satisfaction levels of ProRail's external stakeholders.

Changing maintenance activities would result in developments that stakeholders would appreciate both positively and negatively. For example: increasing maintenance activities would on the one hand positively affect the safety level and unplanned unavailability of the infrastructure, but on the other hand would negatively affect the affordability and planned unavailability of the infrastructure. Clearly there are trade-offs involved and in order to appraise maintenance one needs to have information on the relative importance of performance criteria, which is the main concern of chapter four.

As just mentioned, the satisfaction levels of ProRail's external stakeholders are influenced by these four performance-clusters. Obviously there are more factors that would affect these satisfaction levels since these clusters are only related to the influence of *maintenance* on the *infrastructure performance*. Examples of such "external" factors can be influenced by ProRail; such as the quality of capacity management or traffic guidance. Other factors can be influenced by other external stakeholders, as the satisfaction of ROVER for example is highly dependent on performance of passenger TOCs with respect to quality of information and the interchange capabilities. And lastly, the satisfaction of stakeholders can be influenced by factors that neither ProRail nor ProRail's external stakeholders can influence. Although such influences were not mentioned during the interviews, one can imagine that the satisfaction levels of cargo TOCs are highly dependent on the world's economic growth.

41 Consisting of the comfortlevel, # of train derailments and safety of the rail infrastructure.

42 Consisting of the # of speed restrictions, # of technical malfunctions, # of train derailments, unplanned unavailability, reliability, punctuality and predictability of transport time. The two factors: unplanned unavailability and reliability are more or less the same according to the interview reports. That is why they are connected with a two-directional arrow.

43 Consisting of several factors relating to that specific performance type.

Observe that the satisfaction levels of ProRail's external stakeholders have no outgoing arrows, which suggests that these satisfaction levels have no influence on other factors. This is untrue as these levels have an impact on for instance the "KPI Client satisfaction" and ProRail's evaluation score in the consultation process (ProRail, 2008g, pp. 22-24 and 52-54), where entitled parties[44] evaluate, amongst other things, the performance of the rail infrastructure.

## 3.5 Validating the most important performance criteria

This paragraph is concerned with validating the quality of the most important performance criteria by comparing the results of the DANA-analysis with the analysis of policy documents in section 3.2. This comparison is presented in Table 10.

Table 10: validation of infrastructure related performance criteria

| Performance criteria in: | |
|---|---|
| **Analysis on policy documents[45]** | **Actor analysis** |
| Accessibility | Relating to planned and unplanned unavailability clusters |
| Safety | Safety of the rail infrastructure |
| Financial tariffs | Affordability-cluster |
| Customer Satisfaction | Satisfaction of ProRail's external stakeholders |
| Reliability | Unplanned-unavailability-cluster |
| Availability | Planned-unavailability-cluster |
| Compliance | Safety of the rail infrastructure |
| Efficiency | Affordability-cluster |
| Maintainability | Planned-unavailability-cluster |
| Environment | … |
| Railway safety | Safety of the rail infrastructure |

The table above shows much coherence between the two analyses: most performance criteria extracted from the analysis on policy documents are apparent in one of the performance clusters in Figure 6, except for one: the environmental performance criterion. Environmental issues such as noise hindrance and pollution did not appear to be very important in the actor analysis. In this study we want to include the most relevant performance indicators (see first research question) and due to the perceived lack of importance by ProRail's external stakeholders we will not consider this criterion any further.

44 In Dutch: gerechtigden.
45 Containing only the performance criteria relevant within the scope of this study.

## 3.6 Conclusion

Based on existing (policy) documents, the interview reports and DANA models we come to the conclusion that, from a multi actor perspective, the most relevant and rail infrastructure related performance indicators with respect to maintenance are focusing on: affordability, planned unavailability, reliability, safety, punctuality, quality, comfort, speed, capacity. These performance indicators will provide the basis for the determination of the most relevant performance indicators that will be included as attributes in the stated preference analysis in section 4.2.
All these performance indicators can be clustered into four main performance clusters relating to: affordability, planned unavailability, safety and unplanned unavailability, which all have an effect on the satisfaction levels of ProRail’s external stakeholders.

Again, one should realize that the satisfaction levels of their external stakeholders are influenced by more than ProRail’s maintenance policy such as by other departments of ProRail or by other external stakeholders. Therefore, due to the scope of this study, we will not investigate the full range of stakeholder preferences in detail.

# 4 ANALYZING STAKEHOLDER PREFERENCES

*"Which performance indicator is most important?"*

## 4.1 Introduction

This chapter will deal with the creation and results of the conjoint analysis, where, amongst other things, the relative importance of the most relevant performance indicators from the previous chapter is estimated. The model output on the stakeholder preferences will be the basis for predicting stakeholder valuation in chapter 5. The second section of chapter 4 will elaborate on the process of deciding on which performance related attributes to include in the conjoint analysis, which are derived from the results of the actor analysis in the previous chapter. Next, section 4.3 will elaborate more on the design of the conjoint analysis, including the model estimation procedure. Section 4.4 will go into detail on the questionnaire that is used to acquire the necessary data. Then, section 4.5 deals with the interpretation of the overall aggregated preference model. Next, in 4.6, the main model results; the relative importance of the performance indicators for the stakeholders will be presented. The results on the relevance of the performance indicators will be further elaborated on in section 4.7, where it will be tested which stakeholders have significantly different preferences from one another. Finally, section 4.8 will deal with the reliability and validation of the conjoint analysis, followed by concluding remarks in 4.9.

## 4.2 Performance indicators in conjoint analysis

### 4.2.1 Using DANA for attribute selection

In this subsection, we will use the stakeholders' system perspectives from the previous chapter to identify; the (overall) *most important performance indicators* which *can be influenced by ProRail's maintenance policy*, in order to be able to *select desirable attributes* for the conjoint analysis. 'Desirable attributes' would and need to be, according to Hair et al. (1998, p.405), communicable and actionable; meaning the attributes should form a realistic and comprehensive situation that can be easily evaluated by a respondent. Furthermore, the attributes should be practicable, meaning the attributes should reflect the practical preference perspective of stakeholders.

The factors from the individual stakeholder system perspectives have been extracted and an overview of these factors, along with their frequency of occurrence is presented in Appendix J.
As most different factors have rather similar characteristics, it is possible to make a categorization. The categories are created in such a manner that they are (1) rather independent from one another and (2) able to reflect the essence of most of the factors. These categories along with their accumulated frequency are presented in the Table 11.

Table 11: Frequencies of performance indicators from DANA models

| Category name | Short | Freq. |
|---|---|---|
| Quality railinfra | Q | 14 |
| Reliability | R | 54 |
| Safety | S | 26 |
| Affordability | C | 27 |
| (Planned) Availability | A | 31 |
| Speed | Sp | 7 |
| Comfort | Co | 4 |
| Information | I | 11 |
| Satisfaction | Sa | 12 |
| Other | X | 79 |

The categories that are highlighted in green are characteristics or performance indicators that can be influenced by maintenance activities. And as this study focuses on maintenance, the other characteristics will not be taken into account.

Speed-related characteristics were mentioned seven times, which is relatively few. And as some speed-related factors cannot be influenced by maintenance, 'speed' as a performance indicator will not be included. Similar argumentation holds for comfort-related characteristics as these aspects are scarcely mentioned, and comfort is for a large part safety related[46].

Therefore the four most important performance indicators are related to: reliability, safety, availability and costs: all directly influencing stakeholders' satisfactions according to figure 7. To get a better view of what these performance indicators mean, these indicators are explained by mentioning corresponding factors that are mentioned in the interviews:

**Reliability**: measure of predictability, limitations to functionality, malfunctions, failures, punctuality and unplanned delay.
**Safety**: technical safety specification, safety of passengers, personnel and workers; train derailment, lethal casualty, human suffering and safety incident.
**Availability**: availability, unavailability, planned unavailability and maintenance time.
**Costs**: affordability, use-rate per train kilometre, financial sanction, costs and damage.

Normally, these four performance indicators should be included in the conjoint analysis as they are important with respect to stakeholders' trade-off behaviour. However, the aspect of safety is somewhat special. With respect to the attributes of a conjoint analysis; the attributes should reflect a characteristic or quality that involves a trade-off (Hair et al., 1998; Molin, 1999). When we analyse the interview reports on the responses when safety is mentioned, it becomes apparent that most respondents do not regard 'safety' as a characteristic which involves a trade-off. Some of the

46 According to a ProRail specialist on civil engineering. See also the interview report of NS Reizigers.

responses: "we assume that the Safety Inspectorate ensures the safety", "safety should be 100%", and "safety is a precondition".

Including 'safety' in the conjoint analysis when many stakeholders would not regard 'safety' as a performance involving a trade-off, introduces the risk of (1) this attribute becoming so important that the importance of the other performance indicators cannot be estimated sufficiently, and/or (2) the conjoint analysis will not be taken seriously. Because 'safety' is regarded as a primary boundary value, this criterion has been excluded as an attribute in the conjoint analysis.

#### *Cross-validating the attribute selection*

The selection of the attributes based on only the stakeholders' system perspectives derived from the interviews is no guarantee that the selected attributes are in fact the most important performance indicators according to all stakeholders. It is possible that the interview focused more on one characteristic, which could result in more factors related to that characteristic in the system perspectives. Another possibility would be that not every important performance indicator was mentioned in the interview[47].

To acquire more confidence in the selected attributes (reliability, availability and costs), we have checked these attributes with available policy documents (section 3.2) and the interview reports to ensure that (1) there are no attributes ignored, and (2) the attributes are also mentioned in policy documents and the reports of all (or most) interviews.

By analyzing the policy documents there appear to be no attributes ignored that are related to the performance of the rail infrastructure and are of substantial importance to one or more stakeholders.

When we compare the attributes to the interview reports it becomes apparent that every attribute is considered to be of importance for all stakeholders, except for one: the safety inspectorate IVW. The IVW is solely concerned with safety-relates characteristics and can make no trade-off decisions concerning the other performance indicators. Since 'safety' is not included into the conjoint analysis, there is no point in including IVW in the conjoint analysis.

### 4.2.2 Operationalizing the performance criteria

The three selected performance indicators need to be operationalized for the conjoint analysis. The operationalization of these attributes needs to be done in such a way that: they are well interpretable for each stakeholder, the attributes are as independent from one another as possible, and they reflect the interests of the stakeholders[48].

In reality, the performance level of the attributes is influenced by more than just ProRail's maintenance activities on the rail infrastructure. For instance with respect to reliability; on average 41% and 53% of respectively the quantity and duration of malfunctions (which led to hindrance) were due to *technical* failures. The remaining percentages were mainly due to: third parties, processes and weather (ProRail, 2009b).

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47 Which is rather unlikely, since the respondent was always asked in the interview whether there were any more performance indicators of importance to the organization. It is also possible that the respondent thought he mentioned avery important performance indicator, but was not aware of another performance indicator being of importance.

48 For instance: availability percentages, which ProRail uses, in terms of 99.47% and 99.56% are difficult for stakeholders to interpret, but this small difference has a large impact on their functioning.

Operationalizing the attributes in terms malfunctions due to flaws in the rail infrastructure could result in interpretation problems for the stakeholders, as they cannot accurately know which part of the malfunctions is related to the rail infrastructure. Therefore, there is a good possibility that the stakeholders cannot determine how the overall hindrance changes when the attribute levels change in terms of only the rail infrastructure. When stakeholders feel that the influence of technical malfunctions on all malfunctions is rather low, it is possible that the values in the profiles are not taken seriously, as the perceived relevance of technical malfunctions is slim[49]. For purposes of increasing interpretability, it is preferable to operationalize attributes in a more general manner; relating to the situational context. And, based on historical registry data, it is possible to introduce a plausible relation between malfunctions due to the rail infrastructure and the overall malfunctions, which means the output of the deterioration model (performance indicators dealing with the effects of only maintenance) can be transferred into effect on the general performance indicators which are used in the conjoint analysis.

The operationalization of these performance indicators is based on information from policy documents (section 3.3) and the interviews (section 3.4 and 3.5). Therefore, the following operationalizations are most relevant from a practical perspective, and slightly differ from the definitions provided in section 1.2.1. For this study, practical relevance is considered to be more important than theoretical importance.

### Reliability

'Reliability' should be operationalized in a way that it reflects the unplanned component of unavailability of the rail infrastructure. Most important is that the attribute is easy to interpret for respondents. In the interviews it became clear that stakeholders, and especially TOCs, are not interested in the time of an unplanned malfunction; they want to know how their trains are affected by this. And we have therefore decided to operationalize 'reliability' as:

"The percentage of trains[50] that are (unplanned) hindered"; meaning hindered by more than just technical malfunctions."

### Availability

'Availability' should be operationalized in a way that it reflects the planned component of unavailability of the rail infrastructure. Again, it is important that the attribute is easy to interpret for respondents. We have therefore decided to operationalize 'availability' as:

"The percentage of (planned) trains that need re-planning due to planned unavailability of the infrastructure."

49 The relevance of this argument becomes apparent in the interview of NS Hispeed (Appendix H.1), where the interviewee feels that technical malfunctions rarely occur. And should we decide to include an attribute relating to just technical malfunctions, NS Hispeed would probably feel that technical malfunctions are only a fraction of the causes of unplanned unavailability and thus, the attribute would not be representative for the unplanned unavailability and will probably not be taken seriously.
50 'Trains' refers to the number of trains that are actually operating on that rail section.

Although *reliability* and *availability* and operationalized in the "language" of ProRail's external stakeholders, ProRail can easily translate these PIs into operationalizations matching their own language; as they are directly translated from the frequency and length of the (planned and unplanned) unavailability of the rail infrastructure.

### Costs

'Costs' as a performance indicator is more difficult to interpret, since not every stakeholder is concerned with costs in the same manner: ROVER is concerned with the ticket price, DGMo with cost-effectiveness and TOCs with usage rates. We believe that the 'financial usage rate' has a key position in the financial area. Furthermore, the financial usage rate is also related to ProRail's cost-effectiveness. We have therefore decided to operationalize 'costs' as:

"The relative change in the financial usage rate"

### 4.2.3 Range of performance levels

The range of the attributes has a large influence on the trade-off process made by individuals, as "the range of the attribute levels can best be chosen in a way that they span the range observed in current or planned choice alternatives" (Molin, 1999).
It is therefore eminent that the range is realistic. To determine the attribute range, historical registry data has been used from ProRail's databases (ProRail, 2009b).

The range of the attributes on the "% hindered trains" and "% trains needing re-planning" is dependent on the geographical focus. For instance: track sections with a higher the intensity of train traffic tend to have more malfunctions. Also, on average, more maintenance is required and the length of train traffic on per day is longer. It is therefore important to decide what to base the attribute range on.
The situations or profiles in the conjoint analysis can be hypothetical, but respondents should have a good feeling on what or where the performance related situation refers. We have decided to base the attribute range on a geographical focus in terms of a 'corridor'. A corridor consists of several track sections[51] and is a focus or terminology, which both TOCs and ROVER use.
This hypothetical corridor should resemble realistic corridors on which TOCs are operational. We have chosen three existing corridors that are intensively used by many TOCs and historical performance data on these three corridors have been used to determine the range of the attribute levels for the conjoint analysis. The following corridors are used:

- Rotterdam - Zevenaar border (to Emmerich; without the Havenspoorlijn[52])
- Amsterdam – Eindhoven (also known as A2 corridor)
- Amsterdam – Roosendaal border

The average length of the corridors is 130 km, and therefore the hypothetical corridor mentioned in the questionnaire will have the same length. For more detailed information on the three corridors and their actual ranges, see Appendix V. The ranges of the hypothetical corridor will be calculated

51 And GEO-codes, used by ProRail, for that matter.
52 As the section from Maasvlakte to Kijfhoek us maintained by KeyRail.

based on the actual ranges of the three corridors based on the historical registry data from ProRail's database (ProRail, 2009b). Table 12 gives an overview of these ranges.

**Table 12: Performance ranges of 3 existing corridors**

| HISTORICAL DATA ON THE 3 CORRIDORS | % Hindered trains | % Trains needing re-planning | % Change in usage rate |
|---|---|---|---|
| | | | |
| **Minimum value** | 14.68% | 5.51% | -1.67% |
| **Average value** | 18.60% | 7.06% | +3.17% |
| **Maximum Value** | 22.58% | 10.53% | +10.64% |

As the attribute levels did not exactly match the performance data in the "KPI Beschikbaarheid" (ProRail, 2009b), the historical registry data needed to be converted. The "percentage of hindered trains" was calculated by using the average malfunction durations per day. On average, approximately one train per five minutes would pass on the corridors[53]. We have also taken into account the fact that not every malfunction results in hindrance for every train-direction[54].
With respect to the "percentage trains needing re-planning", we used the registry data on the planned maintenance time during operating times which led to hindrance for train schedules, combined with one train every five minutes. However, with respect to planned maintenance it is more realistic[55] that every activity would result in hindrance for every train-direction on that corridor.
And lastly, the "percentage change in usage rate" was calculated based on fluctuations in actual maintenance costs over the last six years[56] (see also ProRail, 2008h). Combining this information with ProRail's methodology on usage-rate-calculations (ProRail, 2005d), we were able to translate changes in actual maintenance costs into changes in financial usage rates.

Now that we have determined the range of the attribute levels, the number of attribute levels and their values should be decided on. The importance of an attribute likely depends on the range of the attribute levels (Molin, 1999). A larger range would probably result in a larger relative importance of the particular attribute. In order to avoid unrealistic relative importance numbers, we determined the range for every attribute in a similar manner; based on genuine historical registry data on the attributes. Furthermore, research has indicated that attribute importance increases with the number of levels varied (Currim et al., 1981). For example, if the size of an attribute is varied in terms of two levels, instead of four, the importance of the attribute would probably be lower. It is therefore desirable to have a constant number of attribute levels across all attributes.
"Researchers should attempt as best possible to balance or equalize the number of levels across factors. It has been found that the estimated relative importance of a variable increases as the

53 Based on the average train intensity on the three corridors, which is 240 trains per day (according to ProRail's baanvakwaarden), and 20 hours length of trains being operational per day; there is a train once every 5 minutes.
54 On average, according to several experts on ProRail's department of maintenance planning, one malfunction affects 1.5 of the directions. Since the national average of train-directions (in Dutch: rijrichtingen) is 2.36 (ProRail, 2008h); the translation factor is 0.64 (1.5/2.36). For example: 100 minutes malfunction time will, on average, result in 64 minutes hindrance for 1 direction.
55 Again, according to several experts on ProRail's department of maintenance planning.
56 Financial data was only available over the last six years.

number of levels increases, even if the end points stay the same" (Hair et al., 1998, p407; Wittink et al., 1982; Wittink et al., 1990). Using four attribute-levels is desirable for the attribute "% change in usage rate" as we wish to include the attribute level of "0%"[57], and the increase of the percentage should be higher than the decrease[58]. Therefore, including four levels is therefore desired for the other attributes as well to prevent the cost-related attribute becoming unrealistically important. Keeping the ranges shown in Table 12 on the previous page in mind, the following levels in Table 13 will be applied in the profiles for the conjoint analysis.

**Table 13: Attributes and levels for the conjoint profiles**

| ***Attributes*** | **Range** |
|---|---|
| **% Hindered trains** | [11%, 15%, 19%, 23%] |
| **% Trains needing re-planning** | [5%, 7%, 9%, 11%] |
| **% Change in (financial) usage rate** | [-5%, 0%, +5%, +10%] |

## 4.3 Design of the conjoint analysis

As explained in section 4.2, the conjoint analysis is designed with 3 attributes, each with four levels. The analysis design used in this conjoint analysis can be found in Appendix S. This analysis design is derived from the experimental design in Basic Plan 3 that is both orthogonal and balanced, which is preferable as explained in 2.2.2. The analysis design requires 16 profiles to be rated in order to be able to estimate an individual conjoint model. One extra profile was included for validation purposes; the 'holdout' profile. After the conjoint models are estimated this alternative will be used to assess the prediction power of the models. The attribute levels of the holdout profile are selected in order to match the average performance of several corridors which is used to determine the attribute range (see also 4.2). The holdout profile is therefore a realistic representation of the current situation in reality.

As Appendix S shows, effect coding is used to translate the experimental design into the analysis design. There are more ways of coding the attribute levels, such as dummy and orthogonal coding. However, the different coding schemes have no impact on the overall results of the analysis[59] (Molin, 1999) and since model results when using effect coding are easier to interpret, this type of design is used.

To estimate the preference function, an appropriate estimation technique needs to be selected. When rating data are collected, regression techniques are commonly applied, according to Molin (1999). In this study, multiple regression technique is used where the dependent variable is the profile rating, and the independent variables are formed by the coded attribute levels. The estimated regression coefficients are then interpreted as the part-worth utility contributions to the overall ratings of the profiles (Molin, 1999), which will be further explained in the section 4.5. For more detailed information on multiple regression techniques, we refer to Hair et al. (1998), chapter 4.

57 For including the present situation in the conjoint profiles, in order to get a direct (in stead of by interpolation) sense of the satisfaction of the current financial rates.
58 To match the actual range of maintenance costs.
59 But they do effect the interpretation of the estimated regression effects and the significance tests.

Finally, the actual conjoint analysis, using multiple regression analysis, is executed by using the statistical software program SPSS. The results of the analyses will be discussed in sections 4.5 to 4.7.

## 4.4 The Questionnaire

As explained in section 2.2, the conjoint analysis used in this study is a rating based stated preference experiment, where the respondents have to valuate or *rate* different situations, based on which a conjoint analysis is capable of calculating the (relative) relevance of the performance indicators, or attributes, used in the analysis.

The questionnaire that could be accessed through the internet is presented in Appendix N. The questionnaire consisted of several main elements: a general introduction, an explanation on rating the profiles, the actual profiles, direct ranking and some final general questions, which will all be shortly explained below.

The introduction first of all explains the importance of the questionnaire for the stakeholder, as the results can be used to optimize[60] the performance of the rail infrastructure according to their preferences.

The incorporated performance indicators were explained to avoid misinterpretation. The performance indicator "% hindered trains" is explained to be an unplanned hindrance due to more than just technical malfunctions that resulted in a delay of more than 3 minutes. "More than 3 minutes" is quite a range to be left undefined, which introduces the risk of misinterpretation. But since the time slots for trains are three minutes wide, the delay will always result in a train not meeting the ordered train path. To avoid the problems of not defining the length of the time delay, there are two options: (1) introducing an average length of the delay or (2) including another attribute. Both options would introduce even more problems since the length of time delays is dependent on much more than the actual cause; free capacity at that time and the quality of ProRail's department of Traffic Guidance can be of grand influence to the actual length of the delay. Since this study focuses on the impact of maintenance policy, the effects of rail capacity and traffic guidance fall outside the scope of this study. Besides, the lengths of the time delays are often random and cannot be predicted. Therefore, mentioning a time delay of "more than 3 minutes" is considered to the best option.

The attribute "% trains needing re-planning" is explained to be a planned hindrance and the stakeholder will be timely notified so that planning adjustments can be made. The aspect of timely notification is realistic as these maintenance activities are planned months in advance by ProRail's department of Infrastructural Availability Planning[61]. In reality, there are several levels of hindrance by planned maintenance activities, which are all explained in the questionnaire. Like with the previous performance indicator (PI), the actual hindrance level is dependent on much more than ProRail's maintenance concepts and is therefore not further specified.

The attribute "change in financial usage rate" is explained as the costs that are directly linked to the financial tariff for using the rail infrastructure. To avoid misinterpretation, an explanation is given on

60 'Optimize' will probably be inaccurate, since the stakeholders can have conflicting preferences. When conflicting preferences do exist, no optimum is possible and a sub-optimal situation can be determined based on generally known efficiency measures by e.g. Pareto or Kaldor-Hicks.

61 In Dutch: Infra Beschikbaarheids Planning (IBP).

which aspects are included in this financial rate, which are the number of train kilometres, the weight of the trains, the costs of electrical energy and costs for using railway stations or yards (Roos et al., 2005).

The PI of safety is explained to be similar in every situation and can be interpreted as: safeguarded at all times. This notion was included to ensure that safety would have no influence on the ratings, as it would be realistic for respondents to link the 'unplanned unavailability due to malfunctions' to 'safety'.

Furthermore, an explanation is given on how the respondents could valuate a situation; examples on how to interpret a rating are included.

And lastly, the fictional corridor is explained as an existing corridor where the stakeholder is frequently active on. Three examples of such corridors with representative lengths are given. As it is highly likely for a regional TOC not to be active on a corridor with a length of 130 km (=hypothetical corridor), an explanation is given on how these stakeholders should interpret the results. With respect to the PIs related to the unavailability of the rail infrastructure; the regional stakeholders should consider the values in proportion with the length of the corridor which they are active on. Half of the length means half the percentage of trains hindered.

Then, the actual profiles are presented starting with introducing the current situation (=holdout, as described in 4.2) as a possible point of reference; to increase the consistency of the ratings. After all 17[62] profiles are rated, the respondents are asked to rank[63] every PI on their importance, but now including "safety" for validating the dominance of this PI. And lastly, some final general questions were included concerning their organization and function.

### *Administration of data collection*

The questionnaire could be entered through the internet. The questionnaire was constructed in the web-based program 'NetQuestionnaires'. The data collection took place in March and April of 2009. The respondents were sent an e-mail containing an explanation and a request to participate by going to the internet link that led to the questionnaire. The e-mail also included a request to spread the link to colleagues having knowledge on how the performance of the rail infrastructure affects their company objectives.

Ten e-mails were sent in total to ten different stakeholders, requesting their participation and of their colleagues. From these ten stakeholders only five stakeholders finished the questionnaire, and moreover, one stakeholder, Province of Overijssel, participated although this stakeholder was not directly[64] approached.

One stakeholder, ROVER, tried to complete the questionnaire but came to the conclusion that ROVER is not able to make the required trade-offs, as the performance indicators are related to TOCs and translating these PIs to the effects for the actual passengers cannot be easily calculated (Appendix T). ROVER and Overijssel will therefore not be included in the calculation of the response rate, which is: 56% (5/9). Normally a response of 56% is rather high, but since the stakeholders already agreed to participate in the explorative interview, a response rate of 100% was expected and 56% should be considered low. This rather low response has no problematic implications for the individual preference models but one should keep in mind that the preferences of four[65] of ProRail's

62 16 profiles for model estimation according to Basic Plan 3, plus the holdout profile.
63 Meaning: a classification of every PI from most important to least important.
64 The Province of Overijssel probably participated through a reference by the Province of Gelderland.
65 ACTS, DB Schenker, Syntus and DG Mobility.

important stakeholders are not included in the conjoint analysis. Lastly, only one respondent per stakeholder organization did participate. Section 4.8.1 will elaborate more on this. Eventually four stakeholders did not participate despite of five attempts to encourage participation[66].

## 4.5 Overall stakeholder preferences

This section is concerned with analyzing the preference behaviour of all stakeholders in order to know how relatively important different performance criteria are so that the RIM is able to incorporate the preferences of their external stakeholders into the process of policy decision-making.

These results are translated into a preference model for each stakeholder, shown in Appendix R and dealt with in the next section. The aggregated model results of the six stakeholders combined are shown in Table 14.

66 At the end of each interview we requested participation in an Internet questionnaire. Every respondent responded indicated to be willing to participate. Then, an email was sent to individual (of the interviewees) email-accounts containing a short explanation and a link to the questionnaire. After one week, only one respondent had finished the questionnaire. Then, reminder was sent. After another week, three respondents finished the questionnaire. Then, requests were66 made by telephone, where all remaining respondents indicated of having seen the email but were hindered due to a busy time schedules. All indicated of planning to finish the questionnaire soon. After another two weeks, five respondents finished the questionnaire. Again, a second reminder was sent. Lastly, a final reminder (fourth email message) was sent containing the message that that would be the final request and that they would have one week to finalize the questionnaire.

**Table 14: The (aggregated) overall preference model, based on: NSR, NSHispeed, ERS, Veolia, Gelderland and Overijssel**

| **Aggregated overall preference model** | | | | | | |
|---|---|---|---|---|---|---|
| | | **Average rating** | **Part-worth utility** | **p-value** | **Range** | **Relevance** |
| **Overall utility (constant)** | | 3.312 | | 0.000 | | |
| | | | | | | |
| **% Hindered trains** | | | | | | |
| 11 | | 4.54 | 1.229 | 0.000 | 2.291 | 52.9% |
| 15 | | 3.54 | 0.229 | 0.070 | | |
| 19 | | 2.92 | -0.396 | 0.009 | | |
| 23 | | 2.25 | -1.062 | | | |
| | | | | | | |
| **% Trains needing re-planning** | | | | | | |
| 5 | | 3.54 | 0.229 | 0.070 | 0.583 | 13.5% |
| 7 | | 3.54 | 0.229 | 0.070 | | |
| 9 | | 3.21 | -0.104 | 0.356 | | |
| 11 | | 2.96 | -0.354 | | | |
| | | | | | | |
| **% Change in usage rate** | | | | | | |
| -5 | | 4.17 | 0.854 | 0.000 | 1.458 | 33.7% |
| 0 | | 3.50 | 0.187 | 0.122 | | |
| 5 | | 2.88 | -0.437 | 0.006 | | |
| 10 | | 2.71 | -0.604 | | | |
| | | | | | | **Check** |
| **R Square** | 0.981 | | **Total Range:** | | 4.332 | 100.0% |
| **Adjusted R Square** | 0.952 | | | | | |

The first columns shows for each attribute level the average ratings given to the situations/profiles that include that particular level. The second column shows the part-worth utilities of the attribute levels as estimated by regression analysis applying effect coding. By comparing the results presented in the first two columns, it becomes clear that the part-worth utilities indicate the contribution of the attribute levels to the overall utility expressed as the difference with the overall utility.

### 4.5.1 Possibility for generalizations

The p-values in the fourth column show that not every estimated parameter is significant at the conventional level ($p<0.05$)[67]. The p-value in a multiple regression analysis demonstrates if the estimated parameter (or part-worth utility) deviates statistically significant from zero.
However in this study we are not interested to make statements or conclusions for the population, because we have already made the assumption that the respondent is able to reflect the perspective

67 But what does this mean for the results? The p-value or significance level represents the probability for making a Type I error, which means the null hypothesis is wrongfully dismissed. In a Type I error a conclusion is made, based on the samples, that there is a difference or relation in the population, while this is actually incorrect (Hair et al, 1998).

of the entire stakeholder organization. Consequently, *all* regression parameters and part-worth utilities, irrespective of their significance level, are relevant for this study as they are assumed to represent the perspective of a stakeholder organization.

### 4.5.2 Overall preference ratings

The overall utility, or constant, is 3.312, which means that on average the profiles have been rated with a 3.312. Since the possible ratings of the profiles ranged between 1 and 10, one can conclude that, on average, all profiles were very unsatisfactory for the stakeholders.
Furthermore, the holdout profile was on average rated with a 3.83. And since the holdout profile was based on the actual rail infrastructure performance, it is likely that the stakeholders are not satisfied about the current performance of the rail infrastructure system[68].

### 4.5.3 Relative importance of the performance indicators

The part-worth utility of '11% hindered trains' is +1.229, which normally means that the stakeholders consider 11% trains hindered as 'positive'. However, as can be read from the first column, the inclusion of that attribute level in the profiles results in an average rating of 4.54, which should still be considered insufficient.

The absolute difference between the highest and the lowest part-worth of the levels is often taken as an indicator of the importance of that attribute (Molin, 1999). For the model displayed in Table 14, this means that the infrastructure's *reliability* (percentage hindered trains) is the most important attribute as the range of 2.291 (52.9%) is largest, followed by the *affordability* (percentage change in usage rate), with a range of 1.458 (33.7%) and lastly, the *availability* (percentage trains needing re-planning) with a range of 0.583 (13.5%) is least important. However, keep in mind that the importance of an attribute may be conditional on the selected attribute levels. For example, if a larger range on '% change in usage rate' would be selected, say -10%, 0%, +10% and +20%, then the range of the part-worth utilities would probably be larger and thus would be considered a more important attribute.

### 4.5.3 Interpretation of the overall preference results

The quantitative preferences of all included stakeholders first of all showed that stakeholders are not satisfied about the current performance of the rail infrastructure. Second of all, on average, the reliability of the infrastructure proved to be, the most important performance criterion (53%), followed by the affordability (34%) and lastly availability (13%) was considered least important. In order to increase the satisfaction levels of ProRail's external stakeholders; policy measures[69] aiming at improving the infrastructure's reliability would be most effective relative to measures aiming to improve the other two performances.
As explained in section 2.2.2: "with respect to maintenance on the RIS, there is a trade-off between the need for *using* the RIS on the one hand and the need for *maintenance* on the other. Somehow a balance between the two should be found." In order to reduce the technical malfunctions (*increasing* the system's reliability) planned maintenance is needed (*decreasing* the system's

68 Based on the attribute levels in the profiles.
69 Not necessarily maintenance related.

availability). The overall preference results indicate that improving the infrastructure's reliability would be positively valued, even though the infrastructure's availability is negatively affected[70].

## 4.6 Individual importance of performance indicators

In the previous section is explained how an individual preference model needs to be interpreted. This section will elaborate on the main results of all separate stakeholder rating-models, which are displayed in Table 15, in order to investigate possible differences in trade-off preferences amongst stakeholders. Readers interested in more detailed information[71] concerning these rating models are referred to Appendix R.

**Table 15: Relevance and ranking of performance indicators for all stakeholders**

| **Stakeholder:** | ***Train Operating Companies*** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | NSR | | NSHispeed | | ERS Railways | | Veolia Cargo | |
| **Relevance and ranking** | Importance | Rank | Importance | Rank | Importance | Rank | Importance | Rank |
| *% Hindered trains* | 80% | 1 | 50% | 1 | 42% | 2 | 50% | 1 |
| *% Change in usage rate* | 10% | 2 or 3 | 36% | 2 | 50% | 1 | 36% | 2 |
| *% Trains needing re-planning* | 10% | 2 or 3 | 14% | 3 | 8% | 3 | 14% | 3 |

| **Stakeholder:** | ***Public Authorities*** | | | | **Average relevance[72]** | | | |
|---|---|---|---|---|---|---|---|---|
| | Gelderland | | Overijssel | | | | | |
| **Relevance and ranking** | Importance | Rank | Importance | Rank | | Overall | TOCs | Public authorities |
| *% Hindered trains* | 25% | 3 | 55% | 1 | *% Hindered trains* | 53% | 59% | 39% |
| *% Change in usage rate* | 37% | 1 or 2 | 18% | 3 | *% Change in usage rate* | 34% | 32% | 28% |
| *% Trains needing re-planning* | 37% | 1 or 2 | 27% | 2 | *% Trains needing re-planning* | 13% | 9% | 33% |

### 4.6.1 Stakeholder differences in reliability

The PI "Reliability" is the most important performance indicator[73] for most of the stakeholders. Four out of six stakeholders, and three out of four TOCs, find this PI to be the most relevant. This attribute, focusing on the unplanned unavailability of the rail infrastructure, will probably have the largest effect on their company objectives. For most of the stakeholders; improving this performance will[74] increase their level of satisfaction due to their company objectives being positively affected, however, a decrease of this performance will have a relatively strong negative impact.

The two stakeholders that do not perceive this PI to be most important are: ERS Railways and the Province of Gelderland. Although ERS Railways perceives this PI to be second most relevant, the difference with the ERS's most important PI is small, which means that the infrastructure's reliability does have a large influence on ERS's satisfaction level. The Province of Gelderland however, perceives this PI to be least important, although there are minor differences between the other two PIs.

70 Obviously this is also dependent on the size of the impact on these performance indicators. Increasing reliability with 1% that results in decreasing the availability with 90% would "probably" be negatively appreciated by all of ProRail's external stakeholders.
71 Such as the coefficients' significance levels or the R-square.
72 Based on aggregated models. Keep in mind that there are significant differences within these three stakeholder groups.
73 Taking into account the range of the attribute-levels of the three attributes included in the profiles.
74 According to the conjoint model.

The deviation in Gelderland's perception could be directly explained, perhaps (1) the effects of unplanned unavailability are underestimated by the Province of Gelderland, or (2) these effects are not that important for Gelderland[75], or (3) the relative importance of these effects is not accurately translated into the (transportation-) concession.

### 4.6.2 Stakeholder differences in affordability

The relevance of the infrastructure's affordability differs significantly amongst stakeholders. The rank ranges from 1st to 3rd, where the 2nd ranking occurs most. Although these rankings differ a lot, the importance is rather similar for four stakeholders; ranging between 36% and 50%. Interestingly, the importance of the "change in usage rate" is substantially lower for NS Reizigers and the Province of Overijssel. For a public, non-profit driven, authority such as Overijssel, one could explain the cost related aspects being relatively unimportant. However, this does not necessarily mean that Overijssel does not perceive cost aspects to be important as the relevance is calculated in a relative manner.

However for commercial organizations, such as TOCs, one would expect cost related aspects to be relatively important as it has a direct influence to their profitability. The fact that the perceived relevance of this cost related performance is only 10% for NS Reizigers is rather remarkable considering that NSR is a commercial and profit-driven organization. On the other hand, having a dominant market position, one could imagine why the company performance of NSR is relatively less dependent on cost advantages.

### 4.6.3 Stakeholder differences in availability

The attribute related to the planned unavailability of the rail infrastructure is least important for four[76] out of six stakeholders. Interestingly, the two stakeholders that perceive this PI not to be least important are two public authorities.

### 4.6.4 Overall relevance of performance indicators

As can be expected from the previous three subsections, the (average) ranking of the three performance indicators according to the aggregated model of all stakeholders, as presented in section 4.1, is as follows:

- With an importance of 53%: the percentage hindered trains
- With an importance of 34%: the percentage change in usage rate
- With an importance of 13%: the percentage trains needing re-planning

These differences in the relative importance of these three performance-indicators are more influenced by the TOCs than by the public regional authorities, as the TOCs' relevance percentages are substantially more diverging than the public authorities' (see table 15).

One has to keep in mind that these relevance percentages are largely influenced by the range of the attribute-levels. But since all levels are created according to the same rules, we can confidently conclude that the PI relating to the infrastructure's reliability is on average considered to be most important, followed by the infrastructure's affordability and (planned) availability.

75 This is rather unexpected as Gelderland's interviewee indicated that reliability would have a greater impact than for instance the availability.

76 Actually three or four, because NSR's ranking of this PI is similar with the change in usage rate.

### 4.6.5 Interpretation of the individual preference results

By comparing the quantitative preferences of each individual stakeholder it becomes apparent that several differences exist between the stakeholders concerning the relative importance of the performance criteria on the infrastructure's reliability, affordability and availability. The fact that stakeholders differently rank the importance of these performance indicators would mean that a policy measure aiming at the improvement of the infrastructure's performance cannot affect each stakeholder in a similar manner. Some stakeholders will be more positively influenced than others. Some might even be negatively affected. Eventually it is up to ProRail to decide on how to deal with these discrepancies, but the implications will be demonstrated in chapter 5.

## 4.7 Different stakeholder preferences

In 4.5 it became apparent that differences exist regarding stakeholders' preferences. But are these differences statistically significant? Using so called 'contrast coefficients' in the analysis design we can conclude that every individual preference model significantly differs from every other stakeholder model, except for the models of Veolia Cargo and ERS Railways.
Although there are differences between their preference models as can be seen in Table 15, these differences are not large enough to conclude a statistical significant difference between the cargo TOCs ERS and Veolia.

Because ERS Railways and Veolia Cargo are not statistically different from one another, one aggregated preference model for both cargo TOCs can be estimated, which can be found in Appendix R. And by assessing the model fit[77] we can conclude that the variation explained by the aggregated model is higher than by the individual models. In other words: the aggregated model fits better. This aggregated model will be further used in chapter 5, because some inconsistencies in some attribute-levels are eliminated, as will be further explained in 4.8.3.

## 4.8 Reliability and validation

This section is concerned with testing the reliability and validation of the results of the conjoint models. The models' reliability and validity will be tested on:

- Data availability
- Overall model fit
- Face validity
- Prediction power
- Attribute importance
- Linearity of the part worth utilities
- Reliability of stakeholder ratings

Another validation measure for the reliability of the results is the "degree of multicollinearity", which refers to the interaction-effects between the independent variables. But because a fractional factorial design is used, it is not possible to estimate interaction-effects between independent

77 By comparing the (adjusted77) R-square (R2) values of the individual models with the aggregated model (for more info on the R2, see 4.7.2). The average R2 values (R2=0.9005, adj. R2=0.751) of the individual models is lower than the R2 values (R2=0.918, adj. R2=0.795) of the aggregated model.

variables[78], which means that the interaction-effects cannot be estimated. One should keep in mind that, although unexpected, the existence of interaction-effects has not and cannot be tested.
Hair et al. (1998) have described a validation method for multiple regression analysis[79], namely 'validation by sample splitting', where all samples should be splitted and the model results should be compared. However, due to the small sample set this technique has proved not to be useful and will therefore not be further explained.

### 4.8.1 Data availability

This criterium is not related to the individual preference models that are already estimated, but is concerned with reliability implications the lacking of some preference models.

In chapter 3 it was decided to include 11 stakeholders in this study. Due to the fact that the PI "safety" was not included as an attribute in the profiles, there was no point in including the IVW for the conjoint analysis, as the IVW solely focuses on this PI.
Therefore, the objective was to include all remaining 10 stakeholders for the estimation of individual preference models. Unfortunately, only 5 of the intended stakeholders have completed the entire questionnaire.
However, one stakeholder, ROVER, tried to complete the questionnaire but came to the conclusion that ROVER is not able to make the required trade-offs, as the performance indicators are related to TOCs. ROVER indicated that translating these PIs to the effects for the actual passengers could not be easily calculated (Appendix T). Furthermore an extra stakeholder had (unplanned) completed the questionnaire, which is why six stakeholder preference models could be estimated.
Four stakeholders are missing from the analysis:

- Directorate General Mobility
- Syntus
- DB Schenker
- ACTS

The lacking of the three TOCs is considered to be somewhat "problematic" as the principle of DGMo is to leave the trade-off process of the PIs to the rail sector (see also interview report). Especially the absence of DB Schenker, by far the largest cargo TOC, leads to an incomplete picture of the preference models of cargo TOCs as a whole.

Another element relating to representation should be mentioned. As mentioned before, the assumption was made that one respondent should be able to reflect the perceptions of the entire stakeholder organization. As the involved respondents were experienced people with a highly responsible position and with either a good perception with company objectives or with actual policymaking responsibilities, this assumption is rather plausible. This assumption indicates that the stakeholder organization would have one perception, although there is a possibility that different or even conflicting perceptions exist within that stakeholder organization. Unfortunately, due to the lacking of more respondents per organization, it cannot be tested whether there are internal

78 Due to a perfect correlation or perfect milticollinearity.
79 …and since this analysis is used to estime the preference models, this validation technique could be appropriate here.

differences. We can therefore only assume that the respondent reflects one, and the only, perspective of the entire organization[80].

As explained in section 1.4, the lacking of hierarchical mechanisms for safeguarding public values could result in a deficient sense of urgency to participate. The lacking cooperation of these four stakeholders and limited participation of one respondent per stakeholder, could be a result of that.

### 4.8.2 Overall model fit

"The coefficient of determination, or R-square ($R^2$), is a measure of the proportion of the variance of the dependent variable about its mean that is explained by the independent, or predictor, variables. The coefficient can vary between 0 and 1. If the regression model is properly applied and estimated, the researcher can assume that the higher the value of $R^2$, the greater the explanatory power of the regression equation, and therefore the better the prediction of the dependent variable" (Hair et al., 1998). In other words: the higher the $R^2$, the better the estimated preference model is able to predict the stakeholder satisfaction in terms of a numerical rating. When individual models are estimated, which is the case here; the R2 is often high and is dependent on the degrees of freedom, which can be calculated by: [the number of samples] minus [the number of coefficients]. For the estimation of the individual models in this study the degrees of freedom are six[81]. As zero degrees of freedom would result in a perfect model fit, $R^2$=1; it is expected that six degrees of freedom would result in a high $R^2$, but less than 1.

The R-squares in the individual preference models range from 0.86 to 0.973, which means that between 86% and 97% of the variance of the stakeholder ratings can be explained by the individual preference model.

The coefficients of determination give confidence to the models' prediction power.

### 4.8.3 Face validity

The face validity can first of all be determined by analyzing the part-worth utilities; their significance levels but especially their direction.

As every individual model is estimated based on the information acquired from one respondent, the part-worth utilities hold for that particular respondent. Significance levels larger than 0.05 means that the coefficient cannot be assumed to exist (=0) for the population (but again: does hold for that respondent and thus the organization). Not being able to generalize the model is not considered to be a problem in this study as the respondent is assumed to represent the actual organization.

Concerning the direction of the attribute levels; there are two preference models containing inconsistencies: ERS Railways and NS Hispeed.

80 One should be aware that this assumption might not be true in reality, as internal differences are not uncommon within an organization. However, the type of respondents (CEOs and senior staff) would increase the representativeness for their organization.

81 16 samples minus 10 coefficients (9 plus the constant).

Table 16: Inconsistencies in attribute levels and coefficients for ERS and Veolia

| ERS Railways | Average rating | Part-worth utility | p-value | Range | Relevance |
|---|---|---|---|---|---|
| % Trains needing re-planning | | | | | |
| 5 | 2.5 | 0.062 | 0.889 | 0.501 | 8.4% |
| 7 | **2.75** | 0.313 | 0.493 | | |
| 9 | 2.25 | -0.188 | 0.677 | | |
| 11 | 2.25 | -0.187 | | | |

| NS Hispeed | | | | | |
|---|---|---|---|---|---|
| % Trains needing re-planning | | | | | |
| 5 | 4.25 | 0.063 | 0.773 | 0.752 | 13.7% |
| 7 | **4.5** | 0.313 | 0.182 | | |
| 9 | 4.25 | 0.063 | 0.773 | | |
| 11 | 3.75 | -0.439 | | | |

As can be seen in the Table 16, the direction of the part-worth utilities is unexpected. One would expect every increase in the percentage of trains needing re-planning, which is some sort of planned hindrance, to be valued less positive. But an increase in hindered trains from 5% to 7%, in the first table, results in an increase in rating and cannot be logically explained. The same holds for the second table where an increase from 5% to 7% also results in an increase in rating. The part-worth utilities for these two stakeholders, for that attribute, are not very reliable. As the relevance is small for both stakeholders this is not considered to be a large problem, but one has to take this into account when interpreting the results. When predictions are made using the preference models, as will be done in the next chapter, it would be more plausible to assume linearity for the attribute levels than to assume that an increase in hindrance is considered to be positive.

Overall, the preference models have rather good face validity. For every stakeholder, 9 coefficients are estimated which means 54 coefficients in total. Inconsistencies for 2 out of 54 (=3.7%) is not to be regarded as poor. Moreover, the inconsistencies only exist in the attribute which is least important for that stakeholder.

Another way to assess the face validity of the preference models is to compare the part-worth utilities and relevance percentages with information from the interviews (and policy documents) and check for inconsistencies. In interviews with TOCs it was often pointed out that the unplanned unavailability would result in much hindrance and possibly high financial damages (see also section 3.3.3). It is therefore expected that the attribute "% (unplanned) hindered trains" would be most important. Especially the cargo TOCs, being active in a highly competitive market, pointed out that the costs of using the rail infrastructure are also of great importance. Therefore, it is expected that the satisfaction of cargo TOCs would be largely affected by the "% change in usage rate". The importance of the unplanned unavailability for all TOCs and importance for usage costs for cargo TOCs is as expected. Interestingly, NS Hispeed's satisfaction is also largely affected by the usage rate, while this was not very explicitly mentioned in the interview[82]. When looking at the importance of the usage rate for TOCs it can be concluded that NS Reizigers' satisfaction is hardly affected by this

82 Other than: "the price/quality should be balanced"

performance, which could confirm the (lack of) efficiency pressure although operating in a competitive market.

In the interview with the regional public authority Gelderland, the importance of the unplanned unavailability was also pointed out. Planned unavailability was suggested to be less important and the costs even less than that, which is verified in Syntus' concession (including the conditions) and evaluations of Syntus' performances. Interestingly, the expected ranking does not match with the preference model of Gelderland, but does match the model of Overijssel. One should therefore be careful in drawing hard conclusions based on the preference model of the province of Gelderland as the ranking of the performance indicators does not precisely reflect their preferences from the interview and the concession conditions. Again, the relevance percentages are, in general, as can be expected by analyzing the interview reports and policy documents.

And lastly, looking at the regression intercept or constant (representing the average rating of all profiles that were realistically chosen), ranging between 2.375 and 4.188; the stakeholders are very critical at the performance of the rail infrastructure which is not unexpected as every stakeholder gave a critical response to the interview question relating to the current performance of the rail infrastructure. However when we look at for instance NS Hispeed; it is mentioned in the interview that the performance of the rail infrastructure is generally considered to be sufficient, which is why one would expect an average rating of higher than a 6 while the actual average rating is 4.188 and the rating for the holdout (which is the actual current performance) is even less: 3. These unexpected ratings can be explained by looking at the interview, where the interviewee pointed out that NS Hispeed is not often hindered by unplanned malfunctions. It could be caused by the fact that that the percentages of hindered trains were, on average, very high for NS Hispeed's perception, which could results in overall low ratings.

### 4.8.4 Prediction power

Next to the coefficient of determination, as explained in 4.8.2, the prediction power can also be tested by actual checking it. Therefore, a holdout profile was included in the questionnaire. This holdout was not used to estimate the conjoint preference models and is therefore suitable for testing the actual prediction power of the models. Table 17 presents an overview of the actual and predicted ratings of all stakeholders.

Table 17: Actual and predicted ratings of holdout profile

| **Stakeholder** | **Actual holdout rating** | **Predicted holdout rating** | **Absolute difference** |
|---|---|---|---|
| ***Overall aggregated model*** | 3.83 | 3.33 | 0.5 |
| ***NSR*** | 3 | 2 | 1 |
| ***NS Hispeed*** | 3 | 4.126 | 1.126 |
| ***ERS Railways*** | 3 | 3.127 | 0.127 |
| ***Veolia Cargio*** | 5 | 2 | 3 |
| ***Province of Gelderland*** | 5 | 4.626 | 0.374 |
| ***Province of Overijssel*** | 4 | 4.126 | 0.126 |
| Total average | 3.83 | 3.33 | 0.89 |

One should keep in mind that, because the profiles could only be rated by whole numbers, the expected difference of **0.5.**

Looking at the column with the absolute differences we can conclude that, except for one stakeholder, the prediction power of the preference models are good. Especially when keeping in mind that the models cannot, on average, account for differences of 0.5. However, the prediction power of Veolia Cargo seems rather poor, based on the absolute difference of 3(!). One should therefore be careful in interpreting the individual model of Veolia's preference results.
But overall, with high R-squares and hardly any inconsistent directions of the part-worth utilities, there is no particular reason to assume that the preference models have a poor prediction power.

### 4.8.5 Attribute importance

Appendix W gives an overview of the rankings of the performance indicators, determined by (1) model estimation and (2) direct ranking by the respondents. Unfortunately, it can be concluded that the rankings of these stakeholders are useless as it was only allowed to use a ranking position once, as explicitly stated in the questionnaire. NS Hispeed, Veolia Cargo and the province of Gelderland have probably not understood the question, and therefore any conclusions based on these direct rankings would be unreliable.
Lastly, in chapter 3 we expected that the aspect of safety could become a dominant attribute as most stakeholders considered this to be a limiting condition that should be guaranteed. Looking at the last column, assuming every stakeholder did understand what "most important" meant and acted accordingly, five out of six stakeholders ranked "safety" to be the most important element. However, ERS Railways ranked "safety" least important. Judging by ERS's interview report; this is likely to be incorrect[83].

### 4.8.6 Linearity of the part worth utilities

As the values of the attribute levels increase in a linear manner, one would intuitively expect the part-worth utilities to increase likewise. It is however possible that some in- or decreases in attribute levels would be extra positive or negative for the stakeholder without being inconsistent or unreliable.
The relation between the attribute levels of the three attributes for all stakeholders is summarized in Table 18.

Table 18: Linearity of attribute levels

| Attribute level relation | # of occurances |
|---|---|
| ***Linear*** | 1 (6%) |
| ***Non-linear*** | 15 (83%) |
| ***Inconsistent*** | 2 (11%) |
| ***Total*** | 18 |

83 Small anecdote: perhaps that is why an ERS Railways train derailed at Vleuten on March 23 in 2009: safety aspects were underestimated…which could mean that ERS's ranking was correct at the time, but has probably been adjusted after the incident. Safety could have become the dominant PI for ERS.

From the individual preference models can be concluded that 83% of the part-worth utilities within an attribute is non-linear, which implies that in most cases a linear increase of an attribute level would not result in a linear increase or decrease of part-worth utility. This non-linearity is an important characteristic when predictions are made as will be done in chapter 5. See Appendix U for an impression on how these three different relations look like.

### 4.8.7 Reliability of stakeholder ratings

In the interviews with the stakeholders we have asked for a (qualitative) value judgment on the current performance of the rail infrastructure. Most stakeholders were very critical, but the overall feeling on the rail infrastructure performance was ranging from somewhat insufficient to rather good. And since the conjoint profiles were based on actual registry data, one should expect the average rating of the profiles to be somewhere between 4 and 8. However the stakeholders rated the profiles on average between 2.38 and 4.19 (see Table 19), which is substantially lower than was reasonable expected.

Table 19: average ratings of conjoint profiles

| Stakeholder | Average rating |
|---|---|
| Overall | 3.31 |
| NS Reizigers | 2.75 |
| NS Hispeed | 4.19 |
| ERS Railways | 2.44 |
| Veolia | 2.38 |
| Gelderland | 4.19 |
| Overijssel | 3.94 |

There are some possible causes for these ratings being lower than expected:

1. The historical registry data, on which the ranges of the attribute levels were based, could be incorrect.
2. The assumptions made from translating the registry data into the values of the attribute levels are not realistic.
3. The operationalization of the attributes are still not corresponding with how the stakeholders' perceptions, which cause interpretation problems for the stakeholders.
4. The respondents that rated the conjoint profiles have no good feeling on how the actual performance of the rail infrastructure affects the hindrance for trains.
5. The interviewees were deliberately less critical than they actually are, or the conjoint profiles were deliberately rated in a more critical manner for perhaps strategic reasons[84].
6. The ratings of the profiles are actually correct and the qualitative value-judgments in the interviews were either misinterpreted or too optimistic[85].

Further research is needed to determine the reason for these rather unexpected low ratings. Readers should therefore be careful interpreting the ratings, as they could be somewhat unreliable. The reliability of the relative importance of the performance indicators is however not considered to be negatively affected by these rating issues. The <u>relative</u> importance can still be calculated.

84 Perhaps the respondents thought that being extremely critical would cause ProRail to make more improvements in the performance of the rail infrastructure.
85 Perhaps the interviewees were being polite.

## 4.9 Conclusion

The quantitative preferences of all included stakeholders first of all showed that stakeholders are not satisfied about the current performance of the rail infrastructure. Second of all, on average, the reliability of the infrastructure proved to be, the most important performance criterion (53%), followed by the affordability (34%) and lastly availability (13%) was considered least important. In order to increase the satisfaction levels of ProRail's external stakeholders; policy measures[86] aiming at improving the infrastructure's reliability would be most effective relative to measures aiming at improving the other two performances.

With respect to maintenance on the RIS, there is a trade-off between the need for *using* the RIS on the one hand and the need for *maintenance* on the other. Somehow a balance between the two should be found. In order to reduce the technical malfunctions (*increasing* the system's reliability) planned maintenance is needed (*decreasing* the system's planned availability). The overall preference results indicate that improving the infrastructure's reliability would be positively valued, even though the infrastructure's availability is negatively affected[87].

By analyzing the individual models, there are differences in the relative importance of these performance indicators between stakeholders. Looking at the TOCs; NS Reizigers and the other three TOCs have different perceptions on the relative importance of the performance indicators relating to reliability and affordability. Furthermore, the TOCs and the public authorities have different perceptions concerning the importance of the (planned) availability.

The fact that stakeholders differently rank the importance of these performance indicators would mean that a policy measure aiming at the improvement of the infrastructure's performance cannot affect each stakeholder in a similar manner. Some stakeholders will be more positively influenced than others. Some might even be negatively affected. Eventually it is up to ProRail to decide on how to deal with these discrepancies. The following chapter will elaborate more on these discrepancies and its implications.

Lastly, the overall reliability and validation criteria give confidence in the conjoint preference models for both the aggregated and individual models. The relative importance of the performance indicators are considered to be reliable, however, one should be careful in the interpretation of the preference ratings as they appear to be somewhat low.

86 Not necessarily maintenance related.

87 Obviously this is also dependent on the size of the impact on these performance indicators. Increasing reliability with 1% that results in decreasing the availability with 90% would "probably" be negatively appreciated by all of ProRail's external stakeholders.

# 5 PREDICTING STAKEHOLDER SATISFACTIONS

*"What difference can maintenance policy make?"*

## 5.1 Introduction

In this chapter we will give a practical application of the individual preference models, which were estimated in the previous chapter. The second section will shortly explain according to which methodology the effects of three maintenance strategies have been calculated. These three maintenance strategies or concepts are further explained in section 5.3. This section is also concerned with translating the simulation output results into attribute level values corresponding with the stakeholder preference models. Section 5.4 will present the actual effects of the realistic maintenance concepts on the satisfaction level of every stakeholder. Section 5.5 will predict stakeholder preferences in extreme situations. And lastly, section 5.6 will summarize the main conclusions.

## 5.2 Deterioration model of technical components

A method through which the effects of different maintenance concepts on the RIS can be modelled is the FMECA (Failure Mode, Effects, and Criticality Analysis) methodology as described in the American Military Standard 'MIL-STD-1629A' (1980). The FMECA details all the anticipated failure modes associated with a technical system, and includes a consideration of the effect of the failure on the system. Some basic steps in performing a FMECA are: identifying the functions of a technical system, identifying failure modes of a technical system, identifying failure causes and conditions of the failure modes, and quantifying Mean Time Between Failures (MTBFs).

The deterioration behaviour of the physical components of the rail infrastructure can be simulated over time by using the Monte Carlo method. For this purpose, ProRail has an in-house simulation tool "Optimizer+", which makes use of this Monte Carlo method. This simulation tool is further elaborated on in Appendix K.

The simulation process of modelling failure behaviour with the FMECA methodology will not have a significant position in this study, but will merely be used to translate maintenance concepts, via the simulation process, into effects in terms of the PIs of the rail infrastructure corresponding with the attributes used in the conjoint analysis. Some assumptions are required as the model output, in terms of PIs, needs to be matched with the attributes and levels used in the profiles of the conjoint analysis. The next section will further explain how the model output of several maintenance scenarios is translated into matching attribute levels.

## 5.3 Maintenance scenarios

The results of the conjoint analysis, the individual stakeholder preference models, will be practically applied in this section, in order to determine the impact of maintenance activities on the satisfaction levels of external stakeholders. Stakeholder valuations will be predicted when realistic maintenance scenarios are applied to a rail-corridor. These realistic maintenance scenarios are incorporated from Fischer et al. (2008). The authors identified three alternative maintenance concepts and varied the frequencies of three arbitrarily chosen maintenance rules. The three maintenance concepts are called: 'Present performance' (Scenario 1), 'Low costs – Low performance' (Scenario 2), and 'High costs – High performance' (Scenario 3).

In the first scenario it is assumed that the chosen technical systems are maintained according to the present maintenance concept. Next, in the other two scenarios the frequencies of three of the identified maintenance rules are altered, while the frequencies of the other maintenance rules (see section 1.2.1) remain the same. In the second scenario, the frequencies of three maintenance rules are *decreased*, so instead of measuring the insulated joints two times a year, the insulation joints[88] are measured once a year. Finally, in the third maintenance scenario the frequency of the three maintenance rules is *increased*. Table 20 gives an overview of the selected three maintenance rules and their yearly frequency (the simulation inputs). Preventive maintenance rules 'Big' and 'Small' Maintenance are overhauls, with a fixed frequency, composed of several maintenance rules (Fischer et al., 2008).

Table 20: Overview of simulation inputs, from Fischer et al. (2008)

| Technical System | Preventive maintenance rule | Costs of maintenance rule | Frequency of maintenance rule | | |
|---|---|---|---|---|---|
| | | | Scen.1 | Scen.2 | Scen.3 |
| Track detection | Continuity test of insulated joint | 150 | 2 | 1 | 4 |
| Switch | 'Big' Maintenance | 1600 | 1 | 0.5 | 2 |
| Switch | 'Small' Maintenance | 800 | 2 | 1 | 12 |

An important aspect when using simulation models is finding an optimum in the number of simulation runs and a certain relevance of the output. An increase in confidence level will increase the simulation time due to an increase of simulation runs. However, the mentioned software tool enables its users to define a certain confidence level, so the number of runs is automatically calculated. In these simulations, a confidence level of 90% is used, which is below the minimum for a simulation model according to (Sargant et al., 1996). The rather low confidence level is not considered to be problematic within this study, as these scenarios are used for illustrative purposes only. However, one should be careful interpreting the model output with respect to the 'hardness' of the data. The simulation time represents a real time period of 50 years.

The model output of these three maintenance scenarios is presented in Appendix P. To be able to apply the scenarios for predicting stakeholder valuation-ratings, the model output needs to be matched with the operationalization of the attribute levels used in the conjoint analysis. The translation process from the model output in Optimizer+ to values consistent with the attribute levels is presented in Appendix Q, from which the results are shown in the table below. Although these maintenance concepts would probably affect the safety level of the rail infrastructure in a different manner, these affects cannot (yet) be calculated in Optimizer+ and are therefore not presented.

88 In Dutch: isolatie-verbindingen.

Table 21: Attribute levels of 3 scenarios

| ATTRIBUTE LEVEL | % Change in usage rate | % Hindered trains | % Trains needing re-planning |
|---|---|---|---|
| ***Scenario*** | | | |
| *1 Present performance* | 0.00% | 18.60% | 7.06% |
| *2 Low cost - low perf.* | -1.40% | 19.19% | 6.82% |
| *3 High cost - high perf.* | 4.34% | 17.11% | 7.07% |

The calculations of the attribute-values of "Scenario 1: Present performance" are based on real historical registry data, extracted from the KPI Beschikbaarheid (ProRail, 2009b). Obviously, the "% change in usage rate" is zero percent in the first scenario, as this scenario reflects the actual current situation. The attribute-values of the other two attributes in Table 21 are based on the average registry data of the three corridors that were used to create the hypothetical corridor in the conjoint analysis, as explained in section 3.7.
The attribute-values of scenarios 2 and 3 are calculated by taking into account their relative differences[89] with the present performance. As an example, Table 22 illustrates how the attribute-values of Scenario 3 are calculated.

Table 22: Calculation of Scenario 3's attribute-values

| | High cost-high perf | Calculation |
|---|---|---|
| **% Change in usage rate** | | |
| Change in maintenance costs | 9.75% | |
| Normative variable percentage | 44.50% | |
| Change in usage rate | 4.34% | [9.75% * 44.5%] |

| | | |
|---|---|---|
| **% Hindered trains** | | |
| Change in unplanned downtime due to technical malfunctions | -15.19% | |
| Technical malfunction time in reference to total malfunction time | 52.85% | |
| Change in total unplanned downtime | -8.03% | [-15.19% * 52.85%] |
| % Hindered trains in Sc1 | 18.60% | |
| % Hindered trains in Sc3 | 17.11% | [(1-8.03%) * 18.60%] |

**% Trains needing re-planning**

[89] Differences in results of the simulation model from Optimizer+.

| | | |
|---|---|---|
| Change in total maintenance time | 0.16% | |
| % Trains needing re-planning in Sc1 | 7.06% | |
| % Trains needing re-planning in Sc3 | 7.07% | [(1+0.16) * 7.06] |

Let us look at for instance the calculation of the percentage hindered trains in the table above. The unplanned downtime or unplanned unavailability due to technical malfunctions from the model results in Appendix P, in reference to the present performance is -15.19%. But since, on average in reality, only 52.85% of the total unplanned downtime is due to technical malfunctions, the change in the total unplanned downtime is less: -8.03%. And as the total unplanned downtime is directly related to the percentage hindered trains; the percentage hindered trains in scenario 3 is 8.03% less than scenario 1. And as the percentage hindered trains in Scenario1 is 18.60% (see section 4.1 for calculations); the percentage hindered trains in scenario 3 becomes 91.97% of 18.60, which is 17.11%.

## 5.4 Predicting stakeholder satisfaction

In this section, the rating based preference models will be applied for predicting the satisfaction ratings in each of the three scenarios as discussed in the previous section, in order to predict the impact of three realistic maintenance alternatives on the satisfaction levels of ProRail's external stakeholders. One should be careful in interpreting these results as "all stakeholders" are in fact only six stakeholders, and the predicted ratings of each *individual* stakeholder are based on the response of one respondent.

To be able to make such predictions, we have to make an assumption as to how the part-worth utilities develop in between the known attribute levels: we assume the part-worth utilities to have a linear connection in between the part worth utilities of each attribute level, as is displayed in Appendix U.

The predicted ratings for each of the three scenarios are shown in Table 23.

**Table 23: Predicted ratings for three scenarios**

| | ***Predicted ratings of scenario:*** | | |
|---|---|---|---|
| ***Stakeholder*** | ***Sc1: Present performance*** | ***Sc2: Low cost - Low performance*** | ***Sc3: High cost - High performance*** |
| ***All stakeholders***[90] | *3.38* | *3.49* | *3.06* |
| ***NS Reizigers*** | *2.10* | *2.05* | *2.46* |
| ***NS Hispeed*** | *4.22* | *4.41* | *3.92* |
| ***Veolia and ERS*** | *2.58* | *2.85* | *1.69* |
| ***Gelderland*** | *4.66* | *4.63* | *4.40* |
| ***Overijssel*** | *4.19* | *4.16* | *4.23* |

90 Based on the aggregated model of the six stakeholders.

Looking at the overall aggregated model (all stakeholders), one can conclude that the scenario: Low cost-Low performance is preferred, followed by the present performance and lastly the High cost-High performance scenario. Note that the range is rather small: rating shifts of +0,11 and -0,32[91]. Reasoning from the present performance; a maintenance strategy towards scenario 3 is relatively worse than a strategy towards scenario 2 is better.

To demonstrate the impact of different maintenance concepts more clearly, we shall determine the effects of different maintenance strategies on an individual stakeholder level. Let us assume that ProRail is currently in the situation which resembles scenario 1: 'the present performance' and ProRail wishes to improve the satisfaction of its stakeholders. ProRail has two available maintenance strategies which result in scenario 2 and 3. Table 24 shows how every individual stakeholder rating improves or worsens.

Table 24: Predicted changes of stakeholder rating for two scenarios

| | **Predicted rating-changes of scenario:** | |
|---|---|---|
| **Stakeholder** | ***Low cost - Low performance*** | ***High cost - High performance*** |
| ***NS Reizigers*** | **-0.06** | **+0.36** |
| ***NS Hispeed*** | **+0.19** | **-0.30** |
| ***Veolia[92]*** | **+0.27** | **-0.89** |
| ***ERS*** | **+0.27** | **-0.89** |
| ***Gelderland*** | **-0.04** | **-0.26** |
| ***Overijssel*** | **-0.03** | **+0.05** |
| **Total** | **+0.61** | **-1.93** |

Again, notice the relative slim impact of these two maintenance concepts. The largest impact on a stakeholder satisfaction is a rating decrease of 0,89.

### Applicability limits of the conjoint model in preference prediction

The results of the predicted preferences in table 23 and 24 are based upon the effects of the maintenance concepts in Fischer et al. (2008). According to the authors, the impact of maintenance concepts on the rail infrastructure performance could be more extreme than in the two scenarios that we used, by for instance including more different technical components into the simulation model or changing the maintenance frequency more excessively[93]. To know exactly how this would affect the actual performance of the rail infrastructure new simulation runs are necessary, which we have not performed in this study. Should one desire to predict the preferences of more extreme

91 This small range is due to the fact that conflicting preferences between the stakeholders are compensated as a scenario can be a positive change for one stakeholder, but a negative change for another.
92 The preference predictions of ERS and Veolia are based on the average results (aggregated) of both stakeholders and the values of these two stakeholders are therefore similar.
93 Another possibility to increase the impact on stakeholder satisfactions would be to look for improvements that are not maintenance related. Reducing third party hindrance by increasing and improving protective fences is an example of such possibility.

values of the attribute levels (as will be demonstrated in section 5.5), one should be aware of the following three limits of the model's predicting capabilities.

- One rather soft limit of the predicting capabilities of the conjoint model is whether one needs to interpolate or extrapolate to predict satisfaction ratings. The conjoint models are based on performance ranges as presented in table 1, meaning that the predicted ratings are more reliable when the performances of a situation are contained within these ranges. For instance, preference of an increased usage rate of 15% can be extrapolated, but would be less reliable as we only have preference information based on a percentage ranging to 10%.
- A second limit of the predicting capabilities of the conjoint model lies in the range of the ratings. The preference ratings cannot become negative and the maximum is 10, as the ratings of the conjoint profiles in the questionnaire could not exceed this range.
- The third and last limit of the predicting capabilities of the conjoint model is that the percentages of the first two attributes[94] need to be positive.

**Limitations in absolute terms**

The first limit on interpolation is explained in terms of values of the attribute levels. But the limits in absolute terms (terms of output in Optimizer+) are different as:
→ Affordability values are derived from the maintenance costs.
→ Reliability values are derived from the unplanned downtime of the infrastructure.
→ Availability values are derived from the planned maintenance time.

As explained in section 5.3, the performance values of three maintenance scenarios were calculated as changes relative to the current performance (=scenario 1). Using this method, we have calculated the maximum range of the maintenance concepts in absolute terms when stakeholder' satisfactions can still be calculated by interpolation. Increasing the range would mean that extrapolation is required, which is less reliable. These percentages represent changes relative to the *current situation*.

The maximum range of the maintenance costs: -11.24% to +22.47%.
The maximum range of the unplanned downtime of the infrastructure: -77.33% to +44.72%.
The maximum range of planned maintenance time: -29.13% to +55.92%.

### Policymaking decision rules

In first instance it is rather obvious what the most desirable maintenance strategy for ProRail is when the objective is to maximize stakeholder satisfaction. However, the desirability of such a strategy will probably depend on the decision rule that ProRail uses. And as not every stakeholder would be evenly important for ProRail, it is not unlikely that ProRail would not take every stakeholder's preference in an even manner into account. Let us look at three decision rules. Obviously one can think of more decision rules, however these rules are considered logical and therefore realistic:

1. Every stakeholder is evenly important (and the preference of every stakeholder will be evenly taken into consideration).

94 Relating to the reliability and availability.

2. Only TOCs are important, and in an even manner.
3. Only TOCs are important, but in accordance with their usage (…a TOC is considered more important when the organization pays more to ProRail as they make more use of the infrastructure).

Obviously, according to the *first* decision rule: the scenario: 'Low cost-Low performance' is the best option for ProRail (see table 27: +0.61 versus -1.93). The impact of the other two decision rules will be illustrated.

### *Second decision rule: TOCs are evenly important*

When only the preferences of TOCs are considered, and these preferences are taken evenly into account; the best scenario is: 'Low cost-Low performance', as it is the only scenario which results in an increase in the satisfaction of TOCs, as shown in Table 25.

**Table 25: Weighted stakeholder ratings, decision rule = TOCs are evenly important**

| Stakeholder | *Original rating change* | | *Stakeholder decision power* | *Power based rating change* | |
|---|---|---|---|---|---|
| | *Low cost - Low performance* | *High cost - High performance* | | *Low cost - Low performance* | *High cost - High performance* |
| ***NS Reizigers*** | -0.06 | 0.36 | 25% | -0.01 | 0.09 |
| ***NS Hispeed*** | 0.19 | -0.30 | 25% | 0.05 | -0.07 |
| ***Veolia*** | 0.27 | -0.89 | 25% | 0.07 | -0.22 |
| ***ERS*** | 0.27 | -0.89 | 25% | 0.07 | -0.22 |
| **Total** | 0.68 | -1.72 | 100% | **0.17** | **-0.43** |

### *Third decision rule: TOCs' importance based on usage of the infrastructure*

When only the preferences of TOCs are considered, and these preferences are taken into account according to their usage[95] of the rail infrastructure; the best scenario is: 'High cost-High performance', as it is the only scenario which results in a weighted increase in the satisfaction of TOCs, as shown in Table 26.

**Table 26: Weighted ratings, decision rule=importance TOCs based on infra-usage**

| Stakeholder | *Original rating change* | | *Stakeholder decision power* | *Power based rating change* | |
|---|---|---|---|---|---|
| | *Low cost - Low performance* | *High cost - High performance* | | *Low cost - Low performance* | *High cost - High performance* |
| ***NS Reizigers*** | -0.06 | 0.36 | 90% | -0.05 | 0.32 |
| ***NS Hispeed*** | 0.19 | -0.30 | 3% | 0.01 | -0.01 |
| ***Veolia*** | 0.27 | -0.89 | 3% | 0.01 | -0.03 |
| ***ERS*** | 0.27 | -0.89 | 3% | 0.01 | -0.03 |
| **Total** | 0.68 | -1.72 | 100% | **-0.03** | 0.25 |

95 The relative usage rates are shown in the columns "stakeholder decision power". These are a good indication of reality as the percentages were based on historical registry data for several track sections. Basing the percentages on the total usage information on a national level would be more accurate. However, this overall national information was not made available.

## 5.5 Extreme performance options

As can be observed in table 27, the impact of these two maintenance concepts is relatively slim: a change in rating between -0.89 and +0.36. In this section we will present two extreme situations (within the used range of the attribute levels: not exceeding the limits of the applicability of the conjoint models) to see how stakeholder preferences will change when the infrastructure's performance is affected more rigorously: the best option and worst option[96]. For instance, the best option means that ProRail is able to improve the reliability and availability, and do so more cost-efficient. These two situations should demonstrate the possible impact of rail infrastructure performance on the satisfaction on ProRail's external stakeholders.

**Table 27: Predicted ratings in two extreme situations**

| **Stakeholder** | ***Present performance*** | ***Best option*** | ***Worst option*** |
|---|---|---|---|
| | **Predicted ratings of scenario:** | | |
| ***All stakeholders*** | 3.38 | 5.62 | 1.29 |
| ***NS Reizigers*** | 2.10 | 5.50 | 0.50 |
| ***NS Hispeed*** | 4.22 | 7.13 | 1.62 |
| ***Veolia and ERS*** | 2.58 | 5.69 | 0.06 |
| ***Gelderland*** | 4.66 | 5.13 | 3.12 |
| ***Overijssel*** | 4.19 | 5.13 | 2.37 |

| **Stakeholder** | ***Best option*** | ***Worst option*** |
|---|---|---|
| | **Change in predicted ratings of option:** | |
| ***NS Reizigers*** | **+3.40** | **-1.60** |
| ***NS Hispeed*** | **+2.91** | **-2.60** |
| ***Veolia*** | **+3.11** | **-2.52** |
| ***ERS*** | **+3.11** | **-2.52** |
| ***Gelderland*** | **+0.47** | **-1.54** |
| ***Overijssel*** | **+0.94** | **-1.81** |
| **Total** | **+13.94** | **-12.58** |

The left-side of Table 27 are the predicted ratings, the right-side present the change in preference ratings when either the best or worst option is chosen. Table 27 shows that considerable improvements (or decline) of the rail infrastructure performance[97], will result in substantial higher (or lower) satisfaction ratings: ranging from -2.60 to +3.40.

## 5.6 Conclusion

In sum, the impact of different maintenance strategies, based on the concepts in Fischer et al. (2008), on the satisfaction of ProRail's stakeholders is present although rather small. Should these three maintenance concepts/scenarios described in 5.3 contain the maximum range of maintenance possibilities for ProRail, it is not expected that the satisfaction levels of their external stakeholders would be substantially affected. However, more extreme maintenance concepts, containing for instance a higher frequency of maintenance and including more technical components into the simulation model, would result in a substantially larger impact on stakeholder satisfactions as was demonstrated in section 5.5. Another possibility to increase the impact on stakeholder satisfactions would be to look for improvements that are not maintenance related. Reducing third party hindrance by increasing and improving protective fences is an example of such possibility.

96 Attribute levels in [reliability, availability, affordability]: best option = [11%,5%,-5%], worst option = [23%, 11%, +10%]. These performance levels have been chosen in a way that the ratings are predicted by interpolation and are not based on realistic scenarios. However, this does not mean that these performance levels are unrealistic as they could be realized by more extreme maintenance concepts than described in section 5.3, or by non-maintenance related improvements (such as reducing third party hindrance by improving the protective fences).

97 It does not matter whether this is realized by improved maintenance or other measures. The essence is that the performance of reliability, availability and affordability is improved.

Furthermore, the stakeholder preference models can be applied in (maintenance policy) decision-making, however the outcome (in terms of most desirable policy option) is highly dependent on the decision rule ProRail wishes to apply as the relative importance of the performance criteria differ amongst the stakeholders. ProRail therefore needs to determine which stakeholders are of importance with respect to this decision making process, and how relatively influential they should be.

# 6 CONCLUSION

*"What are the study's most important findings?"*

## 6.1 Introduction

In this chapter the main conclusions of this study will be summarized in relation to the posed research questions. In addition, implications and recommendations will be formulated for ProRail. Section 6.2 will summarize the conclusions for the actor analysis where the first research question will be answered; focusing on the most relevant performance indicators. In section 6.3 the conclusion of the conjoint analysis will be presented, answering the second research question; concentrating on the relative importance of these performance indicators (PIs). Section 6.4 is concerned with the application of the stakeholder preference models where the third and last research question will be answered. Finally, section 6.5 will extract implications and present recommendations for ProRail's policymakers.

The underlined sentences reflect the most important aspects within this chapter.

## 6.2 Conclusions on actor perspectives

This section will present the main conclusions on the actor analysis in the third chapter of this report and will answer the first research question:

| |
|---|
| What are, from a perspective of ProRail's external stakeholders, the most relevant performance indicators that should be considered in evaluating different maintenance concepts? |

Determining the most relevant performance indicators from a multi actor perspective required a selection of ProRail's external stakeholders to be included in this study. In order to acquire a comprehensive perspective on stakeholder preferences, it was deemed important to include stakeholder organizations that are both diverse and representative. We therefore we included eleven of ProRail's most relevant external stakeholders[98].

Information on stakeholder perspectives was acquired through qualitative interviews focusing on the desired performance of the rail infrastructure with respect to the goals and objectives of the organization. The interviewees were selected based on their capacity to answer such questions.
The interview reports were translated into causal diagrams representing each stakeholder's system perspective on how they perceive the performance of the rail infrastructure to be affected. These system perspectives are created by using the cognitive mapping methodology: Dynamic Actor Network Analysis (DANA) (Bots et al., 2000; Hermans, 2005). The actual interview reports and DANA models are presented in Brinkman and Fischer (2009) and Appendix H. Next to these interviews, we

98 We included passenger and cargo TOCS (NSR, NSHispeed, regional TOCs, ACTS, DB Schenker, ERS, Veolia), regional and national public authorities (DGMo, IVW, Province of Gelderland) and a consumer representative organization (ROVER).

have also analyzed several relevant policy documents[99] as they should contain criteria of initial importance concerning rail infrastructure performance.

The interview reports and corresponding DANA models show that the preferences of ProRail's external stakeholders can be influenced by more than just ProRail herself, and these factors which can be influenced by ProRail can be influenced by more than just maintenance policy. Due to the research focus on the effects of maintenance policy, we will discuss these aspects in section 6.5.
DANA analysis showed that, in the end, maintenance activities have an influence on four performance related clusters[100] on affordability, planned unavailability, safety and unplanned unavailability. These performance clusters in turn have an effect on the satisfaction levels of ProRail's external stakeholders. Improvements of the infrastructure could therefore better be aiming at improving one or more of these performances. For example, the results suggest that investments in improving the comfort-level or reducing environmental damage, that do not also positively affect on one of these four performances, could better be spent by improvements on affordability, unplanned and planned unavailability and/or safety.
Changing maintenance activities would result in developments that stakeholders would appreciate both positively and negatively. For example: increasing maintenance activities would on the one hand positively affect the safety level and unplanned unavailability of the infrastructure, but on the other hand would negatively affect the affordability and planned unavailability of the infrastructure. Clearly there are trade-offs involved and in order to appraise maintenance one needs to have information on the relative importance of performance criteria, which is the main concern of the next section.

Based on the analysis on policy documents, the interview reports and DANA models we come to the conclusion that, from a multi actor perspective, the most relevant and maintenance related performance indicators are:

- **Affordability**: the affordability of the rail infrastructure.
- **Availability**: planned unavailability of the rail infrastructure.
- **Reliability**: unplanned unavailability of the rail infrastructure.
- **Safety**: the safety of the rail infrastructure.

These four performance indicators will provide the basis for the attribute selection in the conjoint analysis.

## 6.3 Conclusions on stakeholder preference analysis

This section will present the main conclusions on the conjoint analysis in the fourth chapter of this report and will answer the second research question:

> How relatively important are the most relevant performance indicators (question 1) to each of the relevant external stakeholders?

99 ProRail's management concession, Transport concession of the main railsystem, ProRail's Network Declaration, ProRail's Maintenance Plan and the Second Bill on railway safety.
100 Consisting of several factors relating to that specific performance type.

### Preceding to the conjoint analysis

All four most important elements determining the stakeholders' trade-off behaviour should normally be included in the conjoint analysis. However, the aspect of safety is somewhat special, as the attributes of a conjoint analysis should reflect a characteristic or quality that involves a trade-off (Hair et al., 1998; Molin, 1999). After analyzing the interview reports on the responses when safety is mentioned, it becomes apparent that most stakeholders do not regard safety as a characteristic that involves a trade-off. Most of ProRail's external stakeholders consider safety a boundary condition that needs to be safeguarded. Although most stakeholders realize that 100% safety is not realistic, they do expect the rail infrastructure to be safe and are not, and perhaps should not be, concerned with the involved trade-offs. Including safety in the conjoint analysis introduces considerable risks, and therefore, safety has been excluded as an attribute in the conjoint analysis.
Since 'safety' is the primary concern of the Safety Inspectorate IVW, this stakeholder was excluded for the conjoint analysis. Furthermore, one regional TOC was included, "Syntus", instead of ProRail's specialist. Therefore, ten stakeholder organizations were approached for participating in the conjoint analysis by sending a link to an internet questionnaire.
The conjoint analysis was applied using a rating based, stated preference approach where every respondent needed to rate a situation containing performance information on a section of the rail infrastructure on a scale of 1 to 10.

The values of the attribute levels were created based on actual historical registry data (ProRail, 2009b), averaging three existing and intensively used corridors with an average length of 130 km: Rotterdam – Zevenaar border, Amsterdam – Eindhoven, and Amsterdam – Roosendaal border. In determining the values of the attribute levels concerning the affordability or "percentage change in usage rate", policy documents on the calculation of the financial usage tariffs have been used (ProRail, 2005d), to relate the maintenance costs to these rates.

### Overall stakeholder preferences

Of the ten stakeholders that were approached for rating the conjoint profiles: five completed the questionnaire and one, ROVER, was not able to answer the questions as the operationalizations of the performance indicators did not match ROVER's state of mind. This will be dealt with further in chapter 7. Furthermore, one stakeholder, Province of Overijssel, participated while not directly being approached. In total, six individual preference models could be estimated, shown in Appendix R. The aggregated model results of these six stakeholders are presented in Table 28.

**Table 28: The (aggregated) overall preference model, based on: NSR, NSHispeed, ERS, Veolia, Gelderland and Overijssel**

| **Aggregated overall preference model** | | | | | | |
|---|---|---|---|---|---|---|
| | | **Average rating** | **Part-worth utility** | **p-value** | **Range** | **Relevance** |
| **Overall utility (constant)** | | 3.312 | | 0.000 | | |
| **% Hindered trains** | | | | | | |
| 11 | | 4.54 | 1.229 | 0.000 | 2.291 | 53% |
| 15 | | 3.54 | 0.229 | 0.070 | | |
| 19 | | 2.92 | -0.396 | 0.009 | | |
| 23 | | 2.25 | -1.062 | | | |
| **% Trains needing re-planning** | | | | | | |
| 5 | | 3.54 | 0.229 | 0.070 | 0.583 | 13% |
| 7 | | 3.54 | 0.229 | 0.070 | | |
| 9 | | 3.21 | -0.104 | 0.356 | | |
| 11 | | 2.96 | -0.354 | | | |
| **% Change in usage rate** | | | | | | |
| -5 | | 4.17 | 0.854 | 0.000 | 1.458 | 34% |
| 0 | | 3.50 | 0.187 | 0.122 | | |
| 5 | | 2.88 | -0.437 | 0.006 | | |
| 10 | | 2.71 | -0.604 | | | |
| | | | | | | **Check** |
| **R Square** | 0.981 | | **Total Range:** | | 4.332 | 100.0% |
| **Adjusted R Square** | 0.952 | | | | | |

The overall utility, or constant, is 3.312, which means that on average the profiles have been rated with a 3.312. Since the possible ratings of the profiles ranged between 1 and 10, one can conclude that, on average, all profiles were very unsatisfactory for the stakeholders.

Furthermore, the holdout profile was on average rated with a 3.83. And since the holdout profile was based on the actual rail infrastructure performance, it is likely that the stakeholders are not satisfied about the current performance of the rail infrastructure system[101]. The results suggest that substantial infrastructural improvements are required to realize a significant improvement in the overall satisfaction levels of ProRail's external stakeholders.

The part-worth utility of '11% hindered trains' is +1.229, which normally means that the stakeholders consider 11% trains hindered as 'positive'. However, as can be read from the first column, the inclusion of that attribute level in the profiles results in an average rating of 4.54, which should still be considered insufficient.

101 Based on the attribute levels in the profiles.

On average for all included stakeholders reliability is considered the most important attribute (53%), followed by affordability (34%) and lastly, availability (13%) is considered to be least important. Changes of the infrastructure performance would have a greater impact on stakeholder satisfactions when focusing on the most important performance criteria: improving the infrastructure's reliability would be more effective in increasing stakeholders' satisfactions than improving the availability. And vice versa; decreasing the reliability would be worse.

### Individual stakeholder preferences

By analyzing the preference behaviour of each individual stakeholder, we found that there are differences in the relative importance of the performance indicators between stakeholders. Looking at the TOCs; NS Reizigers and the other three TOCs have substantial different perceptions on the relevance of the performance indicators relating to reliability and affordability. Furthermore, the TOCs and the public authorities have considerable different perceptions concerning the importance of the (planned) availability.

Lastly, the overall reliability and validation criteria give confidence in the conjoint preference models for both the aggregated and individual models. The relative importance of the performance indicators are considered to be reliable, however, one should be careful in the interpretation of the preference ratings as they appear to be somewhat low.

The conjoint analysis has shown that significant differences do exist between stakeholders with respect to the relative importance of these performance indicators. Eventually it is up to ProRail to decide on how to deal with these discrepancies, but the implications have been demonstrated in chapter 5 and will be summarized in section 6.4.

## 6.4 Conclusions on stakeholder preference prediction

This section will present the main conclusions on the application of the preference models in the fifth chapter of this report and will answer the third research question:

| |
|---|
| How will the effects of different maintenance concepts affect the satisfaction of all relevant external stakeholders? |

The application of the preference models is made by predicting the stakeholder satisfaction of the effects when different maintenance concepts or scenarios are applied. Fischer et al. (2008) have calculated the effects of three maintenance scenarios using the FMECA (Failure Mode, Effects, and Criticality Analysis) methodology as described in the American Military Standard 'MIL-STD-1629A' (1980) and Monte Carlo simulation. The simulation results from Fischer et al. (2008) are used to translate three maintenance scenarios into effects in terms of the PIs of the rail infrastructure corresponding with the attributes used in the conjoint analysis.

Based on the preference models, we have predicted the quantitative satisfaction for the stakeholders in each of the three scenarios. And to demonstrate the applicability of the conjoint model results in further detail, we have determined the effects of different maintenance strategies on the satisfaction ratings individual stakeholders.

Overall (row: Total), one can conclude that the scenario 2: Low cost-Low performance is preferred, followed by the present performance and lastly the High cost-High performance scenario. Analyzing from the present performance; a maintenance strategy towards scenario 3 is relatively worse than a strategy towards scenario 2 is better. Note that the impact of these maintenance concepts on stakeholders' satisfaction levels is relatively slim. The largest impact on a stakeholder satisfaction is a rating decrease of 0.89.

Table 29: Predicted changes of stakeholder rating for two scenarios

| | **Predicted rating-changes of scenario:** | |
|---|---|---|
| **Stakeholder** | ***Sc2: Low cost - Low performance*** | ***Sc3: High cost - High performance*** |
| ***NS Reizigers*** | **-0.06** | **0.36** |
| ***NS Hispeed*** | **0.19** | **-0.30** |
| ***Veolia***[102] | **0.27** | **-0.89** |
| ***ERS*** | **0.27** | **-0.89** |
| ***Gelderland*** | **-0.04** | **-0.26** |
| ***Overijssel*** | **-0.03** | **0.05** |
| **Total** | **0.61** | **-1.93** |

The results of the predicted preferences in Table 29 are based upon the effects of the maintenance concepts in Fischer et al. (2008). According to the authors, the effects of maintenance concepts on the rail infrastructure performance could be more extreme than the two scenarios that we used. Should one desire to predict the preferences of more extreme values of the attribute levels, one should be aware of the several limits of the model's predicting capabilities, described in section 5.4. In section 5.5 we have showed that more extreme performance levels[103] would result in substantially intensified preference ratings. This means that in order to considerably improve stakeholders' satisfactions, more excessive performance improvements are required than maintenance concepts could probably provide. Perhaps maintenance concepts could be further enhanced but performance improvements due to other policy measures seem necessary.

It is obvious that the effect of different maintenance concepts on stakeholders' satisfactions differs amongst stakeholders. Some stakeholders are more positively or negatively affected than others and in some cases the effect is conflicting; meaning that the implementation of some maintenance measures would positively affect some whilst negatively affecting others. These differing and even conflicting impacts make it difficult to determine a desirable strategy.

102 The preference predictions of ERS and Veolia are based on the aggregated model and therefore, the values of these two stakeholders are similar.
103 More extreme than the effects of these three maintenance scenarios extracted from the Monte Carlo simulation.

The desirability of such a (maintenance) strategy depends on the decision rule that ProRail uses concerning the relative importance of their external stakeholders. And as not every stakeholder would be evenly important for ProRail, it is unlikely that ProRail would take every stakeholder's preference in an even manner into account. The most desirable maintenance strategy proved to be highly dependent on which decision rule ProRail would choose to apply. ProRail should therefore be meticulous in determining the decision power of their external stakeholders.

## 6.5 What can ProRail learn from this study?

This section is concerned with the implications specifically for ProRail and will present recommendations based on the results of this study. Implications and recommendations will be given based on the actor and conjoint analysis. And lastly, some general recommendations will be provided on aspects that were not the primary focus of this study, but nonetheless would be of interest to ProRail. Within each subsection there is a ranking of importance applied, where the first bullets are considered to be relatively more important.

### 6.5.1 Implications and recommendations based on the actor perspectives

**Jointly develop performance indicators with rail sector and improve communication on the status of these performances.**

Current PIs do not seem suitable. Stakeholders' responses with respect to some PIs were that these are hard to interpret and/or stakeholders were not certain whether these PIs were a good reflection of the actual performance. Stakeholders' perceptions on the current performance were very inconsistent and not well founded. Jointly[104] determining which PIs to apply and how to measure these PIs would make the performance evaluation more practically relevant. This approach would (more easily) reconcile the stakeholders' interests and result in a jointly satisfactory solution, according to the principles of Principled Negotiation (Fischer and Ury, 1983; Adler and Blue, 2002). Such PIs could provide a new basis for future performance agreements with TOCs as most TOCs are willing to invest in an increased performance of the rail infrastructure. It would then be imperative that ProRail informs the TOCs on how the performance will be improved for their organization. PIs based on the perspectives of TOCs could become (both communicatively and financially) beneficial for ProRail.

**Clarify the importance of conflicting performance criteria "availability" and "safety" within the Ministry of Transport.**

Conflicting preferences from two departments within the Ministry of Transport: DGMo and IVW, with respect to safety and availability could be difficult for ProRail to cope with. "When is which aspect more important?" These conflicting issues should be solved within the Ministry to determine how ProRail is expected to make such a trade-off. However, ProRail had already identified this problem and indicated that this issue is not easily solved. One step towards solving this issue could be to present different scenarios to the Ministry containing different performance levels of both *availability* and *safety*[105], and make the Ministry decide on which scenario is preferred. This information could be used to derive when availability is more important than safety and vice versa.

104 With ProRail's external stakeholders, more especially the TOCs, since DGMo expects the rail sector to create the PIs.
105 Including financial effects could also be of interest.

**Become more internationally oriented.**

The national, or lack of international, character of ProRail (especially with respect to ProRail's Traffic Guidance) negatively affects international TOCs. Examples of characteristics that cause problems relating to this are: different time slots and lack of clustered maintenance activities with adjacent countries[106].

**Improve balance between capacity and flexibility.**

Especially according to the cargo TOCs; the Dutch rail network lacks flexibility due to the fact that the time slots are small (just 3 minutes, which increases the capacity). Most cargo TOCs would greatly benefit from a more flexible network as one small delay could result in large delays in the end. Bearing in mind that cargo transport on the rail network is expected to increase more than passenger transport; ProRail would be wise to take this into consideration.

**Be aware of regional transportation authorities: demonstrate added value.**

ProRail should be aware of the dissatisfactions of the regional public (transport) authorities. At the moment the regional authorities are jointly lobbying for more authority with respect to maintenance projects. On the long term, these developments could become a threat for ProRail's IM department. This threat could be diminished when ProRail is able to demonstrate their added value to the regional authorities. Their perception at the moment is that ProRail is responsible for many unnecessary delays (with respect to construction projects).

**Do not include all external stakeholders in trade-off decisions concerning safety.**

The most important infrastructure related performance indicators that maintenance can influence are: reliability, (planned) availability, affordability and safety. The safety of the rail infrastructure should be guaranteed according to the stakeholders. Although many stakeholders understand the impossibility of this, stakeholders other than IVW have no interest in dealing with the trade-offs that are involved concerning safety. This is ProRail's responsibility, under supervision of IVW.

**Do not regard safety standards as "rigid".**

Safety standards/measures that ProRail uses are not that "hard". When ProRail can prove why a safety measure should be adjusted, the IVW is willing to accept this. Some standards might be too severe, whilst other standards might be not strict enough. IVW expects ProRail to take such initiatives.

106 When planned maintenance activities on a similar track section that crosses borders are not simultaneously executed, but chronologically after one another (as was the case with the Betuweroute, according to Veolia Cargo). An international TOC cannot operate on that track when there are maintenance activities being performed in the neighboring country.

**Create a direct line of communication with ROVER.**

At the moment ROVER does not have a direct and regular line of communication with ProRail. Their preferences are indirectly communicated to ProRail through TOCs, who can use this information strategically. For ProRail, being able to verify information directly with ROVER could be desirable.

### 6.5.2 Implications and recommendations based on the preference models

**Do not consider every performance indicator evenly important, and realize that the relative importance of these PIs differ amongst stakeholders.**

According to all stakeholders[107] the ranking of the importance of the rail infrastructure related performance indicators are: 1: reliability, 2: affordability and 3: availability. However, there are (significant) differences between stakeholders, meaning that basing policy decisions on maximizing the overall stakeholder satisfaction involves disappointing some stakeholders.

**Prioritize amongst external stakeholders with respect to decision power.**

Within the TOCs: NS Reizigers has substantial preference differences from ERS, Veolia and NS Hispeed. And overall: the regional authorities' preferences differ substantially from the TOCs. These diverging preferences make it imperative for ProRail to determine in what manner each stakeholder preference should be considered when evaluating their policy options. Based on the results of the conjoint analysis it is not possible to affect each stakeholder in a similar manner with one maintenance strategy. Prioritization is necessary.

**Extreme policy measures are required to substantially increase stakeholders' satisfactions, which do not necessarily need to be maintenance related.**

The influence of different maintenance scenarios on the stakeholders' satisfaction ratings is rather limited: a rating *change* ranging between -0.89 to +0.36 (on a scale of 1 to 10) when a change in strategy is implemented. To increase the satisfaction ratings further, more extreme measures are required. And since maintenance activities are not the only influence on these PIs, measures to increase stakeholder satisfaction should also be searched for in other areas; such as reducing third party malfunctions and clustering of construction activities. In general, policy measures focusing on improving the reliability would be more effective in increasing stakeholder satisfaction than measures focusing on planned availability.

**Make a hard distinction between the Key Performance Indicators focusing on the infrastructure's *planned* and *unplanned* unavailability, including their relative importance in the overall evaluation.**

In evaluating ProRail's performance of the rail infrastructure, it seems desirable to make a distinction between the reliability and the (planned un-) availability. At the moment there are three Key Performance Indicators (KPIs) relating to the performance of the rail infrastructure (see also Appendix O): the KPI Punctuality, the KPI planned unavailability and the KPI unplanned unavailability. Constraints or boundary values[108] exist on these KPIs and;

107 Based on the aggregated preference model.
108 In Dutch: grenswaarden

DGMo will heavily sanction exceeding these conditions. In practice ProRail often uses one measure for the availability, combining the unplanned and planned variant[109]: an availability percentage of 99,xx percent. Besides the fact that external stakeholders can hardly interpret such a number, there is another more important reason to avoid one measure concerning the availability of the rail infrastructure: it implies that one hour of planned unavailability results in similar hindrance as unplanned unavailability[110], while the results of this study strongly indicates that this is not the case. Furthermore, the KPI Punctuality and the KPI unplanned unavailability seem to overlap for a large part. The following would probably be an improvement for ProRail:

- Do not merge the unplanned and planned unavailability of the rail infrastructure into one KPI (see also appendix O).
- With respect to KPIs focusing on the availability and reliability of the rail infrastructure: use two instead of three KPIs to avoid overlap.
- In evaluating the rail infrastructure performance; prioritize amongst the KPIs as not every performance criterion is evenly important.
- In order to improve communication and agreements concerning the performance of the rail infrastructure, the operationalization should become more practically relevant, increasing the TOCs' perspective. Like in this study; performance expressed in the number or percentage of hindered trains appears to be a good option. TOCs will then have a better perspective on how performance improvements will affect their company objectives and will probably be more willing to invest in these future improvements.

### 6.5.3 Remaining recommendations

**Create a sense of urgency for negotiations, between ProRail and her relevant external stakeholders, on trade-offs regarding performance criteria, by demanding a hierarchical intervention by the Ministry.**

The infrastructure provides a collective value to many of ProRail's external stakeholders and therefore the infrastructure provides a public value, as explained in section 1.4. The main focus of this study is on how public values can be safeguarded. We argued that these values can be safeguarded by managing the infrastructure correctly; meaning that ProRail has that ability. But in order to safeguard these public values we first needed to know (1) which elements (or performance criteria) determine the public value, (2) the trade-off behaviour of stakeholders regarding these elements, and (3) how different situations impact the overall public value. Now that we have (quantitative) stakeholder information on these three important aspects ProRail needs to think on how to actually safeguard these public values.

As De Bruijn and Dicke (2006) have discovered that a combination of the two safeguarding mechanisms *network* and *hierarchy* is very suitable for realizing a solution that is satisfactory for all involved stakeholders, we believe that intensive negotiations between ProRail and their external stakeholders could help ProRail in managing the infrastructure in a way that is satisfactory for all involved. Perhaps the results of this study could be used as a starting position, indicating that differences in infrastructure performance are differently valued amongst stakeholders. However, this

109 Which can be explained as there is also a separate constraint for the combined "KPI Beschikbaarheid", see also appendix O.

110 ProRail does take the difference in hindrance into account by incorporating not only the length of the unavailability, but also the number of 'railzones' (in Dutch: spoorzones) being affected. The effects of the hindrance in terms of the resulting time delays are, however, not taken into account.

negotiation process has little chance of succeeding without a hierarchical intervention by the Ministry as stakeholders could lack a sense of urgency to participate, which currently seems to be the case. This would certainly explain the lacking stakeholder response in this study with respect to the preference analysis (see section 4.8.1). Therefore, ProRail should increase the stakeholders' sense of urgency by requesting[111] such a hierarchical intervention, obligating the entire rail sector (ProRail and external stakeholders) to participate in the process of dealing with the problem of differing trade-off behaviour with respect to the infrastructure's performance.

**<u>Improve relations with external stakeholders.</u>**

The relation between ProRail and its external stakeholders has potential for improvement. The lacking response rates with the conjoint analysis; four stakeholders have not responded and only one respondent per stakeholder, is rather unexpected. Especially bearing in mind that we had already made contact during the explorative interviews where every stakeholder offered to cooperate by filling out the questionnaires on the Internet. Moreover, most stakeholders were enthusiastic on the focus of this study and recognized the importance for their organization.

An explanation for the lacking response rates is therefore rather difficult. Perhaps, the stakeholders, mainly the TOCs[112], did not get the impression that their preferences would actually be considered in ProRail's policymaking.

111 Or even demanding.

112 DGMo gave notice of having no sufficient time available.

# 7 REFLECTION

*"Critical notes and suggestions for further research"*

## 7.1 Introduction

In this chapter some critical notes will be made in relation to assumptions, demarcations and methodologies in this study. In addition, possible directions for further research will be presented. Section 7.2 will reflect on the stakeholder selection and its implications. Next, section 7.3 will elaborate on the performance indicators that are extracted from the DANA models and used in the conjoint analysis. Section 7.4 will give a reflection on the conjoint analysis; on the usability of the preference models for policy evaluation in reference with other possible methods. Section 7.5 deals with the remaining reflective comments and lastly, section 7.6 will elaborate more on possibilities for further research.

## 7.2 Reflection on stakeholders

- Eleven of ProRail's external stakeholders were included in this study. These stakeholders were selected in a way that the types of stakeholders were diverse and represented a large part of the market. But taking into account all TOCs and public authorities, ProRail has over sixty stakeholders. One should be careful to extrapolate the stakeholder preference results in this study to all of ProRail's external stakeholders. Especially since the individual conjoint models have indicated that there are differences within stakeholders apparent, even within the same stakeholder group such as passenger TOCs.
- Furthermore, only one respondent per stakeholder was included in the conjoint analysis. We have made the assumption that one respondent should be able to reflect the perceptions of the entire stakeholder organization. However, one should be aware that this assumption might not be true in reality, as internal differences are not uncommon[113] within an organization[114]. There is a possibility that different or even conflicting perceptions exist within that stakeholder organization. Unfortunately, due to the lacking of more respondents per organization, it could not be tested whether there are internal differences and one should therefore be careful in interpreting the individual models in terms of representing the *entire* organization.
- Lastly, this study has focused on the effects of ProRail's maintenance activities on the *external* stakeholders. It is highly likely that ProRail's internal departments are also affected, possibly in a different and conflicting manner. Based on this study, we cannot determine in what manner ProRail's internal departments are influenced by their maintenance activities.

## 7.3 Reflection on performance indicators

- We used DANA analysis to acquire the perspectives of ProRail's external stakeholders regarding their goals, objectives and preferences on the performance of the rail infrastructure. We chose to make use of this methodology because DANA is able to grasp an actor's point of view into a causal map that contains factors which are useful as input for further analyses steps in this study.

113 See also the discrepancy within the Ministry of Transport between DGMo and IVW on "safety" and "availability".
114 However, the type of respondents (CEOs and senior staff) would increase the representativeness for their organization.

Although we did not make full use of the capabilities that DANA provides; such as quantitative analysis, the causal mappings of each stakeholder proved to be useful. In first instance because the causal diagrams were much more structured and therefore easier to interpret than the interview reports. The essence of the stakeholders' perspectives was more clearly visible. Secondly, because the factors each causal mapping could be counted and clustered in order to derive the most important performance clusters. Although the number of factors in the DANA diagrams does not necessarily reflect the measure of importance[115], they did correspond substantially with criteria of importance in the analysis of several policy documents and in the overall (analyst view) perspective. DANA analysis, more specifically the structuring of the interviews in cognitive causal maps, proved to be useful in determining the most important factors that could be used for the purpose of further analysis.

- The performance indicators that are extracted from the DANA models and used as a basis for the attributes in the conjoint analysis, were only included if and only if ProRail´s maintenance activities could have a significant influence on these performance indicators. During the interviews it became rather obvious that ProRail's influence on stakeholders is far more extensive than their maintenance activities. Especially the TOCs are probably even more affected by ProRail´s departments of Capacity Management (CM) and Traffic Guidance (TG). Although it was not the focus of the interviews, the overall perception of the performance of CM and TG was rather negative. Therefore this study, due to its focus on maintenance policy, has limited capabilities of improving the satisfaction of ProRail's external stakeholders.
- We decided to operationalize the performance indicators in *relative* terms, in percentages: the percentage of trains that would be affected and the percentage change in usage rate. Another option would have been to operationalize these performance indicators in absolute terms: number of trains hindered and annual costs for using the infrastructure. Although the interpretation of these performance values would probably be easier for TOCs[116], some disadvantages would also arise. In a conjoint analysis it is necessary that the set of profiles are identical for every respondent, which introduces the advantage of being able to compare the results of every respondent. Operationalization in absolute terms would make it impossible to create similar profiles as there are many differences between stakeholders that would result in differences in the absolute performances. Different train frequencies would result in a different *number* of trains affected and different annual usage costs. We could also operationalized the affordability in terms of a concrete financial value per train kilometer. However due to different trains with respect to weight and length this would not have been a good alternative. Although performance indicators in absolute terms could be easier to interpret, wanting to *compare* stakeholder preference models, make these absolute operationalizations impossible. Furthermore, performance indicators in absolute terms would be extremely hard for other stakeholders, next to TOCs, to interpret. For example: ROVER could hardly interpret if a TOC needs to pay 1 million Euros for infra-usage, or when ProRail's maintenance costs are 50 million Euros, because of the large distance to the effect on the price of a train ticket. The current operationalization of change in usage rate could be interpreted as change in price of a train

115 As it could also be possible that one subject was disproportionately discussed while not being that important for the stakeholder, and resulted in more factors in the causal diagram related to that subject.
116 Because the performance levels are specific for that particular stakeholder.

ticket[117]. Taking these considerations into account, we believe that operationalizations in relative terms could not be circumvented when one desires to compare quantitative preference results amongst stakeholders that are different in nature.

- Two out of three of the performance related attributes in the conjoint profiles; '% hindered trains' and '% trains needing re-planning' are actually a combination of more characteristics, combining the number of (planned or unplanned) unavailability of the rail infrastructure and the average length of the unavailability. There is a good possibility that stakeholders differently valuate a constant length of (total) unavailability when the frequency and average length varies. As these two attributes do not separate the quantity and average length of the unavailability, we cannot make any conclusions on the relative importance of these two aspects[118].
- With respect to the other performance indicator, the affordability, we have made the assumption that changes in maintenance costs will be translated into changes in the financial usage rates for TOCs. Although these rates should be (partly) based on maintenance expenses according to policy documents on rate-calculations, in practice no relation between maintenance costs and rates can be detected. And since the effects of the maintenance scenarios in the practical application of the preference models in chapter 5 are based on this assumption, one should be careful with interpreting the realism with respect to the translation from the effects of the maintenance scenarios to the values of the attribute levels used for predicting the stakeholder ratings.
- As mentioned in chapter 4, ROVER indicated of not being able to rate the conjoint profiles as ROVER had difficulties in the interpretation of the performance levels in these profiles. ROVER responded that these performances are difficult to translate into effects specific for ROVER, or train passengers. For example, the "% trains hindered" could not be directly calculated into the effects for the passengers as these effects are also highly dependent on for instance the impact on train connections and the length of these delays. Although the operationalizations of the PIs are perhaps more in the "language" of TOCs, we did expect ROVER to be able to interpret the performance profiles. The question that then rises is "is it possible to operationalize PIs on reliability, affordability and availability in a way that all of ProRail's stakeholders would have no difficulty in interpreting them?" Based on this study, we are not able to answer this question, but we do believe that changing the operationalizations towards the language of train passengers introduces the risk of TOCs having interpretation difficulties. This is considered, also by ProRail, to be worse since the relation with TOCs is more important for ProRail than their relation with their indirect clients: the passengers. One should also wonder when the responsibility of ProRail ends and where the responsibilities of the TOCs begin. To what extend can and should ProRail be accounted for effects on train passengers?

## 7.4 Reflection on the analysis and prediction of stakeholder preferences

- We used conjoint analysis to acquire the quantitative stakeholder preferences because a conjoint analysis is able to quantify the relative importance of several (performance related)

117 This interpretation would also be an assumption that is not checked in this study.

118 This could be interesting for ProRail with respect to the planned unavailability, where maintenance is planned according to the TRS-method (Tijd-Ruimte-Slots), where projects are combined to be executed within the same time period. The idea is: or a higher frequency of planned unavailability with a lower average length, or a lower frequency with a higher length (=TRS). Based on this study we do not know what is preferred by the stakeholders.

characteristics in a reliable[119] manner. We expected that the rating based stakeholder preference models (1) could be used to calculate the relative importance of several performance criteria and (2) could be used to predict ratings in different performance scenarios. The overall expectations on the usability of conjoint analysis were met: the differences in the relative importance of the PIs could be calculated and the preference models could be used to predict the stakeholder ratings. One element that was somewhat disappointing is the relative small effect of the different conjoint profiles on the ratings. This can easily be explained as the ranges of the attribute levels are rather small. Although these small ranges were realistic, a rating based conjoint analysis using ratings between 1 to 10 resulted in small effects on the satisfaction levels. Perhaps other comparable analysis methods exist that are more suitable for extracting quantitative stakeholder preferences when the ranges are rather small.

- The practical relevance of conjoint analysis for ProRail is the possibility to evaluate maintenance policy-options based on the effects of the satisfaction of ProRail's external stakeholders. However, it would probably not be realistic or even desirable to make policy decisions solely based on how the external stakeholders are affected. There are several elements that the conjoint analysis in this study does not take into consideration which ProRail would and should also incorporate in their policy evaluation process. An example of such an element is the effects on ProRail's internal company objectives. Another example is (life cycle) costs; although the conjoint analysis includes a cost related attribute, the cost values are translated from the actual maintenance costs where 45% of increases in maintenance costs are translated. This means that 55% of the extra maintenance costs, for which ProRail should pay, are not taken into account.
- ProRail should also evaluate their maintenance policy on other evaluation methods, which take more than the effects on stakeholder preferences into account, such as Life Cycle Costing (LCC)[120]-analysis (which is fairly similar to CBA) or Social Cost Benefit Analysis (SCBA). However, there are some problems with LCC and SCBA, as was already recognized by one of the stakeholders[121]. LCC is a method focusing solely on the actual financial expenses during the life cycle and does not account for "soft" effects such as environmental damage, coherence with company objectives, effects on stakeholders. SCBA is an analysis method with a more broad focus than LCC and CBA as it takes into consideration not only the "hard" internal financial aspects, but also external effects such as the environmental impact and the impact on the stakeholders. In a SCBA the policy measures are evaluated by quantifying the effects, in financial values if possible, which just is the problem with measuring the effect on stakeholder satisfaction. Conjoint analysis should therefore not be used as a single basis for policy decisions, but can be of substantial importance to other evaluation methods. The results of the conjoint analysis could be used to complement and improve a SCBA as the

119 Meaning not directly asking for a ranking of the importance of several characteristics, but doing so indirectly by letting the respondent make implicit trade-offs.
120 Or Life Cycle Management (LCM)
121 The interviewee of NS Reizigers indicated that many good projects were rejected purely based on CBA where difficult to measure benefits were underappreciated. The interviewee explicitly mentioned that basing a go/no-go decision on solely a CBA is not desirable as he was certain that many rejected projects were beneficial; perhaps not according to a CBA but based on the overall effects.

preference models are suitable for quantifying the effects on stakeholders that are qualitative in nature. Another evaluation method ProRail uses is the “Prioritization Matrix” or “priomatrix” (Appendix A), which is a type of Multi Criteria Decision Analysis (MCDA). ProRail’s existing project evaluation methods, such as the priomatrix, could be improved through using the results of the preference models either by adding criteria on the effects on stakeholders’ preferences or validating current calculations on similar stakeholder related criteria.

- In chapter five we used three scenarios, containing the effects of three different maintenance concepts from the output of a Monte Carlo simulation from Fischer et al. (2008), to predict the effects on the stakeholder satisfaction ratings. Because the focus of this study is on the effects of ProRail’s maintenance policy, these scenarios were the logical choice for applying the preference models. However, affecting these PIs can be realized by more than maintenance activities, resulting in a larger impact on stakeholders’ satisfactions as demonstrated in section 5.5. The performance values in 5.5 are not based on realistic policy measures and it would have been interesting to examine the effect of more realistic policy measures.
- In chapter 4 we explained why safety should not be included as a PI in the conjoint analysis. The safety levels in the conjoint profiles were explained to be similar in every situation, to prevent respondents of making assumptions on the safety level based on the values of the other PIs. In chapter 5, we used the effects of maintenance concepts on these PIs. In reality it is realistic that different maintenance concepts would somehow affect the safety level of the rail infrastructure. Therefore, the predicted stakeholder ratings might not be entirely realistic.
- The ranges of the attribute-levels were chosen in a way that the ranges were realistic, which is recommended in scientific literature (Hair et al., 1998 and Molin, 1999). We could have also increased or decreased this range. Decreasing this range would be undesirable as predicting stakeholder satisfaction in realistic situations could in some instances only be predicted through extrapolation. But larger ranges would result in the opposite: making it less likely that extrapolation is required for satisfaction prediction. Would an increased range be better or is the current range in the conjoint profiles sufficiently able to predict stakeholder satisfactions through interpolation? Looking at the maximum ranges in absolute terms in section 5.4 we believe that the range is sufficient to be able to make predictions when substantial performance changes are realized[122] through excessive adjustments in the maintenance concepts. However, when the edge of these ranges are reached by adjusting maintenance concepts and next to that other measures (not related to maintenance concepts) are implemented that affect the performance; prediction by extrapolation cannot be circumvented.

122 These percentages represent changes relative to the current situation: The maximum range of the maintenance costs: -11.24% to +22.47%. The maximum range of the unplanned downtime of the infrastructure: -77.33% to +44.72%. The maximum range of planned maintenance time: -29.13% to +55.92%.

## 7.5 Remaining reflective remarks

- The policy analysis framework, presented in section 1.3, showed how the rail infrastructure system (RIS) can be influenced. Next to ProRail's *maintenance activities* being of influence on the performance of the RIS, external forces can also affect the RIS. These external forces are developments outside the system but can affect the structure of the system significantly and therefore its performance. Examples of such external forces are: changing demand for train services (passenger and freight), changing frequencies in train traffic, changing trains (dimensions, weight, etc.), changing time schedules (e.g. more freight traffic at night; causing less time for nightly maintenance), and changing operating speeds. These forces are not controllable by ProRail and were therefore not further considered in this study. However, one should be aware that the outcomes of this study may not hold when external forces would substantially impact the RIS[123]. The relevance of the outcomes of this study is therefore highly dependent on the external forces, and should be considered as a snap-shot in time of ProRail's preferences with respect to the performance of the RIS. Substantial changes could result in a modified snap-shot.
- One of the key assumptions in this study is that stakeholders are able to make trade-offs with respect to different performance criteria. During the interviews we perceived that stakeholders were *capable* of making such trade-offs, although there were differences in the degree that the stakeholders were actively concerned with such trade-offs. But do they actually *want* to be involved in making such trade-offs? Although our general feeling is that stakeholders do wish to be involved in making such trade-offs[124], it is possible that some stakeholders[125] do not want to be bothered with such decisions. Emphasizing the existence of these trade-offs and moreover the effect on the stakeholders would improve the perceived relevance and would probably increase their willingness to be involved in decisions on these performance related trade-offs.
- Due to the complexity and diversity of the research objective we decided to use research methodologies crossing disciplines. We combined the scientific areas of actor analysis, policy analysis and (quantitative) preference analysis to be able to answer the variety of research questions. The multidisciplinary approach that we used in this study proved to be beneficial as the combinations of approaches complemented each other and created substantial added value. Especially the combination of Dynamic Actor Network Analysis and Stated Preference analysis has been successful. In a conjoint analysis it is important that the attributes are realistic and comprehensive, and can be easily evaluated by a respondent (Hair et al., 1998, p.405). When researchers experience difficulties in choosing the right attributes and/or in operationalizing these attributes due to diverging objectives and preferences of respondents, we believe that DANA can be of substantial assistance as DANA is suitable for extracting factors of mutual importance.

123 For instance, more train traffic with much heavier trains would increase the need for planned maintenance whilst there is less time available. The importance of planned availability would probably increase for ProRail's stakeholders. But due to increased train intensity the effects of unplanned unavailability would probably become more troublesome and the importance of this PI would therefore also probably increase. These developments could cause the relative importance of these PIs to change.
124 Some of the larger stakeholders indicated of being actively concerned with these trade-off aspects.
125 Likely the smaller stakeholder organizations.

## 7.6 Further research

Based on the results and the reflection of this study several directions and recommendations for further research are formulated. Some of the following directions would be especially interesting for the PhD study of R. Fischer as this study is considered to be a contribution to it.

- This study has included twelve stakeholder organizations in total, six of which were included in the conjoint analysis. Since ProRail has over 60[126] external stakeholders, the perspective of ProRail's external environment can be expanded to acquire a more comprehensive view on the preferences of ProRail's external relations.
- The individual stakeholder preference models are based on preference data originating from one respondent per stakeholder. Further research could focus on the internal consistency of a stakeholder organization by including more respondents per stakeholder. Internal consistent preferences would result in a more robust preference model, and internal inconsistent preferences would mean that the preference model presented in this study is not representative for the stakeholder. Either way, including more respondents per stakeholder would complement the conjoint results in this study.
- In this study some assumptions were made to translate the number and duration of both malfunctions and planned maintenance into the percentage of trains hindered by these causes. Further research focusing on how planned and unplanned unavailability of the rail infrastructure is actually translated into a percentage of hindered trains would be interesting. On the one hand, because the quality of the assumptions in this study could be validated, but more importantly, on the other hand, ProRail would be able to know the exact effects of, for instance, less technical malfunctions on the number of trains affected. It would also be of interest to know the extent of the hindrance[127].
- As mentioned in the reflection, the relation between the maintenance costs and the usage tariffs for TOCs are not as straightforward in practice as policy documents suggest. The interview reports and conjoint models suggest that stakeholders are willing to invest in a higher performance. Transferring a large part of the extra maintenance costs to the TOCs via the usage tariffs would have an impact on the evaluation of such projects as the costs for ProRail decreases. Further research could focus on how (maintenance) cost based usage rates affects the valuation of ProRail's projects[128].
- Further research could be directed at investigating how the results of performance related stakeholder preference models can improve existing project evaluation methods such as (Social) Cost Benefit Analysis and the priomatrix.
- Lastly, future research could focus on investigating other measures, besides maintenance activities, with respect to their impact on the performance of the rail infrastructure in terms of the attributes in the conjoint profiles as the values of these performance indicators can be influenced by much more than ProRail's maintenance policy. Perhaps, based on the preference models, other measures exist that are more cost-effective than improving maintenance concepts.

126 Taking into account all (37) TOCs and 20 regional authorities with transportation responsibilities on the rail sector.

127 Next to the percentage or frequency of the trains hindered.

128 Which do not necessarily

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# APPENDICES

## Appendix A: ProRail's maintenance selection and planning

The production of ProRail's maintenance plan mainly consists of three aspects: (1) detecting the need for maintenance, (2) making sure that the "right" maintenance activity is performed and (3) making sure the most important activities are carried out first.
Figure 7 describes the main aspects of the creation of ProRail's current maintenance policy.

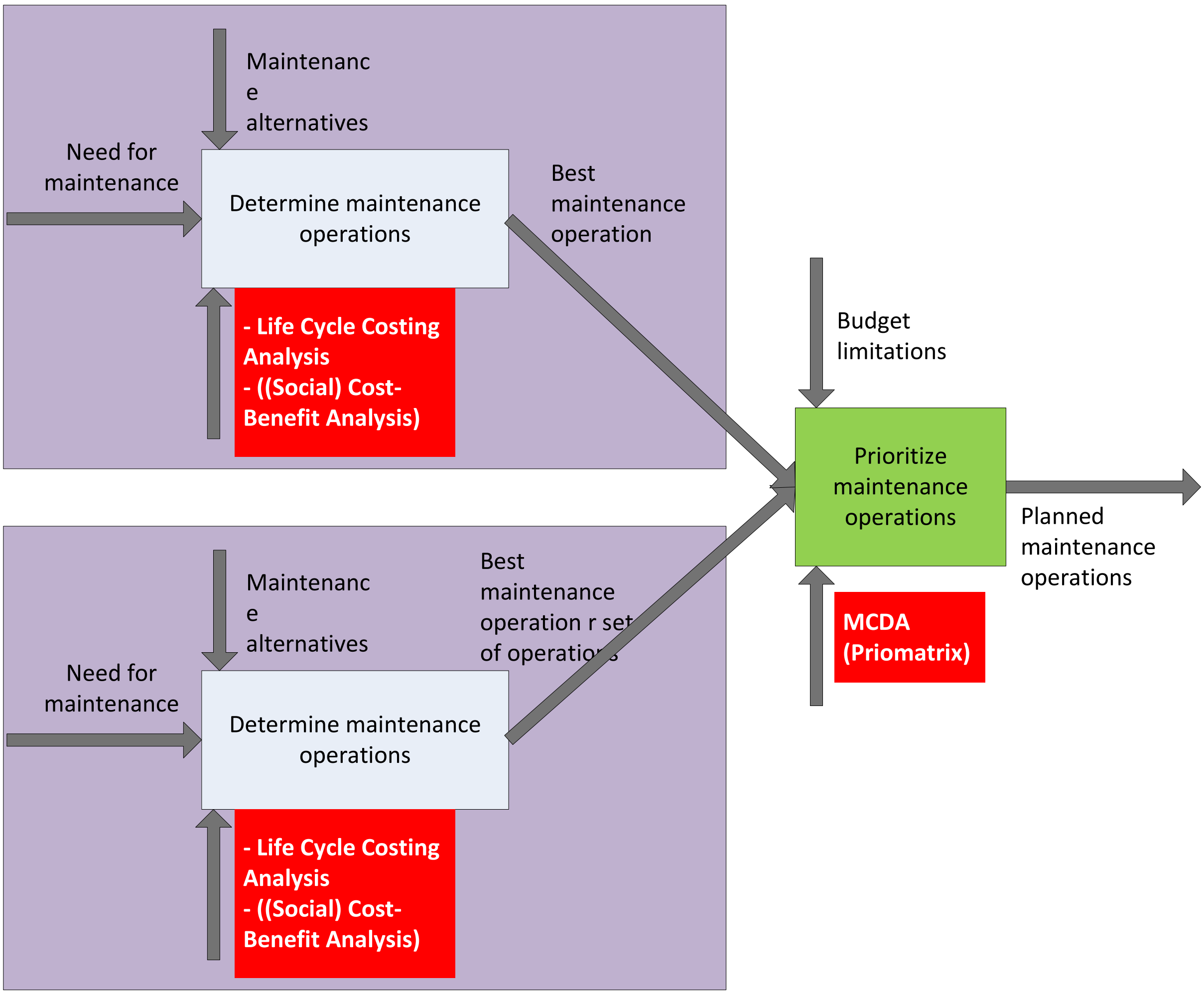



**Figure 7: Process diagram of ProRail's maintenance policy operations**

When there is a need for maintenance it needs to be determined which maintenance can best be performed, shown in the purple rectangles. Although just two of these processes are shown in Figure 6, they are performed frequently and independent from each other.

Often, there are multiple maintenance activities optional (maintenance alternatives), and it needs to be decided which of those options is most desirable. This requires analysis, where the alternatives can be compared. Two methods that ProRail currently uses in assessing the alternatives are: a Life Cycle Management-analysis (LCM) and Social Cost Benefit Analysis (SCBA).
The LCM-tool is concerned with the initial investment costs of a project and the costs of exploitation, during the entire life span of an object or system (ProRail, 2008c). The focus of the criteria used in the LCM tool are limited and only concern the cost aspect during its life cycle; *initial investment costs, exploitation costs, removal costs and residual value*. The LCM takes into account *the social*

*costs of unavailability of the infrastructure*. A SCBA is used to test whether a planned project contributes sufficiently to the social benefits (ProRail, 2008c). The focus of a SCBA is much more comprehensive than the LCM. The performance criteria that are used in the SCBA consist of: *investment costs, maintenance costs, travel time, comfort, reliability, transport size, overcapacity, efficiency transporters, environment, safety, efficiency infraprovider*.

At ProRail, using a LCM and SCBA should be done in the following circumstances (ProRail, 2008c):

- When the investment is more than €500.000, LCM is obligatory.
- When the investment is less than €500.000, LCM is advised.
- When an activity is added within a project that changes the function of the rail infrastructure and costs more than €100.000; LCM is obligatory
- In principle, when the functionality of the rail infrastructure is altered, a SCBA should be used. The government has made the SCBA obligatory for “large infrastructural interventions”, however ProRail recognizes that a SCBA could also be useful with respect to maintaining the functionality infrastructure.

Both the SCBA as well as the LCM methodology focus on choosing the measure which adds the highest value for the stakeholders, at the lowest (Life Cycle) costs (ProRail(c), 2008). Stakeholder involvement in deciding on which criteria need to be included is therefore desirable.

Besides the SCBA and the LCM, another multi criteria selection methodology is used: the prioritization matrix, or priomatrix. The priomatrix is a methodology that prioritizes ProRail’s entire portfolio of planned maintenance activities by using various criteria and their weights (ProRail, 2004). The contribution of each planned activity in the portfolio is tested to these criteria. The overall goal of the priomatrix is to be able to prioritize planned activities based on their effectiveness on the company objectives (ProRail, 2008d). The criteria that are used in the priomatrix are related to: reliability, availability, system safety, Life Cycle Costing, Transfer, technical quality, legal demands, policy Board of Directors, and client demands.

ProRail has identified that the selection criteria used in the priomatrix should be synchronized with the criteria used in other selection methods (ProRail, 2008c). Using similar criteria should prevent non-consistent and even contradictive decision making.

ProRail’s multi criteria selection methodologies are all meant to assist in the decision making process with respect to investments in the rail infrastructure, by assessing their contribution to the company objectives. In that respect, the criteria used in these methods should be consistent and synchronized. The following table summarizes the range of criteria that are currently used (ProRail, 2004, 2008c, 2008d):

Table 30: performance-criteria in ProRail's selection methods

| **Selection method** | LCM | SCBA | priomatrix |
|---|---|---|---|
| **Criterion** | | | |
| Reliability | | | X |
| Availability | X | | X |
| System safety | | X | X |
| Life Cycle Costing | | X | X |
| Transfer | | | X |
| Technical quality | | | X |
| Legal demands | | | X |
| Policy of Board of Directors | | | X |
| Client demands | | | X |
| Investment costs | X | X | |
| Maintenance costs | X | X | |
| Travel time | | X | |
| Comfort | | X | |
| Transport size | | X | |
| Overcapacity | | X | |
| Efficiency transport companies | | X | |
| Environment | | X | X |
| Safety | | X | X |
| Efficiency infraprovider | | X | |
| Initial investment costs | X | X | |
| Exploitation costs | X | X | |
| Removal costs | X | | |
| Residual value | X | | |
| Unavailability infrastructure | X | | |

With regard to table 30 it can be concluded that ProRail’s internal criteria are not consistent:
- Some criteria overlap between the three selection methods.
- Many criteria differ amongst the selection methods.
- The terminology of the criteria is not consistent.

This lack of synchronization between criteria can be problematic for ProRail, especially when ProRail has identified that the selection criteria used in the priomatrix should be synchronized with the criteria used in other selection methods.
An example is given in box 1 to clarify how these incomplete and inconsistent criteria can become problematic:

**Box 1: Example on comfort**

ProRail keeps data of the vertical deviations of the rail infrastructure. These vertical deviations result in vibrations in the train, which affects the comfort for the travelers. The criterion 'comfort' is only taken into account in the SCBA (used only when the function of the rail infrastructure changes). This means that the criterion 'comfort' is not taken into account with respect to 'normal' maintenance activities, which do not change the function of the infrastructure. This situation is undesirable, as 'normal' maintenance activities do have an effect on vertical irregularities and thus 'comfort'. But because of the simple fact that "comfort" is not used in the priomatrix or LCM-tool, the prioritized maintenance activities do not always reflect the company objectives and stakeholder preferences correctly.

## Appendix B: Other actor analysis methods (next to DANA)

### *Actor analysis*

In order to obtain information from the relevant stakeholders, some sort of actor analysis method is required. This method needs to be able to extract specific information from that stakeholder. Many sorts of information can be gathered from actors, and therefore many actor analysis methods are available for generating knowledge about the relevant actors so as to understand for instance, their: behavior, intentions, interrelations, agendas, interests resources, power, influence, goals, objectives, strategy, perceptions, values, environment, etc. (Brugha and Varvasovszky, 2000; Grimble and Wellard 1996; Hermans and Thissen, 2008).
In this study, the type of knowledge that needs to be generated from the actors needs to be on: "what does each actor find important with respect to the effects of ProRail's maintenance activities".

### *Available research methodologies*

There are many methods available that function as a tool for extracting relevant information from different actors. Most of these methods can be classified within the area of "actor analysis methods", which are methods that help policy analysts to get a better understanding of multi-actor policy processes (Hermans et al., 2008). However besides actor analysis methods, other methods can also be helpful although they were not particularly meant for this purpose. That is why the "Delphi" method and the "Grounded Theory" approach are being considered next to the actor analysis methods.
With respect to methods which are classified as actor analysis methods; Hermans and Thissen (2008) have created an overview article that analyses, classifies and compares the most important actor analysis methods. Roughly, these methods can be classified in three categories:

1. Focusing on **network level and on values** which include value preference elicitation models, focusing on the values of the actors' preferences. These methods seem relevant for answering the fourth research question. However, they require preliminary preference information as input data. These methods will therefore not be taken into consideration as actor analysis methods.
2. Focusing on **actors' resources**. This category of methods focus more on the power and influence of those involved within the network. One example is the stakeholder analysis, which is one of the most popular and often used methods. Stakeholder analysis is very extensive and is desirable when a broad range of actor information is desired. This method is also considered. "Stakeholder analysis" should not be mistaken with "actor analysis" in this respect, as stakeholder analysis is a *type* of actor analysis.
3. Focusing on **actor perceptions**. These methods are more oriented on acquiring actor information on objectives and perceptions and have a good fit with respect to answering the third research question. Methods focusing on actor perceptions can be classified into discourse analysis and cognitive mapping. Both will be considered.

### *Stakeholder analysis*

Stakeholder analysis is a tool for gathering information on the environment of the stakeholders and to assess cooperative potential and threat of obstruction (Hermans et al., 2008). This study method

has a broad view of investigation. A case study by Bryson et al. (2002) exemplifies its focus on: power, interests, influences, sources of power, cooperative potential, inspiration and motivation.
This type of analysis would not only extract information on actor perceptions and objectives, which is essentially what we need, but much more. The practical relevance and time efficiency in particular are not desirable for this study and will not be given further consideration.

### *Methods focusing on actor perceptions*

The preference based actor analysis methods can be subdivided into two categories according to Hermans and Thissen (2008):

- Discourse analysis
    - Argumentative analysis
    - Narrative policy analysis
    - Q-methodology
- Cognitive mapping
    - Comparing causal maps
    - Dynamic Actor Network Analysis

#### Discourse analysis

Discourse analysis is concerned with processing the different arguments of the stakeholders. One type of discourse analysis is “argumentative analysis”, which deals with reasoning in policy debates. With respect to the objective of this study, *argumentative analysis* does not seem appropriate. Another method is “narrative policy analysis”, used in a case study by Van Eeten (2001). The narrative policy analysis can best be used when the problem at hand is a controversial issue, which is not the case in this study.
Lastly, the Q-methodology is another type of discourse analysis. This method assumes that there are groups of actors that share similar perspectives. By analyzing their opinions on a representative set of statements, the method uses statistical factor analysis to correlate people’s views on certain issues (Hermans et al., 2008). Although the Q-methodology could provide information on differences between actors, it is not what the method is initially meant for, and what is desired within this study.
These three discourse analysis methods all have one or more significant deficiencies with respect to the type of information it should extract from the stakeholders. Discourse analysis methods are therefore not considered suitable and will not be given further consideration.

### *Delphi*

The Delphi method was first used in 1948 and was originally created to improve the use of expert opinions in the policy making process (Woudenberg, 1991). The Delphi survey is a group facilitation technique, which is an iterative multistage process, designed to transform opinion into group consensus (Hasson et al., 2000). According to Woudenberg (1991) “a Delphi is extremely efficient in obtaining consensus, but this consensus is not based on genuine agreement; rather, it is the result of the same strong group pressure to conformity.”
When the objective of the study would be to seek consensus and conformity, the Delphi method would be a good option. However, in this study, differing opinions or perceptions of stakeholders are assumed to exist and when they do exist, these differences should be detected. Although these different perceptions will later on be merged in this study to a set of “most important criteria”, identifying important differences between actors could mean that criteria will be taken into account

of which their importance is not uniformly agreed upon. When a group pressure exists to create conformity, the chances of *not* detecting these differences are rather high. The Delphi method is therefore not suitable for this study. Furthermore, the quality of a Delphi method also depends on the qualities of the person monitoring the process. In many cases a specialized monitoring team is used for guiding the Delphi process (Linstone and Turoff, 2002). It is safe to say that experience in the Delphi process is desirable for the researcher, which is hardly the case in this study.

### *Grounded Theory*

Grounded theory is a qualitative research method which emerged from socialists Barney G. Glaser and Anselm L. Straus's successful collaboration during their studies of dying in hospitals. They proposed that systematic qualitative analysis had its own logic and could generate theory. In particular, Glaser and Strauss intended to construct abstract theoretical explanations of social processes. The defining components of grounded theory practice include (Glaser and Strauss, 1967; Glaser, 1978; Strauss, 1987; adopted from Charmaz, 2006):

- Simultaneous involvement in data collection and analysis.
- Constructing analytic codes and categories.
- Using the constant comparative method.
- Advancing theory development during each step of data collection and analysis.
- Memo-writing to elaborate categories, define relationships between categories and identify gaps.
- Sampling aimed toward theory construction
- Conducting the literature review after developing an independent analysis.

Furthermore Corbin and Strauss (1990) describe with respect to the grounded theory approach:
"While grounded theory has not changed in form since it was first introduced in 1967, the specificity of its procedures has been elaborated in some detail as the method has evolved in practice. The procedures of grounded theory are designed to develop a well integrated set of concepts that provide a thorough theoretical explanation of social phenomena under study. A grounded theory should explain as well as describe. It may also implicitly give some degree of predictability, but only with regard to specific conditions."

The fifth bullet from the defining components clarify that the grounded theory method is able to extract specific information with respect to important factors (categories), relationships and differences (gaps), which is relevant for this study. However, grounded theory is primarily aimed for the development and construction of new theories. This is not the main objective of this study and the grounded theory approach therefore seems too thorough and time consuming for the smaller focus within this study.

Appendix C is concerned with comparing the actor analysis methods according to their characteristics and how these characteristics meet the requirements necessary to answer the second research question. DANA proves to be the most suitable method and will be discussed in further detail relevant for this study.

# Appendix C: Criteria and scorecard analysis for choosing the most suitable actor analysis method

### *Criteria for the actor analysis method*

Actor analysis methods can be used to acquire many types of information, most of which are irrelevant for this study. Therefore, the actor analysis methods suitable for this study are preferred to meet the following specifications:

- Be able to extract information on the actors' goals, objectives, preferences and interests.
  *We are interested in this specific information of the actors. Methods focusing on other aspects of interest are not desirable.*

- Be able to identify how their objectives and preferences are related.
  *Identifying causal relations can lead to a more extensive system view of the actor, which can lead to new insights and perhaps new criteria.*

- Be able to extract concrete and practical information that results in a register of relevant factors or criteria.
  *A list of relevant (for all stakeholders) factors or criteria should be easily extracted that has a practical importance. Identifying criteria and related factors increase the understanding of a stakeholder's perspective and can result in the identification of new criteria.*

- Be able to identify and analyze all relevant factors; whether they are shared between actors or not.
  *We are not only interested in factors that have common interest; factors that are not of importance to all stakeholders can be important for ProRail. Identifying a complete picture of the relevant factors is therefore required.*

- Be able to extract this actor information in a relative short period.
  *No long interviews to avoid inconvenience for the stakeholders. Furthermore, time savings are eminent as the time for the MSc-project is limited and actor analysis will not be the only scientific methodology used in this study.*

### *Suitability of the methods*

The description of the available research methods for answering the third research question probably provides sufficient information to determine the most suitable method. However, the impacts of the individual methods are not explicitly tested for the criteria defined above and the methods were not simultaneously compared. To increase the reliability of this decision making process, a simple MCDA is used for the comparison of the research methods and their performance on the criteria. This is done in a score card, using the following range of performances: --, -, 0, +, ++, which can be translated into numbers 1-5 for the final evaluation. The scores in Figure 6 are determined by estimating the performance of a method on a specific criterion.

Table 31: MCDA for suitability of actor analysis methods

| Methodologies → Criteria ↓ | Comp. Causal maps | DANA | Delphi | Grounded Theory |
|---|---|---|---|---|
| Extract preference info | ++ | ++ | 0 | + |
| Detect relations between factors | ++ | ++ | -- | + |
| Extract practical info | ++ | ++ | ++ | 0 |
| Diversity of factors included | 0 | ++ | - | ++ |
| Time efficiency | ++ | ++ | 0 | -- |
| Total | 23 | 25 | 14 | 17 |

### *Most desirable option*

The values represented in the score card should not be considered as hard facts. However, the scorecard provides a clear overview of each alternative and its performance on the criteria. The outcome of the comparison between the research methods is rather reliable and expected considering the description of the fit of the methods.

The DANA method proves to be the most desirable research method to extract stakeholder information concerning their preferences. Methods for "comparing causal maps" have a high performance as well, which is also expected as they are fairly similar as DANA, but especially their capability to identify and use factors that are different between actors is somewhat lacking.

Dynamic Actor Network Analysis is the most desirable method to answer the first research question, because:

- DANA captures the stakeholders' system perspectives.
- DANA focuses on stakeholders' preferences.
- DANA provides a social basis for policy decisions.
- DANA provides a basis for discussion amongst policy analysts and the decision makers.
- The causal diagrams can provide justification of ProRail's maintenance policy to public authorities and the TOCs.
- Quantitative analysis in DANA can provide important insights and;
- It can assist in testing the validity of the results in the next research questions.

# Appendix D: Other Value preference elicitation methods (next to SP analysis)

### *Analytical Hierarchy Process*

The analytical Hierarchy Process (AHP) is an intuitive method for analyzing decisions. AHP has been applied to numerous practical issues in the last few decades (Shim, 1989). The APH is intuitive and flexible and is therefore routinely used by many corporations and governments for making major policy decisions (Ramanathan, 2001). A more detailed description of AHP and its application is for instance provided by Saaty (1990). In essence, four main steps are involved when AHP is used in a decision problem (Ramanathan, 2001):

1. Structuring of the decision problem into a hierarchical model.
   Which criteria determine the overall objective/strategy?
2. Making pair-wise comparisons and obtaining the judgmental matrix.
   Comparison of each of the individual criteria with respect to the goal, Saaty (1990) suggests a 9-point scale to transform the verbal judgments into numerical quantities.
3. Local priorities and consistency of comparisons. Comparing the alternatives to each criterion.
4. Aggregation of local priorities. Finalize priorities to determine the ranking of alternatives.

The AHP is originally a type of Multi Criteria Decision Analysis (MCDA). Looking at step three and four: alternatives (maintenance activities for this study) will be compared to criteria (answer research question two) in order to make a ranking of these alternatives. The focus of the third research question is not on the MCDA-process itself, but on the values or weights of the criteria used in this MCDA.

The second step is concerned with the values of the criteria. It has been generally agreed (Saaty, 1980, 2000) that priorities of criteria can be estimated by using the AHP; by finding the "eigenvector".

Disadvantages of the AHP are firstly that the valuation of the different criteria is not simultaneously compared, but always one-on-one. Secondly, the output information the importance of each criterion is not well interpretable. The results can be normalized, which means that a result can be: "the importance of this criterion is.. %". No objective rating or financial value can be assigned to the results.

### *Revealed Preference Analysis*

The revealed preference (RP) approach has been used extensively in deducing value preference information, such as the valuation of a statistical life (Adamowicz et al., 1997; De Blaeij et al., 2003; Lanoie et al., 1995). The underlying assumption of this method is that individuals reveal their preferences by their market behavior. The information is obtained by identifying situations in which individuals, either implicitly or explicitly, actually make a trade-off decision between wealth and physical risk for example (Lanoie et al., 1995).

Revealed preference analysis is for instance used in customer-market studies where observable trade-offs concerning peoples everyday consumption decisions are examined. One significant advantage on revealed preference methods is that they are based on actual behavior (Lanoie et al., 1995). The interpretability of the results of a RP study would probably be better than a stated preference (SP) study.

In the research of Lanoie et al. (1995), Adamowicz et al. (1997) and De Blaeij et al. (2003) both RP- and SP-methods were used to acquire value preference information. Both methods lead to different results and Lanoie et al. (1995) have stated that RP may provide less representative results, due to the effects when risk-averse people are involved.

The analysis of revealed preference data is often hindered by lack of data on the choice-set considered by the actor and the risk perception of the actor. Moreover, econometric difficulties (such as multicollinearity) may severely obstruct the estimation of the trade-offs between money outlays and safety increases for example. These problems can be evaded by the use of stated preference data, but then a major problem is that the answers of the respondents can depend rather strongly on the way in which contextual information is being presented (De Blaeij et al., 2003).

A more general problem, relevant for both RP and SP, is the small magnitude of risks and the simultaneous problem of many respondents having difficulties dealing with these rather abstract, small probabilities. In this respect, an advantage of the stated preference approach is that the information provided in the questionnaire can be used to guide respondents to a proper understanding of the ‘good’ to be valued (De Blaeij et al., 2003).

With respect to this study, acquiring information from the stakeholders seems very difficult. As explained before, revealed preference methods use data from actual market behavior. In here lies one large problem. The market mechanism in the rail sector is represented rather poorly, due to the government’s responsibility for covering most of ProRail’s expenses, making (financial) trade-off decisions for ProRail’s clients less important. The lack of observable data for ProRail on choice-sets makes the RP-method less desirable.

Appendix E is concerned with comparing the value preference analysis methods according to their characteristics and how these characteristics meet the requirements necessary to answer the third research question. Conjoint analysis proves to be the most suitable method and will be discussed in further detail relevant for this study.

# Appendix E: Criteria and scorecard analysis for choosing the most suitable value preference analysis method

### *Criteria for the value preference analysis method*

Value preference methods are diverse and have different characteristics. As not every characteristic would be suitable for this study, the value preference method that is selected needs to meet the following specifications:

The value preference analysis methods are preferred to meet the following requirements:

- The information for using the analysis should be easily available.
  *The information should be accessible and available in a relative short amount of time.*

- Be able to extract the relative importance of a criterion, compared to other criteria.
  *Information on relative importance is necessary to put the value information into perspective.*

- Be able to compare different criteria simultaneously.
  *Comparing different criteria simultaneously means acquiring more realistic information on the involved trade-offs.*

- Be suitable for segmentation purposes.
  *It is desired to estimate an individual preference model per stakeholder organization. A method's ability to do so is of importance.*

- Be able to derive financial information regarding willingness to pay (WTP).
  *ProRail is planning to use financial values for criteria that cannot be easily translated into quantitative financial numbers; environmental pollution for example. Extracting WTP information from each stakeholder should help ProRail determining their own WTP. Furthermore, when ProRail decides to use financial values for non-financial effects; information on how this corresponds with stakeholder values is available.*

### *Suitability of the methods*

The scores in Table 32 are determined by estimating the performance of a method on a specific criterion. Appendix B gives more information on why a scorecard is used for comparing the methods.

**Table 32: MCDA for suitability of value preference analysis methods**

| Methodologies → Criteria ↓ | Analytical Hierarchy Process | Conjoint Analysis (Stated preferences) | Revealed Preferences |
|---|---|---|---|
| Ease of acquiring information | ++ | + | -- |
| Extract info on relative importance | + | ++ | ++ |
| Process multiple trade-off information | - | ++ | 0 |
| Segmentation ability[129] | 0 | ++ | -- |
| Information on willingness to pay | -- | ++ | + |
| Total | 15 | 24 | 14 |

### *Most desirable option*

From the scorecard can be read that conjoint analysis is the most suitable method for analyzing the valuation of actor preferences. Again, the scorecard is no hard science, but can easily show the relative differences between the methods. The Analytical Hierarchy Process's lack of providing multiple trade-off and WTP information, and Revealed Preference's difficulties in acquiring the necessary information from the stakeholders, result in Stated Preferences Analysis as the most desirable option.

Conjoint analysis is the most desirable method to answer the second research question, because:

- Conjoint analysis is suitable for the simultaneous comparison of multiple criteria.
- Conjoint analysis is reliable in extracting stakeholders' trade-off behaviour.
- Using conjoint analysis does not require (historical) data, which is not or limited available.
- The output of a rating based SP analysis is relatively easy to interpret.
- A rating based SP analysis is very suitable for segmentation purposes
- The final SP models represent individual stakeholder models and are suitable for simulating stakeholders' satisfactions in different (maintenance) scenarios.

[129] Segmentation characteristics were acquired from the lecture sheets of spm3610 (2005) by Eric Molin on behavioral models, lecture 4, slide 48.

## Appendix F: Part of ProRail's maintenance document IHD 00018: Rail, page 15



Witte achtergrond = Verplicht | Grijze achtergrond = Advies

| | Objectstr. | Failure Modes | | | Instandhoudingsconcept | | | | | | Specificaties | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0. Nr. | 1. Onderdeel | 2. Faalvorm | 3. Faaloorzaak | 4. Condities v/d fout | 5. IH strategie | 6. IH-actie (IH = Instand-houding) | 7. Kostensoort / Unit | 8. Interval | 9. Vervolgactie bij TAO | 10. Kostensoort / Unit | 11. Afkeurwaarde / Norm | 12. Opmerkingen |
| 1.3 | Ballast | Niet dragen/geleiden (Het niet meer overbrengen van de belasting naar ondergrond) | Vervuilde ballast | Afname effectieve dikte ballastbed door onkruidgroei | GAO | Chemische onkruid bestrijding | BA.0067 | 2x per jaar 1) voor 1 juni 2) voor 15 september | | | BW: Hoofdspoor: 2% Zijspoor: 4% Rangeerspoor en emplacementen: 10% Maximale hoogte onkruid > 0,15 m VW: n.v.t. | Bij waterwin gebieden gelden afwijkende normen |
| 1.4 | Ballast | Niet dragen/geleiden (Het niet meer leveren van voldoende zijdelingse weerstand) | Afmeting ballastbed (ballastkop/schouder) voldoet niet aan norm | O.a. na liggingonderhoud niet goed hergeprofileerd. | TAO | Inspectie van het ballastprofiel | BA.0086 | 1x per jaar | Ballast lossen<br>Herstellen vereiste profiel | BA.0001<br>BA.0029 | BW=VW: OVS00056-7.2 | OVS00056-7.2 |
| 1.5 | Ballast | Niet geleiden van stromen of signalen | Onvoldoende elektrische weerstand | Vervuiling ballastbed (zie ook 1.2 en 1.3) | TAO | Meten ballastweerstand | Zie IHD00019 | | Vernieuwen ballastbed | GO/ BBV | | Zie IHD00019 |

## Appendix G: Interview questions

In this Appendix, an example of the (Dutch) questions used in the interviews is presented. Due to some differences in tasks and responsibilities between the stakeholders, some interview-questions were somewhat different from the ones shown below, but the subjects treated were practically identical and therefore, the following questions provide a good representation of the content of every interview.

**Interviewvragen DB SCHENKER**

**Introductie**

1. Wat is uw functie binnen deze organisatie?

**Bedrijfsdoelstellingen in relatie met de gewenste prestaties van de railinfrastructuur**

Uitleg railinfrastructuur

Met 'railinfrastructuur' wordt bedoeld: alle fysieke technische componenten[130] die het treinverkeer over het spoor mogelijk maken.

2. Aan welke prestaties moet de railinfrastructuur voldoen vanuit het oogpunt van (de doelstellingen van) DB SCHENKER? Welke definities worden gehanteerd?
3. In welke mate kunt u deze genoemde prestaties prioriteren op basis van belangrijkheid? Is de ene prestatie-eigenschap belangrijker dan de andere?
4. Kunt u aangeven welke normen DB SCHENKER hanteert omtrent de genoemde prestaties? Bijvoorbeeld in termen van "acceptabel" of "onacceptabel". Een andere schaalverdeling is uiteraard ook mogelijk.
5. Wat vindt DB SCHENKER van de huidige prestaties van de railinfrastructuur?
6. Is er volgens DB SCHENKER sprake van een trend of ontwikkeling in de geleverde of te leveren prestaties van de railinfrastructuur? Zo ja, welke?
7. Wat zijn volgens u de oorzaken en gevolgen van deze ontwikkelingen?
8. Beschouwd DB SCHENKER de railinfrastructuur als één geheel of wordt er bijvoorbeeld onderscheid gemaakt in baanvakken/lijnen[131]? Worden er bijvoorbeeld voor de ene spoorlijnlijn andere afspraken gemaakt of andere eisen gesteld dan voor de andere?

**Waarde van een verhoogd prestatieniveau**

9. Wat kost een [tijdseenheid] onbeschikbaarheid voor DB SCHENKER?
10. Is er een onderscheid te maken in de kosten tussen geplande en ongeplande onbeschikbaarheid? Zo ja, wat is het verschil in kosten?
11. Heeft een tijdshorizon[132] van de kennisneming van geplande onbeschikbaarheid nog invloed op deze kosten?
12. Zijn de aspecten "Veiligheid" en "Betrouwbaarheid" nog eventueel in financiële zin uit te drukken?

---

[130] Zoals: spoorstaven, ballast, dwarsliggers, wissels, slagbomen, bovenleidingen, etc.

[131] Of wellicht een andere geografische opsplitsing van de railinfrastructuur.

[132] Hiermee wordt bedoeld: heeft het vroeg op de hoogte zijn van een toekomstige onbeschikbaarheid van de infra lagere kosten tot gevolg?

13. In welke mate is DB SCHENKER bereid om te investeren in een verhoogd prestatieniveau van de railinfrastructuur? (meer betalen voor verhoogde service bijv. hogere veiligheid, beschikbaarheid en/of betrouwbaarheid)

**Klanten van DB SCHENKER**

14. Op welke aspecten wordt DB SCHENKER beoordeeld door de klanten?
15. Hoe wordt DB SCHENKER op dit moment op de genoemde aspecten beoordeeld? Zijn hier bepaalde ontwikkelingen uit af te leiden?

**Proces van afstemming en afspraken tussen DB SCHENKER en ProRail**

16. Op welke manier en met welke frequentie vindt er afstemming tussen DB SCHENKER en ProRail plaats omtrent de gewenste prestaties van de railinfrastructuur?
17. Wat zijn uw wensen omtrent afstemming tussen DB SCHENKER en ProRail?

**Afsluiting**

18. Heeft u, in het kader van dit onderzoek, nog relevante informatie?
19. Welke personen kunnen in het kader van dit onderzoek nog een toegevoegde waarde leveren?
20. Heeft u zelf nog vragen en/of opmerkingen?

# Appendix H: Stakeholders' system perspectives

### *Explanation DANA Diagrams (from Hermans, 2008)*

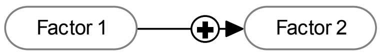
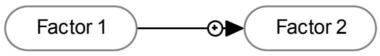
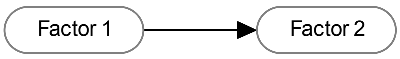
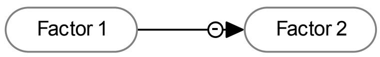
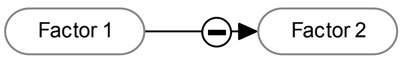
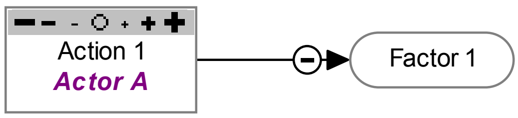
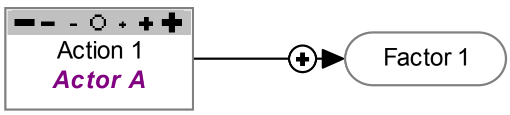
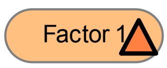
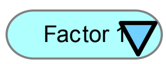
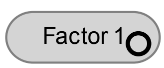
DANA diagrams are causal relations diagrams that depict the results of the interviews with actors. These diagrams are used to support the comparison and analysis of the interview results. A diagram consists of factors, instruments or actions and the causal relations between them. The basis of the diagrams consists of the factors, depicted in ovals. Factors can also be used to present objectives, using colours. An orange factor means that an increase in this factor is desired by an actor. A blue factor indicates that a decrease in this factor is desired.

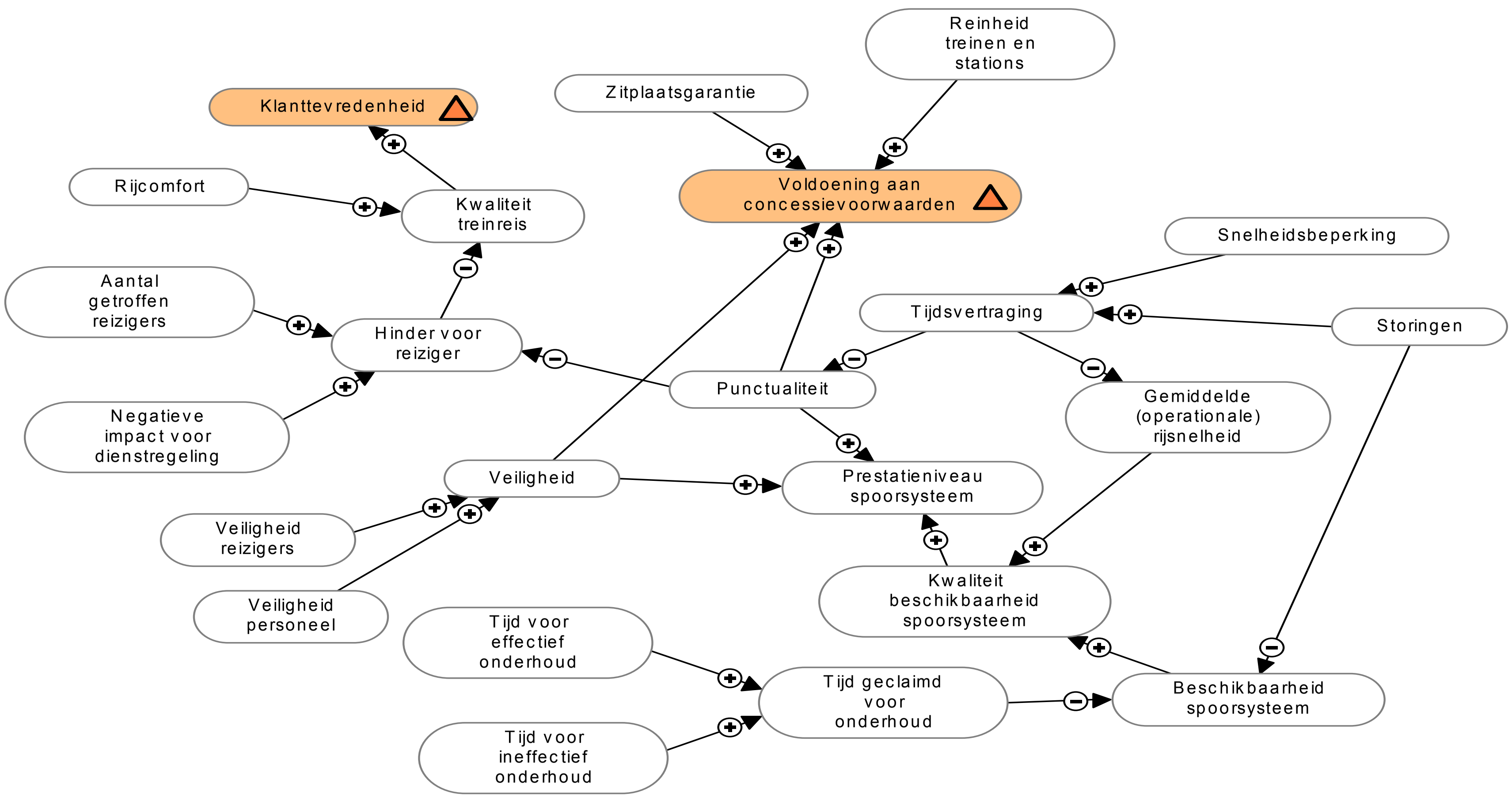
Factors can be influenced by other factors or by actions. Actions are depicted in rectangles. Below each instrument, a purple text shows the name of the actor that controls the instrument. In most cases, abbreviations are used for actor names.

The nature of the causal relations between factors and instruments is indicated by arrows. An arrow from factor A to factor B, indicates that factor A influences factor B. The arrows contains a + or - to further specify the nature of this influence. An + arrow indicates a positive causal relations: this means that if factor A increases, factor B will also increase. A - arrow indicates a negative causal relations, meaning that if factor A increases, factor B will decrease. A arrow without + or - indicates that factor A influences factor B, but that the nature of this influence cannot be specified further. These rules also apply to the arrows going from instruments to factors. A factors influence can vary in strength of effect; when a factor has a large affect, the arrow will have a larger + or – attached to it.

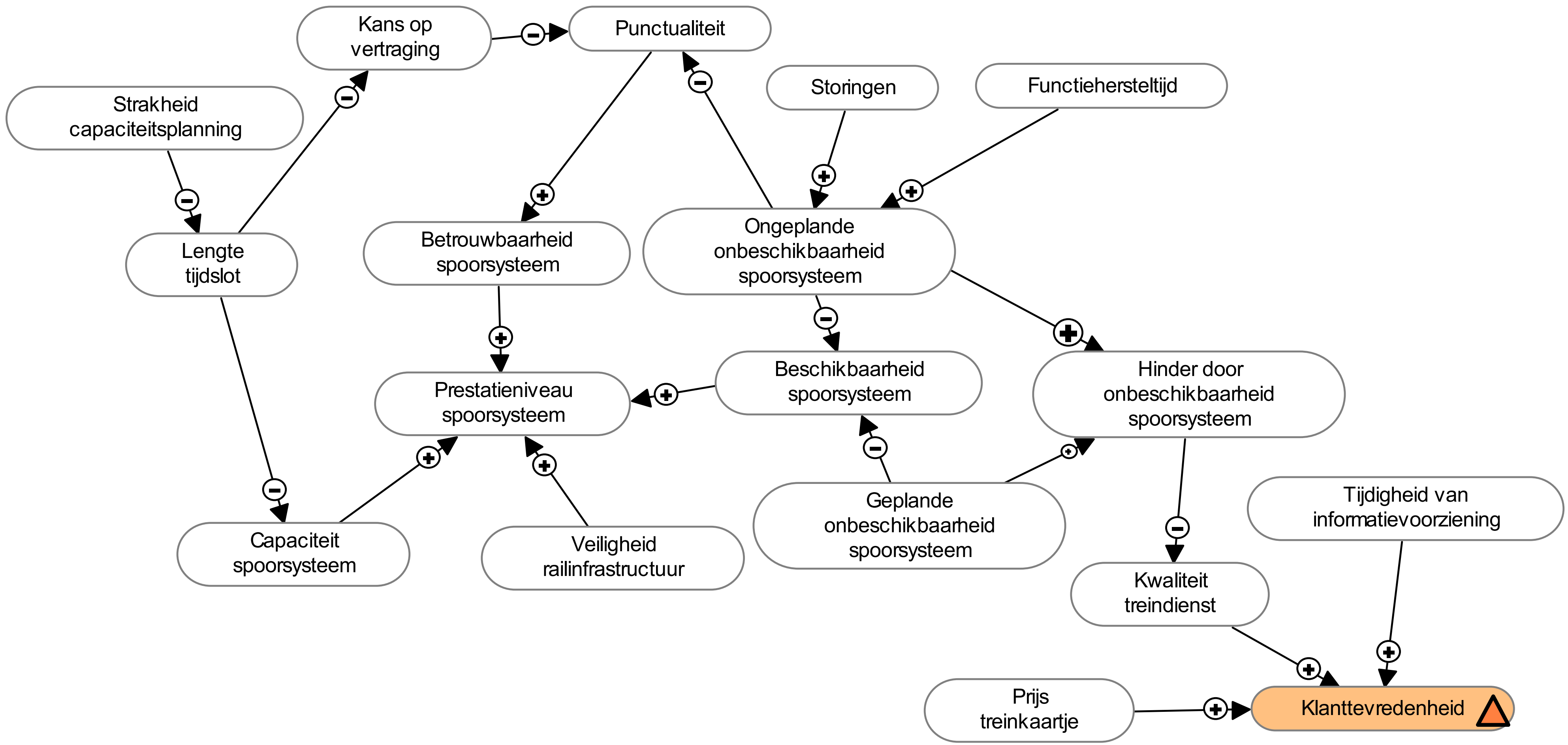
The legend on the next page summarizes the above explanation of the DANA diagrams.

## *Legend DANA model*

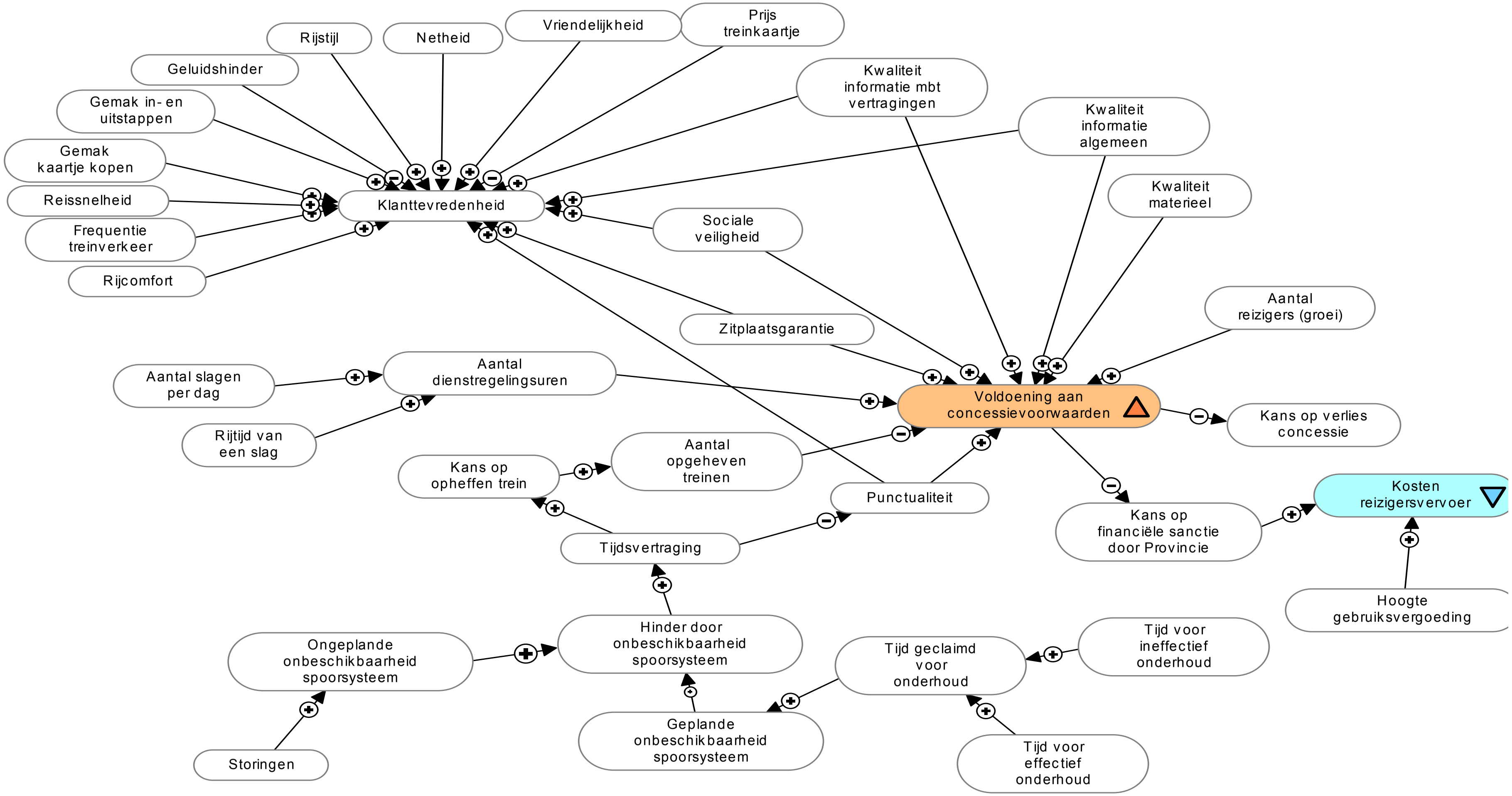
| | |
|---|---|
|  | If Factor 1 increases, Factor 2 will also increase (strongly)<br>If Factor 1 decreases, Factor 2 will also decrease (strongly) |
|  | If Factor 1 increases, Factor 2 will also increase (slightly)<br>If Factor 1 decreases, Factor 2 will also decrease (slightly) |
|  | Factor 1 influences Factor 2. The exact influence is not known |
|  | If Factor 1 increases, Factor 2 will decrease (slightly)<br>If Factor 1 decreases, Factor 2 will increase (slightly) |
|  | If Factor 1 increases, Factor 2 will decrease (strongly)<br>If Factor 1 decreases, Factor 2 will increase (strongly) |
|  | If Actor A uses Action 1, Factor 1 will decrease |
|  | If Actor A uses Action 1, Factor 1 will increase |
|  | Actor objective: Factor 1 should increase |
|  | Actor objective: Factor 1 should decrease |
|  | Actor objective: Factor 1 should remain as it is |


Klanttevredenheid
Zitplaatsgarantie
Reinheid treinen en stations
Voldoening aan concessievoorwaarden
Rijcomfort
Kwaliteit treinreis
Snelheidsbeperking
Aantal getroffen reizigers
Hinder voor reiziger
Tijdsvertraging
Storingen
Punctualiteit
Gemiddelde (operationale) rijsnelheid
Negatieve impact voor dienstregeling
Veiligheid
Prestatieniveau spoorsysteem
Veiligheid reizigers
Veiligheid personeel
Kwaliteit beschikbaarheid spoorsysteem
Tijd voor effectief onderhoud
Tijd geclaimd voor onderhoud
Beschikbaarheid spoorsysteem
Tijd voor ineffectief onderhoud

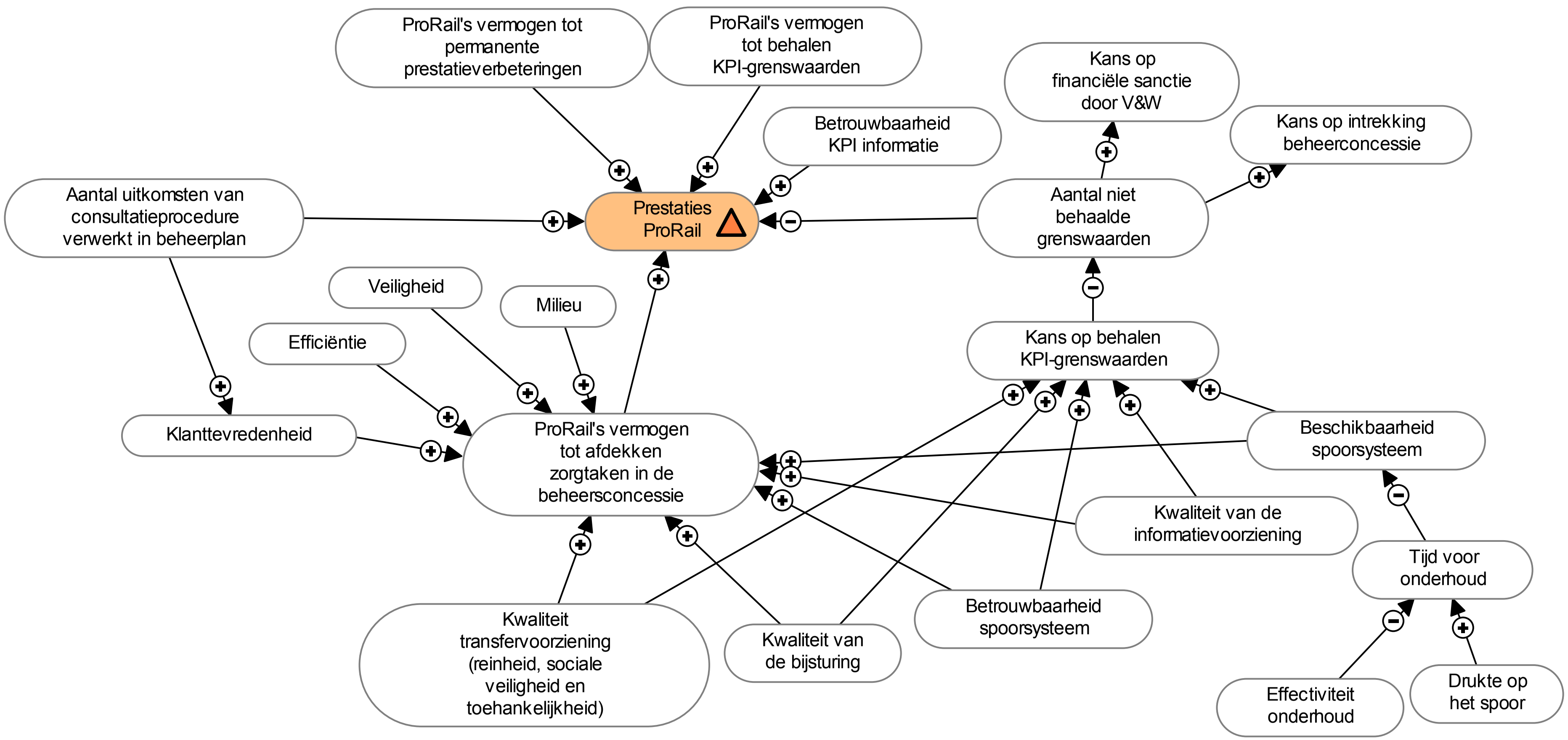
### *NS Hispeed*


Kans op vertraging
Punctualiteit
Strakheid capaciteitsplanning
Storingen
Functiehersteltijd
Lengte tijdslot
Betrouwbaarheid spoorsysteem
Ongeplande onbeschikbaarheid spoorsysteem
Prestatieniveau spoorsysteem
Beschikbaarheid spoorsysteem
Hinder door onbeschikbaarheid spoorsysteem
Capaciteit spoorsysteem
Veiligheid railinfrastructuur
Geplande onbeschikbaarheid spoorsysteem
Tijdigheid van informatievoorziening
Kwaliteit treindienst
Prijs treinkaartje
Klanttevredenheid

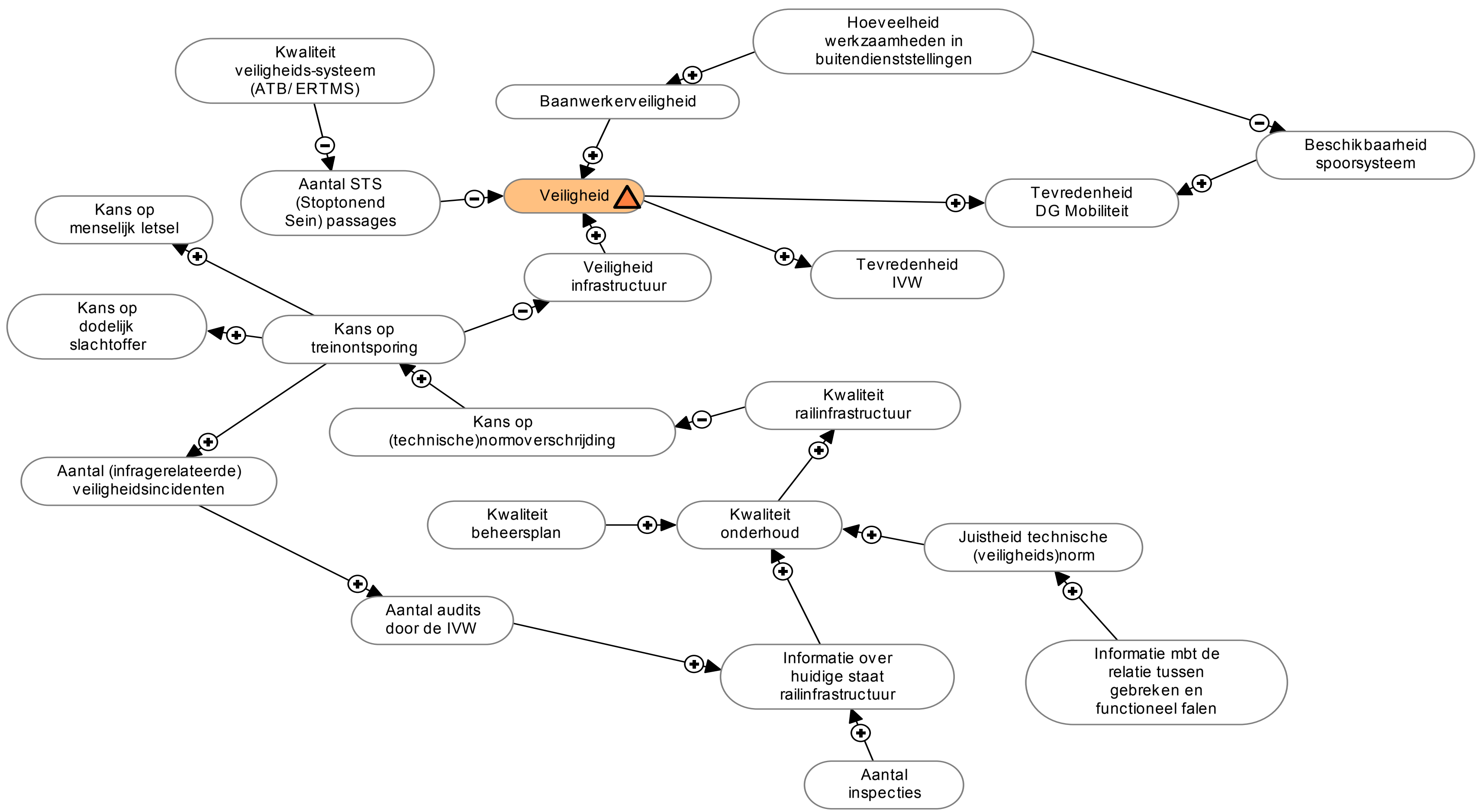
## Regionale reizigersvervoerders



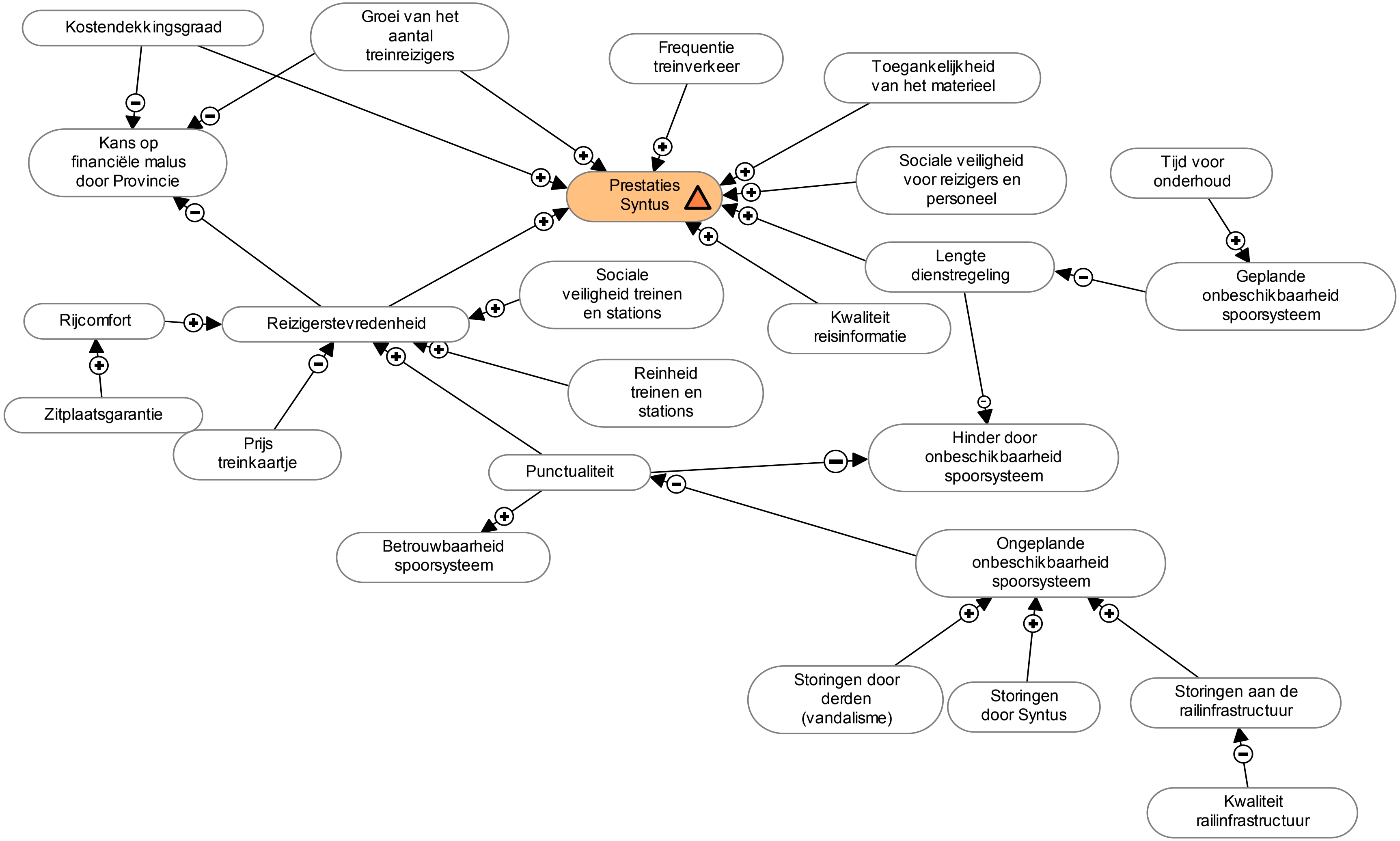
### Directoraat Generaal Mobiliteit (Min V&W)



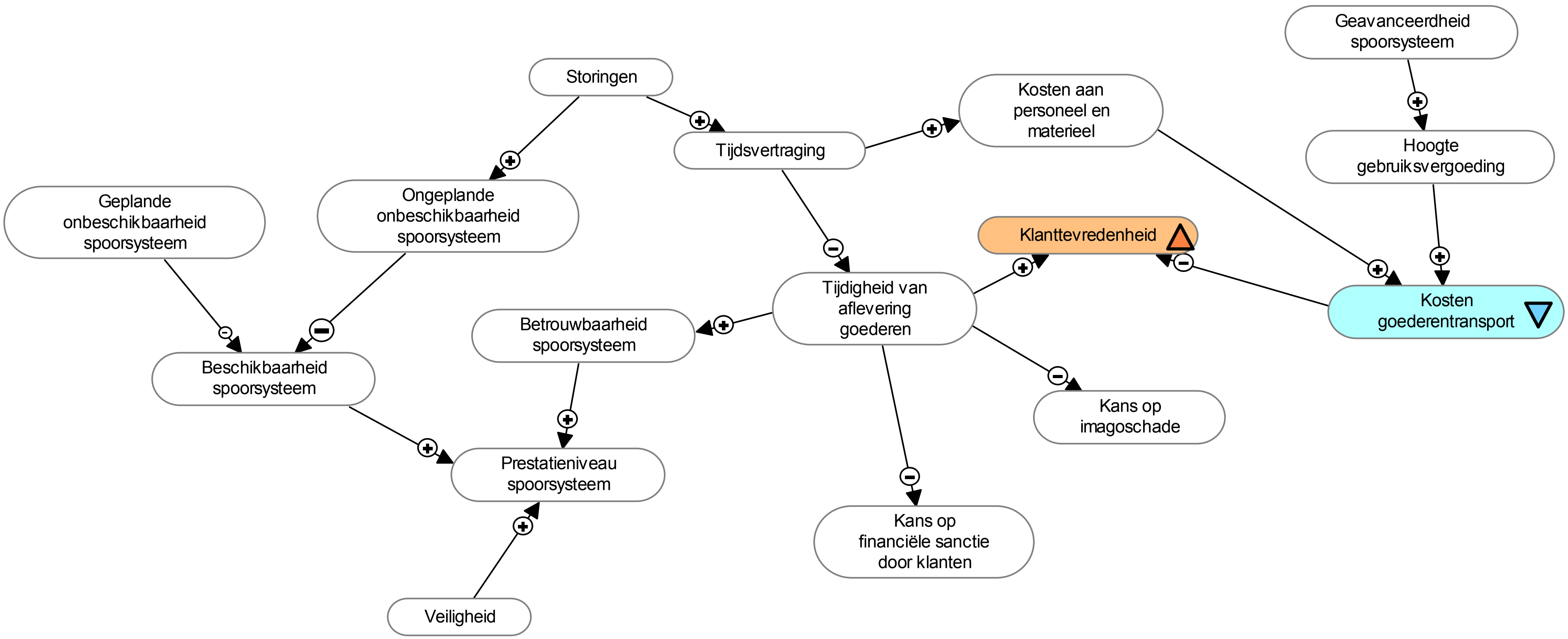
## Inspectie Verkeer en Waterstaat (Min V&W)



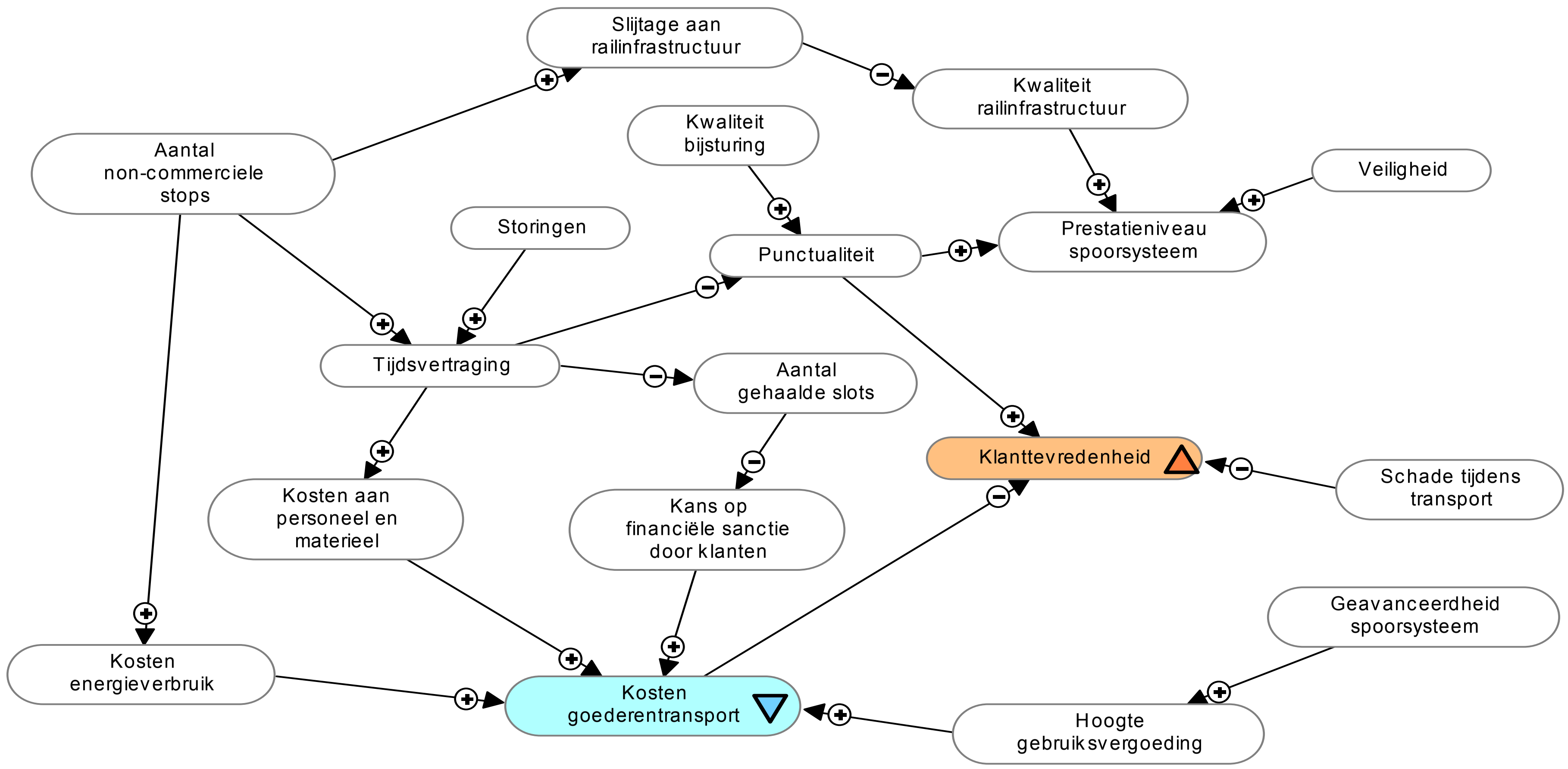
## *Provincie Gelderland*



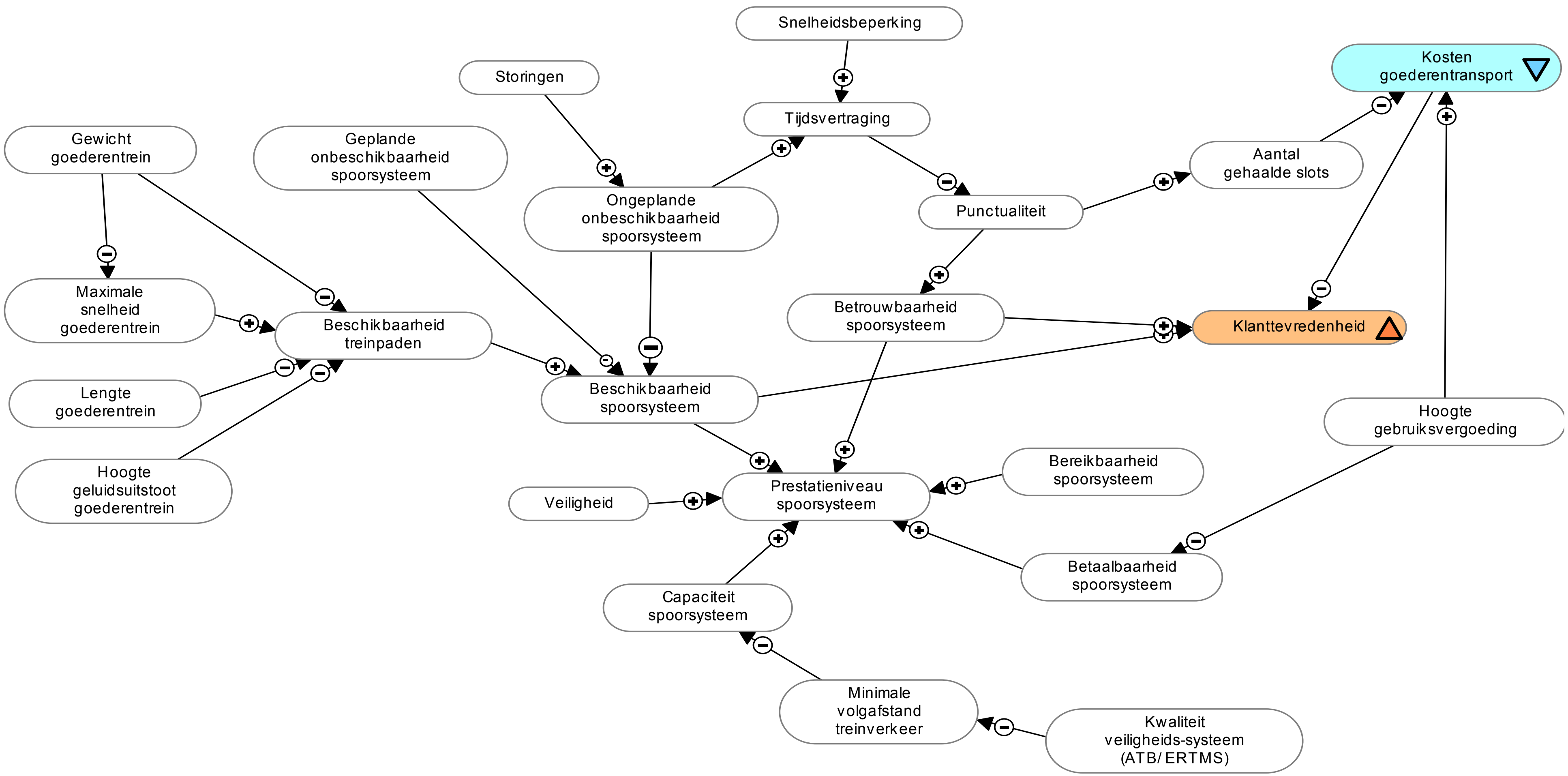
## ACTS


Storingen
Tijdsvertraging
Kosten aan personeel en materieel
Geavanceerdheid spoorsysteem
Hoogte gebruiksvergoeding
Geplande onbeschikbaarheid spoorsysteem
Ongeplande onbeschikbaarheid spoorsysteem
Klanttevredenheid
Tijdigheid van aflevering goederen
Kosten goederentransport
Beschikbaarheid spoorsysteem
Betrouwbaarheid spoorsysteem
Kans op imagoschade
Prestatieniveau spoorsysteem
Kans op financiële sanctie door klanten
Veiligheid

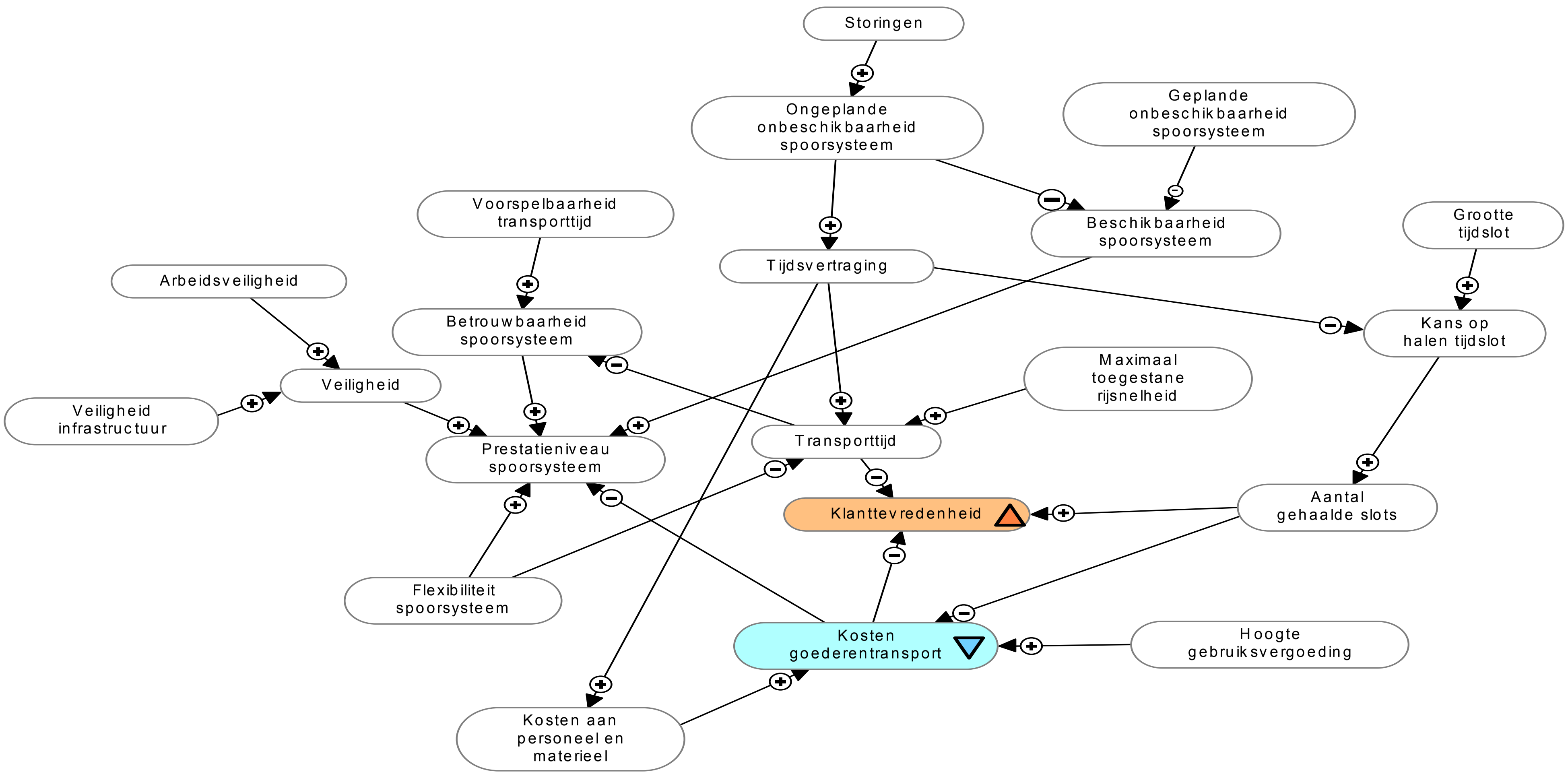
### DB Schenker


Slijtage aan railinfrastructuur
Kwaliteit railinfrastructuur
Aantal non-commerciele stops
Kwaliteit bijsturing
Veiligheid
Storingen
Punctualiteit
Prestatieniveau spoorsysteem
Tijdsvertraging
Aantal gehaalde slots
Klanttevredenheid
Kosten aan personeel en materieel
Kans op financiële sanctie door klanten
Schade tijdens transport
Geavanceerdheid spoorsysteem
Kosten energieverbruik
Kosten goederentransport
Hoogte gebruiksvergoeding

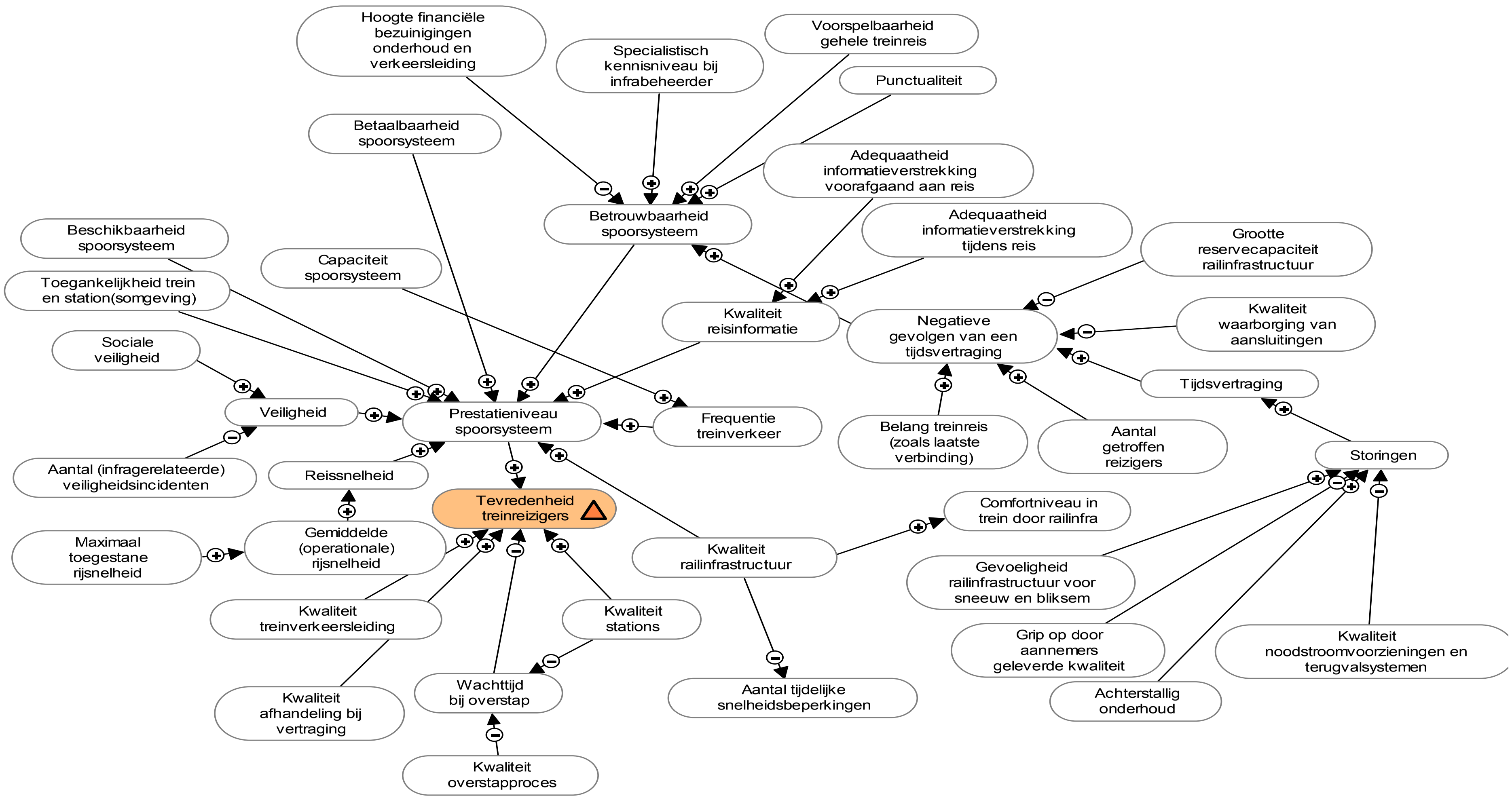
## *ERS Railways*



## Veolia Cargo

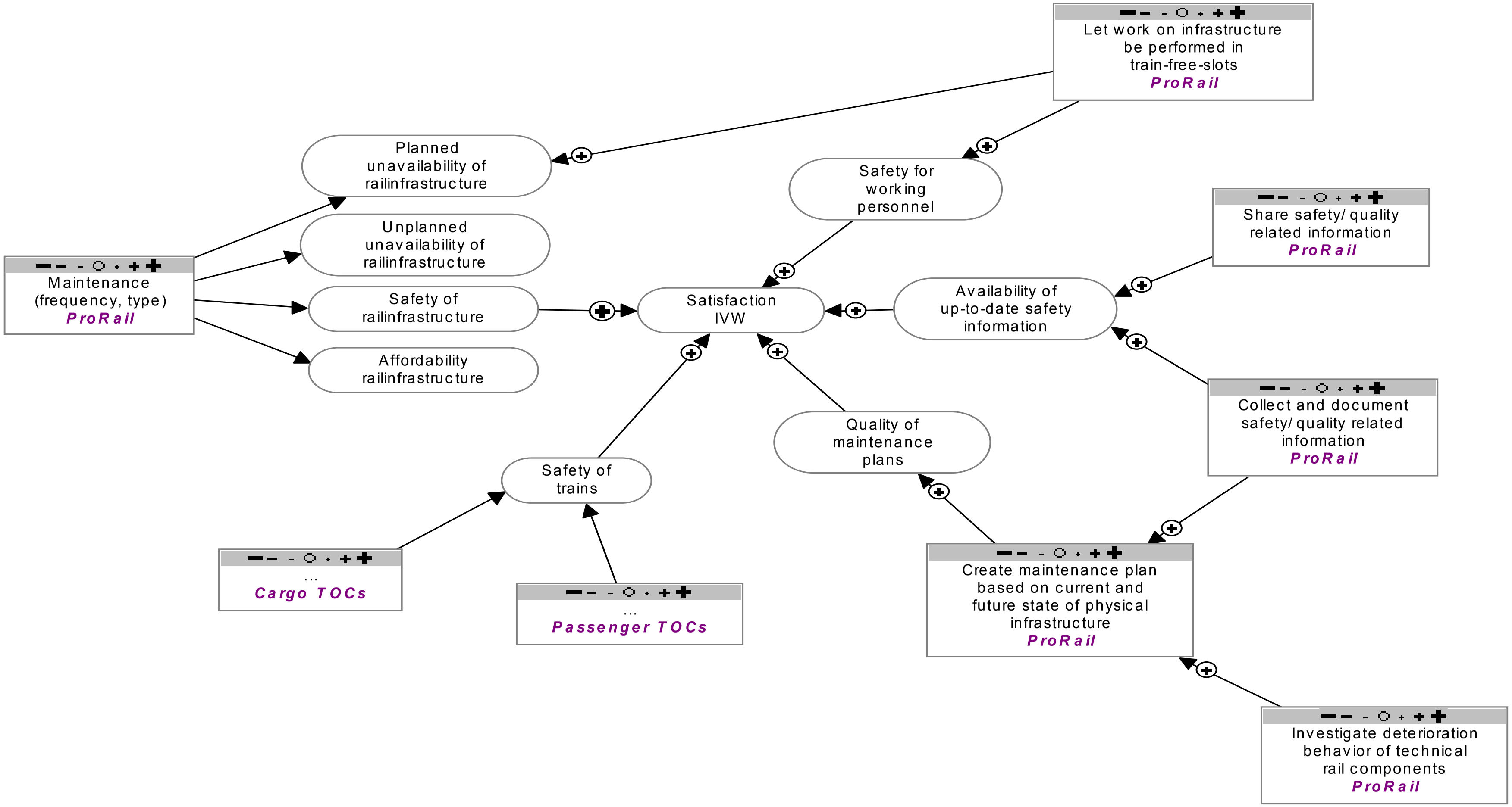


## ROVER

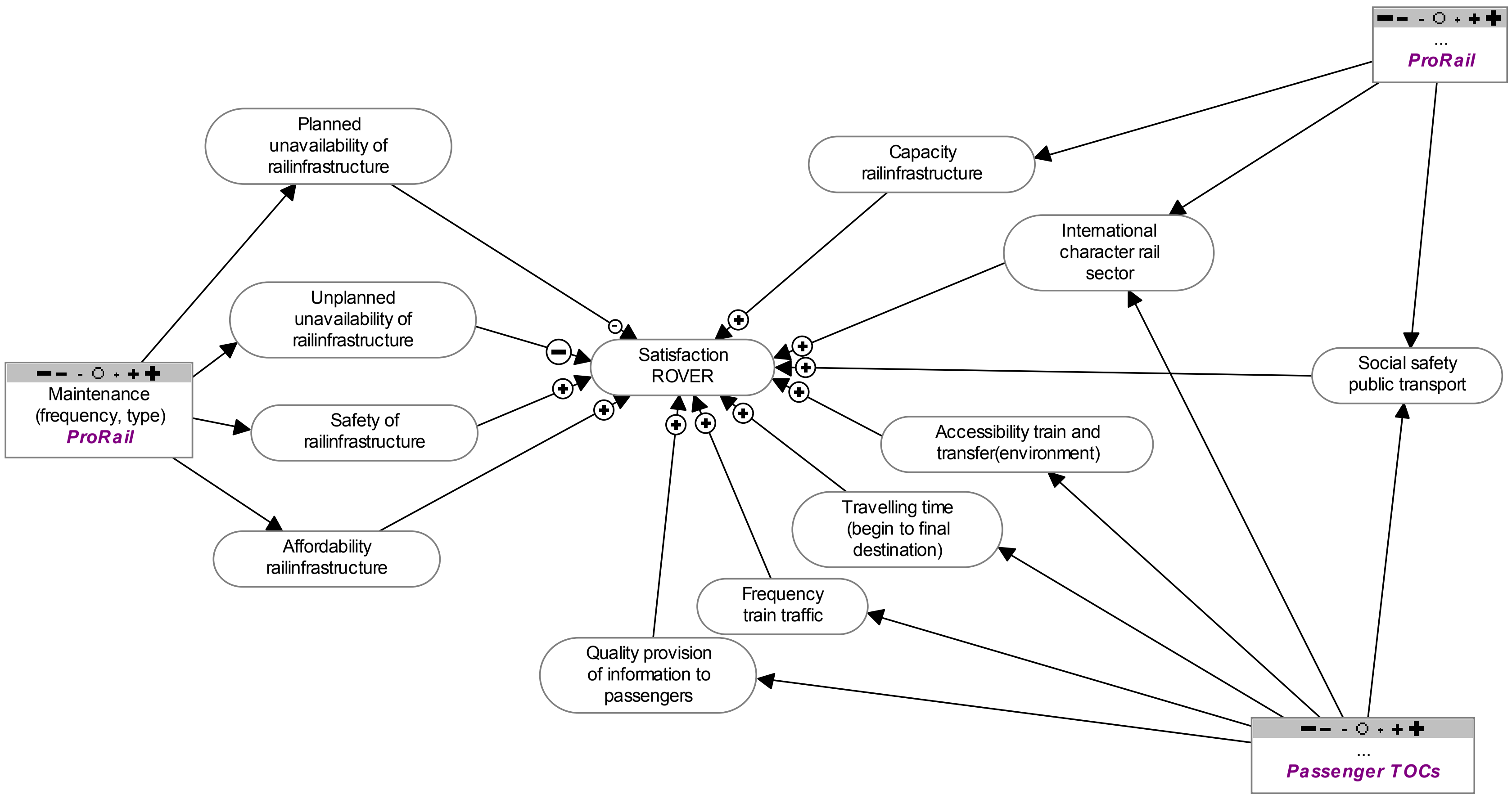

Hoogte financiële bezuinigingen onderhoud en verkeersleiding
Specialistisch kennisniveau bij infrabeheerder
Voorspelbaarheid gehele treinreis
Punctualiteit
Betaalbaarheid spoorsysteem
Adequaatheid informatieverstrekking voorafgaand aan reis
Betrouwbaarheid spoorsysteem
Adequaatheid informatieverstrekking tijdens reis
Grootte reservecapaciteit railinfrastructuur
Beschikbaarheid spoorsysteem
Capaciteit spoorsysteem
Toegankelijkheid trein en station(somgeving)
Kwaliteit reisinformatie
Negatieve gevolgen van een tijdsvertraging
Kwaliteit waarborging van aansluitingen
Sociale veiligheid
Tijdsvertraging
Veiligheid
Prestatieniveau spoorsysteem
Frequentie treinverkeer
Belang treinreis (zoals laatste verbinding)
Aantal getroffen reizigers
Storingen
Aantal (infragerelateerde) veiligheidsincidenten
Reissnelheid
Tevredenheid treinreizigers
Comfortniveau in trein door railinfra
Maximaal toegestane rijsnelheid
Gemiddelde (operationale) rijsnelheid
Kwaliteit railinfrastructuur
Gevoeligheid railinfrastructuur voor sneeuw en bliksem
Kwaliteit treinverkeersleiding
Kwaliteit stations
Grip op door aannemers geleverde kwaliteit
Kwaliteit noodstroomvoorzieningen en terugvalsystemen
Kwaliteit afhandeling bij vertraging
Wachttijd bij overstap
Aantal tijdelijke snelheidsbeperkingen
Achterstallig onderhoud
Kwaliteit overstapproces

## DANA diagrams: analyst interpretation of stakeholder perspectives

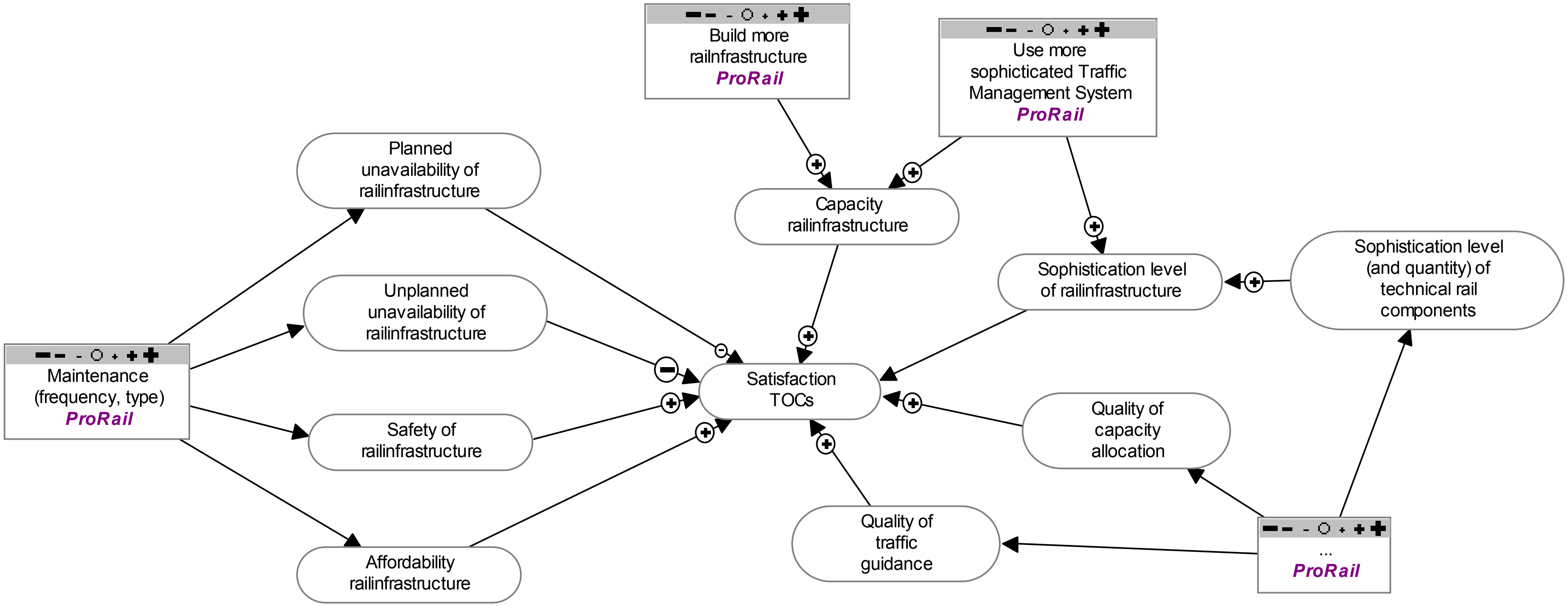
### DANA model – Analyst view of satisfaction IVW



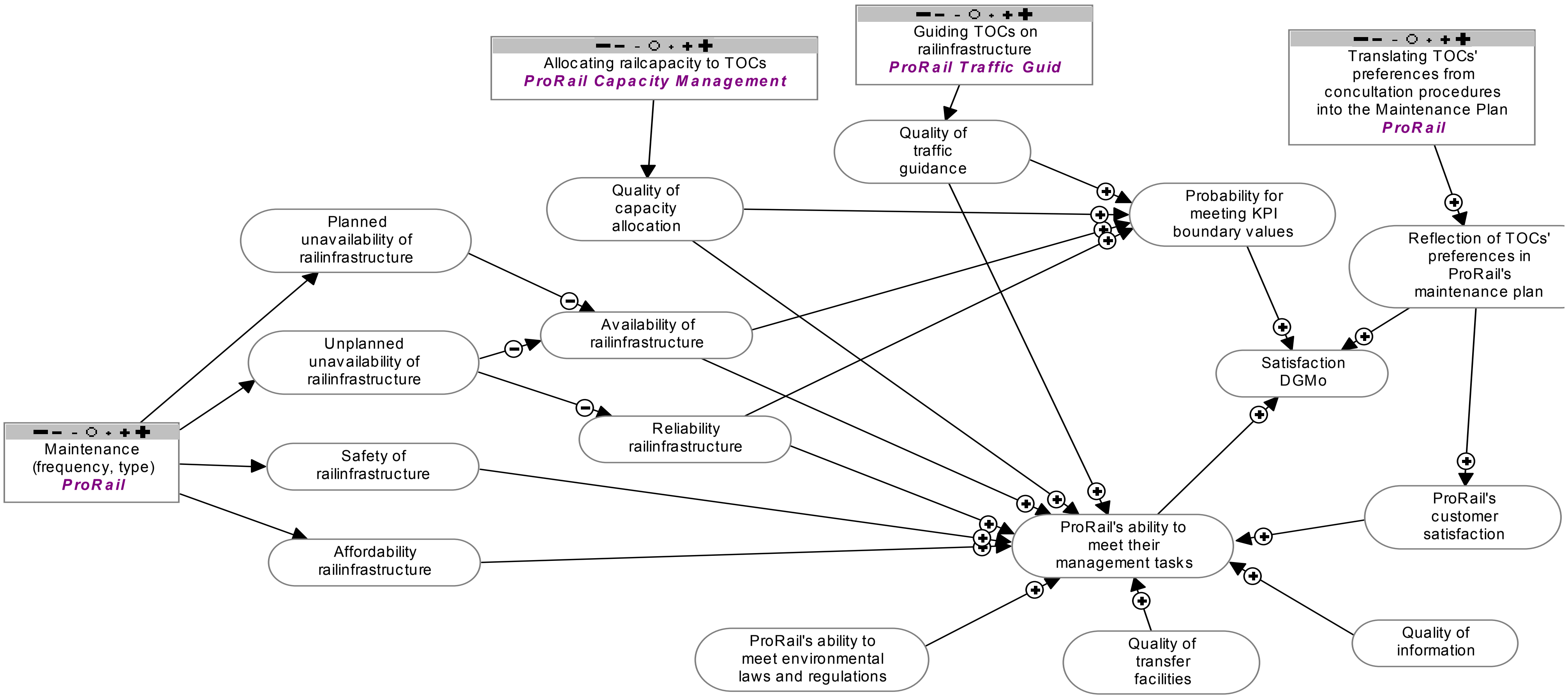
### DANA model – Analyst view of satisfaction ROVER



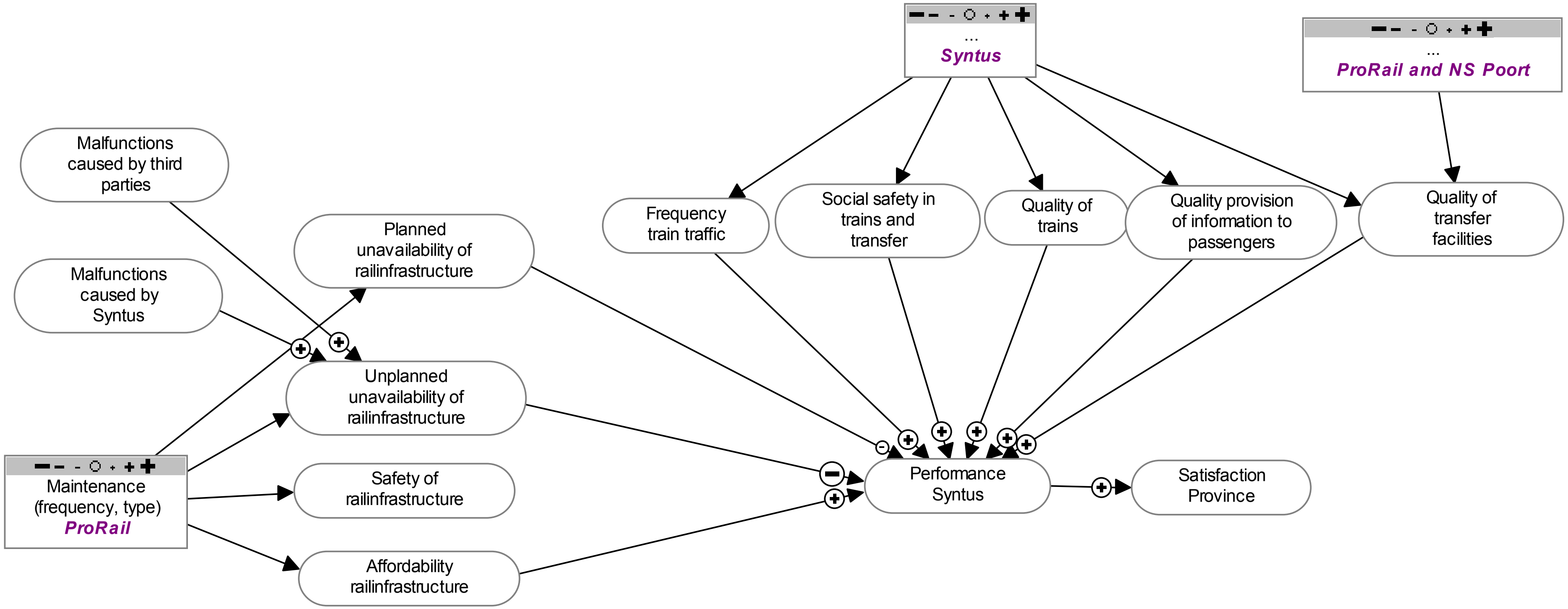
## DANA model – Analyst view of satisfaction Train Operating Companies



## *DANA model – Analyst view of satisfaction DGMo*



### DANA model – Analyst view of satisfaction Province of Gelderland



## Appendix I: General information on interviewees

| Actor group | Organization | Interviewee | Function |
|---|---|---|---|
| Passanger TOC | NS Reizigers | Geert-Jan Bazuin | Managing Director Infrastructure |
| | NS Hispeed | Hans Driesen | Studieleider |
| | Regional TOCs | Maartje Claessens | Senior Manager Relationships ProRail |
| Freight TOCs | ACTS | Toon Habers | General Manager |
| | DB Schenker | Hans-Willem Vroon | Manager Safety, Quality Health and Environment |
| | ERS Railways | Eric ten Feld | General Manager Director Benelux |
| | Veolia Cargo | Anthonie de Hulster | Manger Operations Benelux |
| Governmental Inspection | IVW Rail Inspectorate Expertise and Approvals | Helmuth Götz | Senior projectmanager |
| Concession provider | DG Mobility | Otto van Rooij | Senior staff bij Directie Spooor |
| | | Henk Schutte | Senior staff bij Directie Spooor |
| | Province of Gelderland | Ton Spaargaren | Projectleider Mobiliteit |
| Consumer interest association | ROVER | Tineker van der Werf | General Manager |

## Appendix J: Factors and their occurrences by category

| Factors | # of Occurrences | Category | Sum |
|---|---|---|---|
| Aantal dienstregelingsuren | 1 | A | |
| Beschikbaarheid spoorsysteem | 8 | A | |
| Beschikbaarheid treinpaden | 1 | A | |
| Functiehersteltijd | 1 | A | |
| Geplande onbeschikbaarheid spoorsysteem | 6 | A | |
| Hinder door onbeschikbaarheid spoorsysteem | 3 | A | |
| Hoeveelheid werkzaamheden in buitendienststellingen | 1 | A | |
| Kwaliteit beschikbaarheid spoorsysteem | 1 | A | |
| Lengte dienstregeling | 1 | A | |
| Tijd geclaimd voor onderhoud | 2 | A | |
| Tijd voor effectief onderhoud | 2 | A | |
| Tijd voor ineffectief onderhoud | 2 | A | |
| Tijd voor onderhoud | 2 | A | 31 |
| Betaalbaarheid spoorsysteem | 2 | C | |
| Efficiëntie | 1 | C | |
| Hoogte financiële bezuinigingen onderhoud en verkeersleiding | 1 | C | |
| Hoogte gebruiksvergoeding | 5 | C | |
| Kans op financiële malus door Provincie | 1 | C | |
| Kans op financiële sanctie door klanten | 2 | C | |
| Kans op financiële sanctie door Provincie | 1 | C | |
| Kans op financiële sanctie door V&W | 1 | C | |
| Kosten aan personeel en materieel | 3 | C | |
| Kosten energieverbruik | 1 | C | |
| Kosten goederentransport | 4 | C | |
| Kosten reizigersvervoer | 1 | C | |
| Kostendekkingsgraad | 1 | C | |
| Prijs treinkaartje | 3 | C | 27 |
| Comfortniveau in trein door railinfra | 1 | Co | |
| Rijcomfort | 3 | Co | 4 |
| Adequaatheid informatieverstrekking tijdens reis | 1 | I | |
| Adequaatheid informatieverstrekking voorafgaand aan reis | 1 | I | |

| Category name | Short | Freq. |
|---|---|---|
| Quality railinfra | Q | 14 |
| Reliability | R | 54 |
| Safety | S | 26 |
| Costs | C | 27 |
| Availability | A | 31 |
| Speed | Sp | 7 |
| Comfort | Co | 4 |
| Information | I | 11 |
| Satisfaction | Sa | 12 |
| Other | X | 79 |

| | | | |
|---|---|---|---|
| Betrouwbaarheid KPI informatie | 1 | I | |
| Informatie mbt de relatie tussen gebreken en functioneel falen | 1 | I | |
| Informatie over huidige staat railinfrastructuur | 1 | I | |
| Kwaliteit informatie algemeen | 1 | I | |
| Kwaliteit informatie mbt vertragingen | 1 | I | |
| Kwaliteit reisinformatie | 2 | I | |
| Kwaliteit van de informatievoorziening | 1 | I | |
| Tijdigheid van informatievoorziening | 1 | I | 11 |
| Achterstallig onderhoud | 1 | Q | |
| Kwaliteit onderhoud | 1 | Q | |
| Kwaliteit railinfrastructuur | 4 | Q | |
| Prestatieniveau spoorsysteem | 7 | Q | |
| Slijtage aan railinfrastructuur | 1 | Q | 14 |
| Aantal gehaalde slots | 3 | R | |
| Aantal opgeheven treinen | 1 | R | |
| Aantal tijdelijke snelheidsbeperkingen | 1 | R | |
| Betrouwbaarheid spoorsysteem | 7 | R | |
| Kans op halen tijdslot | 1 | R | |
| Kans op opheffen trein | 1 | R | |
| Kans op vertraging | 1 | R | |
| Kwaliteit noodstroomvoorzieningen en terugvalsystemen | 1 | R | |
| Negatieve gevolgen van een tijdsvertraging | 1 | R | |
| Negatieve impact voor dienstregeling | 1 | R | |
| Ongeplande onbeschikbaarheid spoorsysteem | 6 | R | |
| Punctualiteit | 7 | R | |
| Snelheidsbeperking | 2 | R | |
| Storingen | 8 | R | |
| Storingen aan de railinfrastructuur | 1 | R | |
| Storingen door derden (vandalisme) | 1 | R | |
| Storingen door Syntus | 1 | R | |
| Tijdigheid van aflevering goederen | 1 | R | |
| Tijdsvertraging | 7 | R | |
| Voorspelbaarheid gehele treinreis | 1 | R | |
| Voorspelbaarheid transporttijd | 1 | R | 54 |
| Aantal (infragerelateerde) | 2 | S | |

| | | | |
|---|---|---|---|
| veiligheidsincidenten | | | |
| Aantal niet behaalde grenswaarden | 1 | S | |
| Aantal STS (Stoptonend Sein) passages | 1 | S | |
| Arbeidsveiligheid | 1 | S | |
| Baanwerkerveiligheid | 1 | S | |
| Juistheid technische (veiligheids)norm | 1 | S | |
| Kans op (technische)normoverschrijding | 1 | S | |
| Kans op dodelijk slachtoffer | 1 | S | |
| Kans op menselijk letsel | 1 | S | |
| Kans op treinontsporing | 1 | S | |
| Kwaliteit veiligheids-systeem (ATB/ERTMS) | 2 | S | |
| Veiligheid | 8 | S | |
| Veiligheid personeel | 1 | S | |
| Veiligheid railinfrastructuur | 3 | S | |
| Veiligheid reizigers | 1 | S | 26 |
| Klanttevredenheid | 8 | Sa | |
| Reizigerstevredenheid | 1 | Sa | |
| Tevredenheid DG Mobiliteit | 1 | Sa | |
| Tevredenheid IVW | 1 | Sa | |
| Tevredenheid treinreizigers | 1 | Sa | 12 |
| Gemiddelde (operationale) rijsnelheid | 2 | Sp | |
| Maximaal toegestane rijsnelheid | 2 | Sp | |
| Maximale snelheid goederentrein | 1 | Sp | |
| Reissnelheid | 2 | Sp | 7 |
| Aantal audits door de IVW | 1 | X | |
| Aantal getroffen reizigers | 2 | X | |
| Aantal inspecties | 1 | X | |
| Aantal non-commerciele stops | 1 | X | |
| Aantal reizigers (groei) | 1 | X | |
| Aantal slagen per dag | 1 | X | |
| Aantal uitkomsten van consultatieprocedure verwerkt in beheerplan | 1 | X | |
| Belang treinreis (zoals laatste verbinding) | 1 | X | |
| Bereikbaarheid spoorsysteem | 1 | X | |
| Capaciteit spoorsysteem | 3 | X | |
| Drukte op het spoor | 1 | X | |
| Effectiviteit onderhoud | 1 | X | |
| Flexibiliteit spoorsysteem | 1 | X | |
| Frequentie treinverkeer | 3 | X | |

| | | |
|---|---|---|
| Geavanceerdheid spoorsysteem | 2 | X |
| Geluidshinder | 1 | X |
| Gemak in- en uitstappen | 1 | X |
| Gemak kaartje kopen | 1 | X |
| Gevoeligheid railinfrastructuur voor sneeuw en bliksem | 1 | X |
| Gewicht goederentrein | 1 | X |
| Grip op door aannemers geleverde kwaliteit | 1 | X |
| Groei van het aantal treinreizigers | 1 | X |
| Grootte reservecapaciteit railinfrastructuur | 1 | X |
| Grootte tijdslot | 1 | X |
| Hinder voor reiziger | 1 | X |
| Hoogte geluidsuitstoot goederentrein | 1 | X |
| Kans op behalen KPI-grenswaarden | 1 | X |
| Kans op imagoschade | 1 | X |
| Kans op intrekking beheerconcessie | 1 | X |
| Kans op verlies concessie | 1 | X |
| Kwaliteit afhandeling bij vertraging | 1 | X |
| Kwaliteit beheersplan | 1 | X |
| Kwaliteit bijsturing | 1 | X |
| Kwaliteit materieel | 1 | X |
| Kwaliteit overstapproces | 1 | X |
| Kwaliteit stations | 1 | X |
| Kwaliteit transfervoorziening (reinheid, sociale veiligheid en toehankelijkheid) | 1 | X |
| Kwaliteit treindienst | 1 | X |
| Kwaliteit treinreis | 1 | X |
| Kwaliteit treinverkeersleiding | 1 | X |
| Kwaliteit van de bijsturing | 1 | X |
| Kwaliteit waarborging van aansluitingen | 1 | X |
| Lengte goederentrein | 1 | X |
| Lengte tijdslot | 1 | X |
| Milieu | 1 | X |
| Minimale volgafstand treinverkeer | 1 | X |
| Netheid | 1 | X |
| Prestaties ProRail | 1 | X |
| Prestaties Syntus | 1 | X |
| ProRail's vermogen tot afdekken zorgtaken in de beheersconcessie | 1 | X |

| | | | |
|---|---|---|---|
| ProRail's vermogen tot behalen KPI-grenswaarden | 1 | X | |
| ProRail's vermogen tot permanente prestatieverbeteringen | 1 | X | |
| Reinheid treinen en stations | 2 | X | |
| Rijstijl | 1 | X | |
| Rijtijd van een slag | 1 | X | |
| Schade tijdens transport | 1 | X | |
| Sociale veiligheid | 2 | X | |
| Sociale veiligheid treinen en stations | 1 | X | |
| Sociale veiligheid voor reizigers en personeel | 1 | X | |
| Specialistisch kennisniveau bij infrabeheerder | 1 | X | |
| Strakheid capaciteitsplanning | 1 | X | |
| Toegankelijkheid trein en station(somgeving) | 1 | X | |
| Toegankelijkheid van het materieel | 1 | X | |
| Transporttijd | 1 | X | |
| Voldoening aan concessievoorwaarden | 2 | X | |
| Vriendelijkheid | 1 | X | |
| Wachttijd bij overstap | 1 | X | |
| Zitplaatsgarantie | 3 | X | 79 |

## Appendix K: Simulating failure behaviour by using the Monte Carlo method

'Simulation' can be defined as: "the process of designing a model of a real system, and conducting experiments with this model for the purpose either of understanding the behaviour of the system or of evaluating various strategies (within the limits imposed by a criterion or set of criteria) for the operation of a system" (Shannon, 1975). Simulation can be viewed as 'pretending', or more specific for this study: 'the calculation of a reliable reflection of reality'.
Simulation is often used in situations where the complexity and quantity of calculations make it virtually impossible for analytical calculations. These types of situations often occur in the area of maintenance (Roost et al., 2003).
Calculating the expected costs of one component that is certain to malfunction once in every five years is not that difficult. But when for instance the failure behavior is not that straightforward, or preventive maintenance is included based on measurements of the condition of a component; the maintenance model is rapidly becoming too complex from analytical calculation methods to suffice as it becomes too complex and time consuming. That is why ProRail uses 'Optimizer+', a Monte Carlo-method based simulation program, specially developed for maintenance applications and capable of solving problems in the RIS where analytical methods fail.

Because sampling from a particular distribution involves the use of random numbers, stochastic simulation is sometimes called Monte Carlo simulation (Reubinstein, 1981). The principle behind Monte Carlo simulation is "that the behaviour of a statistic in random samples can be assessed by the empirical process of actually drawing lots of random samples and *observing* this behaviour" (Mooney, 1997). These statistical distributions are represented in Optimizer+ by failure behaviour, replacement and maintenance times for preventive maintenance, lead times and the Mean Time To Critical Condition (MTTCC) of condition based maintenance, which are stochastic in nature (Roost et al., 2003).

Several time values are generated in Optimizer+, such as Time To Failure (TTF) and repair times, which are based on random numbers and probability density functions. The input for the generation of these time values are random numbers between 0 and 1. These random numbers are generated by a "random generator" that pseudo[133]-randomly generates values between 0 and 1 in a way that: (1) there is no serial correlation in the range of numbers, (2) the range of values is long enough to prevent repetition and (3) the numbers are uniformly and equally distributed (Roost et al., 2003).

Maintenance concepts are, amongst other things, based on the FMECA methodology, specifying failure modes, failure causes of the failure modes, failure distribution functions and their corresponding MTBFs. The description of this failure behaviour by specifying distribution functions and characteristic parameters are one of the most important relations towards the simulation, as we need this data to be able to calculate numbers, through simulation, necessary for making informed decisions concerning maintenance.

133 When the formula and starting value (the initial "seed") are known, one can for 100% certainty predict the sequential values.

The following example (from Roost et al., 2003) should give a good impression of how Optimizer+ uses Monte Carlo simulation in order to generate data required for informed decision making. Imagine a simplified situation where there is one technical component of which the failure behaviour can be described by one failure mode, one failure cause and one failure condition. In the example, the probability distribution function of the failure condition is normally distributed with an average of 1 year and a standard deviation of 3 months, see Figure 8.

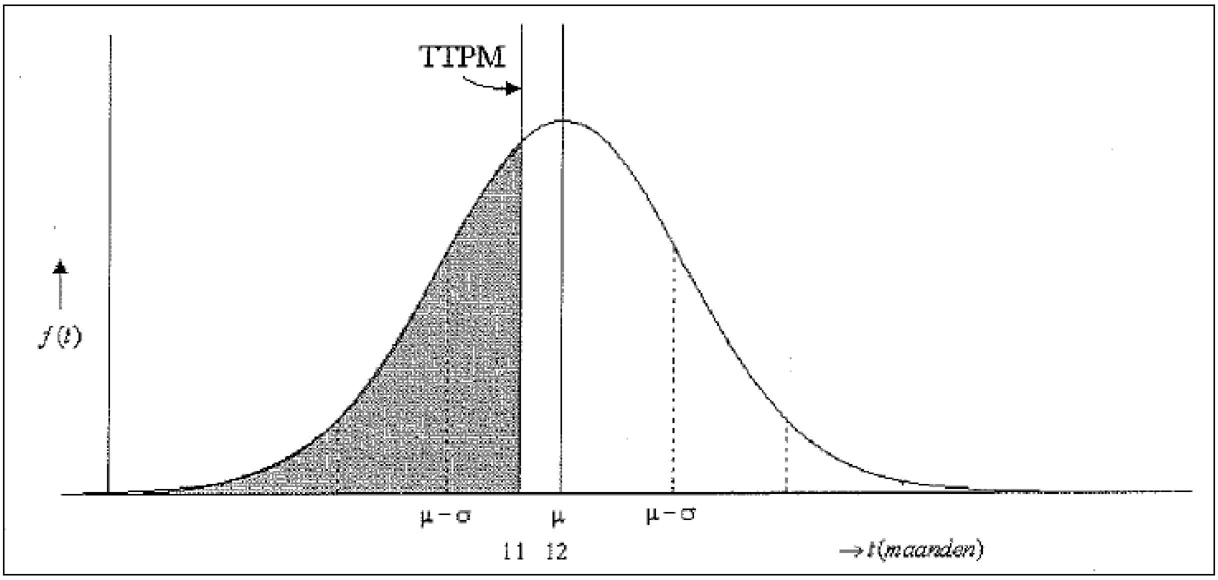



Figure 8: Normal distribution function f(t), mean: 1 year and st.deviation: 3 months, TTPM: 11 months

When the pseudorandom generator generates 0,35; the first TTF (TTF1) can be determined by calculating at which TTF the surface under the probability distribution is 0,35. The cumulative probability function, shown in Figure 9, easily shows that the TTF1 is 9 months when 0,35 is used as input. Therefore, the TTFs are randomly generated. The TTF1 of 9 months, means the component will fail, assuming *no* preventive maintenance is executed.

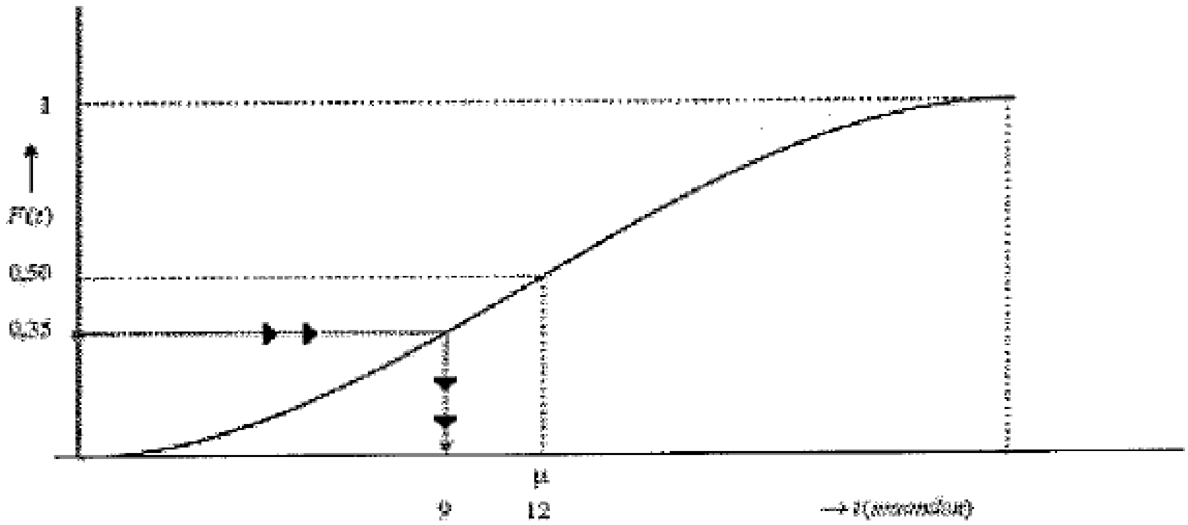



Figure 9: Calculation TTF for 0,35 in cumulative probability function F(t)

In Optimizer+ it can be specified which action, is required after the component has failed and how long it takes for this maintenance to be finalized. In the example we use replacement of the component, taking 12 hours.
The second generated number is 0,78, resulting in a TTF2 of 15 months (Figure 10).

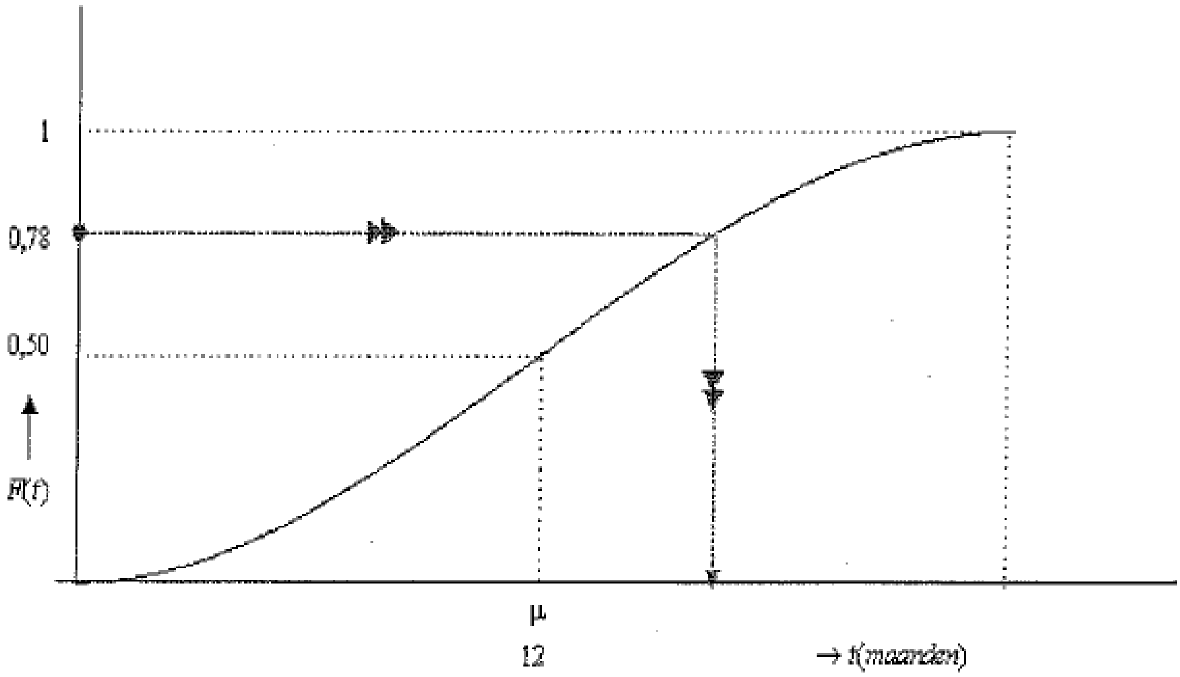



Figure 10: Calculation TTF for 0,78 in cumulative probability function F(t)

The second moment of failure will therefore be on t = TTF1 + 12 hours + TTF2. Again, including the assumption that no preventive maintenance will be used. This process, of calculating TTFs based on the randomly generated number, will repeat itself until the end of the simulation period. The length simulation period can be determined by the user.

We can also include a replacement interval, determining the Time To Preventive Maintenance (TTPM). We use 11 months in the example (see Figure 11). The first TTPM is ineffective as the TTPM1>TTF1. The preventive maintenance is simply too late. Optimizer+ then calculated the second TTPM on: TTF1 + 11 = after 20 months, where the PM is effective as it is executed before the component has failed.

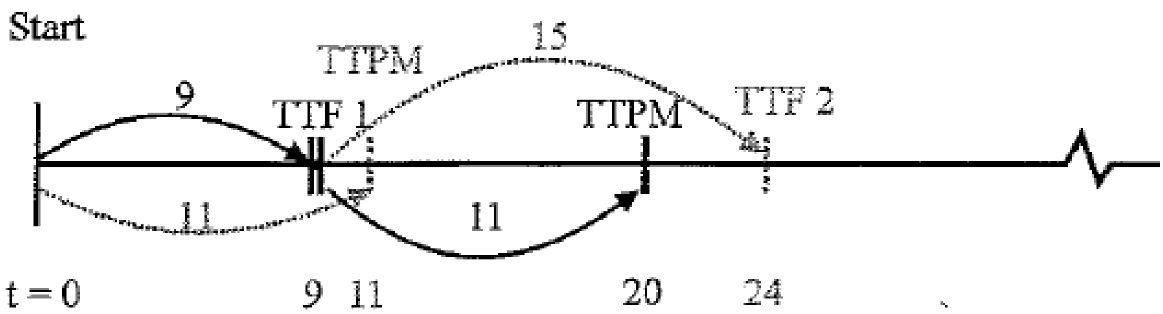



Figure 11: Timeline including TTF1 plus maintenance time and TTF2; TTPM: 11 months

Going through the time length of the simulation and calculating the TTFs is called a 'run', shown in Figure 11. To acquire a sufficient reliability level suitable for decision making, many of these runs are required, which will be elaborated in further detail in the next section.

### *Reliability of Monte Carlo simulation and Optimizer+*

It is important to know when simulation results are reliable. Answering the following question is central: "how many simulation runs are required to be able to make reliable conclusions on the actual RIS?" Many research shows that it is unnecessary to simulate everything to infinity, as the 'central limit theorem' applies (Chatfield, 1975; Vose, 1996; Lewis, 1996). The central limit theorem (CLT) states that the re-averaged sum of a sufficiently large number of identically distributed independent random variables each with finite mean and variance will be approximately normally distributed (Rice, 2007), meaning that the simulation results will eventually converge towards the final outcome.

The CLT makes it possible to measure the reliability based on known testing algorithms, from which Optimizer+ uses the Students T-Test. The reliability interval reflects the margin of error we accept. Optimizer+ can use 90%, 95% and 99% as confidence levels. For example when 95% is used as a confindence level, 5% of the simulation results will not be within the testing area (see also Chatfield, 1975).

## Appendix L: Performance indicators concessions for regional TOCS

Received from Maartje Claessens, a senior manager external relations, on 19 january 2009.

| | | |
|---|---|---|
| Concessie | Inhoud | Valleilijn |
| | Startdatum | december 2006 |
| | Einddatum | december 2021 |
| | Opdrachtgever | Provincies Gelderland |
| Gunningscriteria | Prijs | Niet openbaar |
| | Treinkm's | 70% van de gunning is gebaseerd op het aantal dienstregelingsuren wat Connexxion rijdt: Dienstregelingsuren = rijtijd van een slag x # slagen p/d x dagen in de week.<br>→ Als kering is verlegd naar Barneveld C duurt slag langer en hoeven er minder slagen gereden te worden om het # afgesproken bedrijfsuren te halen.<br>→ # bedrijfsuren: 20 uur p/d van 5.00-1.00 uur (= veel) |
| | Punctualiteit | Per kwartaal x% ritten komt met minder dan 3 min te laat aan, oplopend naar y% in 2015 |
| | Opgeheven treinen | Per kwartaal maximaal x% rituitval, per dag maximaal y%, busvervanging niet langer dan x weken. |
| | Sociale veiligheid | Stond in PvE: Connexxion moet alles doen om de reiziger veilig te vervoeren. Connexxion heeft hier plan voor gemaakt. Afspraak over aantal uit te voeren controles; steward-diensten, veiligheidsinspecties, inzet beveiligingsbedrijven. |
| | Zitplaatsgarantie | In spits maximaal x% maximaal y min staan, daarbuiten maximaal a% maximaal y min. |
| | Informatievoorziening aan reizigers | O.a afspraken over informeren over dienstregeling, omroep op stations en in de trein. |
| | Ov. kwaliteit (reinheid, materieel) | Netheid: Afspraak is x% tevreden reizigers over netheid materieel<br><br>Er is een afspraak over serviceverlening personeel.<br><br>Klachtenregeling: bereikbaar tijdens kantooruren, personeel vriendelijk en goed geïnformeerd. |
| | Groei reizigers | Ambitie die is afgesproken was x%, maar er is nu al (april 2008) een groei van y% bereikt. |
| | Afspraken over GV met concessieverlener | nvt |

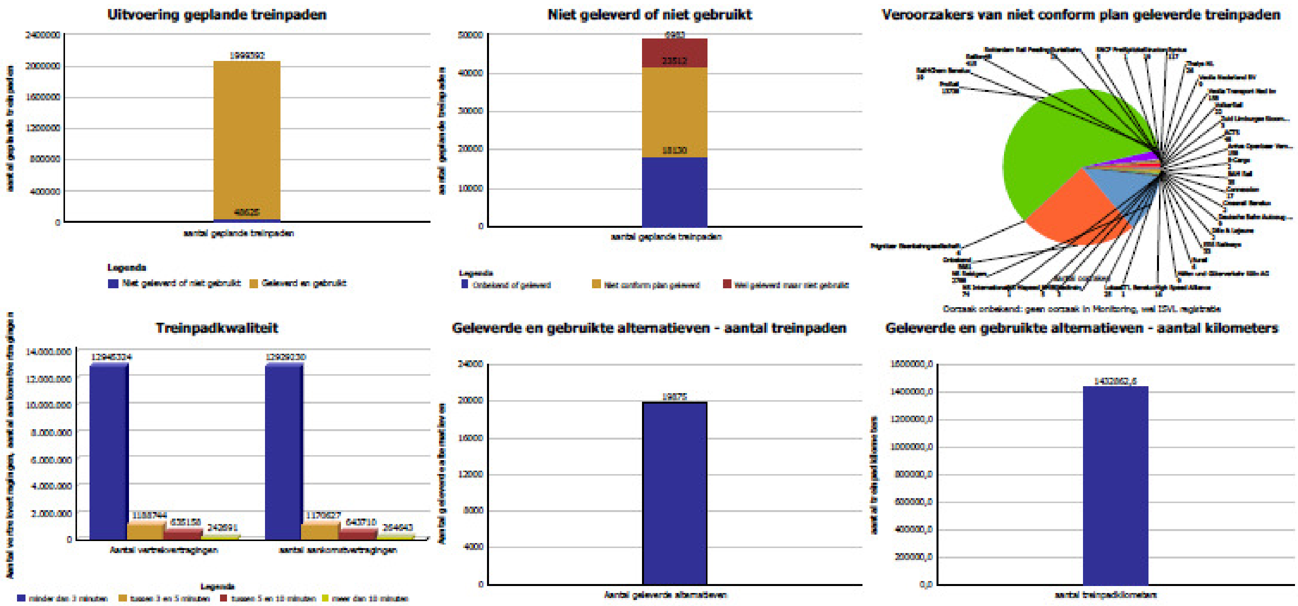
NB: Over veel items zijn malus-afspraken gemaakt, bonus zit in de groei van het aantal reizigers.
NB 2: Bussen in de regio worden gereden door Veolia. Door de Provincie wordt het als één product gepresenteerd.

# Appendix M: Historical data concerning the number of realized trains over the year 2008

## Dashboard KPI Treinpad - ProRail

**Gebruikte filters en normen**

**Type trein** : Reizigerstreinen
**Periode** : Between 1-jan-2008 and 31-dec-2008
**Vervoerder** : ACTS, Arriva, Connexxion, DB-Regio, DB Autozug, HSA, Lokaal, NS Int, NSR, PEG, ProRail, RailChemB, Railion, RRF, Rurtal, Syntus, Thalys NL, Veolia C, Veolia Rzg, VSM, ZLSM
**Netwerk** :
**Post** :
**Vertragingsnorm**: 3
**Plantype** : Oorspronkelijk Plan (OP)




25-feb-2009 - 1 - 9:37:29

# Appendix N: Questionnaire in NetQ

## Vragenlijst

### *Introductie*

Als beheerder van de railinfrastructuur is ProRail IM verantwoordelijk voor het optimaal instandhouden van de railinfrastructuur. ProRail wil hierbij in de toekomst een meer klantgerichte benadering gebruiken, waarbij de klantwensen m.b.t. de prestaties van de railinfrastructuur centraal staan. Wanneer ProRail het onderhoudsbeleid baseert op klantwensen, kunnen de geleverde prestaties zo dicht mogelijk bij de gewenste situatie komen te liggen. Dit is de focus van ons promotie- en afstudeeronderzoek aan de Technische Universiteit in Delft. Naar aanleiding hiervan willen we u vragen om deze vragenlijst in te vullen.

In eerste instantie waren wij geïnteresseerd in: de prestaties die de railinfrastructuur volgens uw organisatie zou moeten leveren. Dit is aan bod gekomen in een eerder interview die we met u of uw collega gehad hebben. Uit meerdere interviews is naar voren gekomen dat de prestaties welke voor klanten belangrijk zijn, in sommige gevallen tegenstrijdig zijn, waardoor een afweging gemaakt moet worden.

Het is voor ProRail van groot belang dat het onderhoudsbeleid zorgvuldig wordt ontworpen, rekening houdend met de impact van de prestaties van de railinfrastructuur op de klanten. Hiervoor is kennis nodig van waarderingen van klanten in verschillende situaties. Daarover gaat deze vragenlijst.

Op de volgende pagina zal een uitgebreide uitleg gegeven worden. Het is belangrijk dat u deze goed doorneemt. Het invullen van de vragenlijst duurt ongeveer 10 minuten. U kunt beginnen met de vragenlijst door onderaan deze pagina op "Verder" te klikken.

U wordt zeer bedankt voor uw medewerking!

Paul Brinkman (0641204308)
Randy Fischer (0628813125)

Technische Universiteit Delft

### *Uitleg prestaties*

Het eerste deel van de vragenlijst bestaat uit 17 fictieve situaties, waarbij de waarden van 3 verschillende prestatie-indicatoren worden gegeven. We willen u hierbij vragen om elke situatie te waarderen met een rapportcijfer tussen de 1 en 10.

Na deze 17 situaties zullen nog enkele algemene vragen volgen.

Hieronder zullen deze drie prestatie-indicatoren worden beschreven, inclusief de waarden die voor kunnen komen.

***1: % Gehinderde treinen door storingen***
Deze prestatie heeft betrekking op het aantal gehinderde treinen veroorzaakt door ongeplande storingen, waardoor een deel van de corridor niet beschikbaar is voor treinverkeer. De hierdoor gehinderde treinen zullen een tijdsvertraging van meer dan 3 minuten oplopen. Deze prestatie zou men ook kunnen zien als de "betrouwbaarheid".
Het is belangrijk dat u onderscheid maakt tussen "het percentage gehinderde treinen" en "de tijdsvertraging van de trein als gevolg van deze hinder". De prestatie "% Gehinderde treinen door storingen" heeft enkel betrekking op het percentage treinen dat hinder ondervindt door storingen. De grootte van de hinder wordt verder buiten beschouwing gelaten en zal in elke situatie gelijk zijn, namelijk: meer dan 3 minuten vertraging.

De storingen worden hierbij veroorzaakt door meer dan alleen technisch falen. Andere oorzaken zijn storingen door bijvoorbeeld: derden (omgeving, vervoerders, aannemers), weersomstandigheden en processen (zoals ongeplande uitloop van werkzaamheden).

De prestatieniveaus in de situaties zullen variëren tussen: 11%, 15%, 19%, en 23%.

*Bijvoorbeeld: wanneer "het percentage gehinderde treinen door storingen" 11% is, betekent dit dat, gemiddeld genomen, ongeveer 1 op de 9 treinen die over de corridor rijden, een tijdsvertraging van meer dan 3 minuten zal oplopen als gevolg van onverwachte storingen. Maar: het overige deel, 8 van de 9 treinen, zullen geen vertragingen oplopen door storingen.*

***2: % treinen waarvoor planningswijzigingen nodig zijn***
Deze prestatie heeft betrekking op het aantal treinen waarvoor wijzigingen in de planningen nodig zijn, doordat een deel van de corridor onbeschikbaar is vanwege geplande onderhoudsactiviteiten tijdens het geplande treinverkeer. Deze onttrekkingen voor geplande onderhoudsactiviteiten zullen ruim van tevoren aan vervoerders bekend worden gemaakt zodat planningen van treinen hierop tijdig aangepast kunnen worden.

De hinder door deze geplande onbeschikbaarheid kan bestaan uit:

− treinen worden opgeheven en busdiensten zijn noodzakelijk, of
− treinen worden omgeleid.

Voor goederenvervoerders:
− treinen worden omgeleid of opgeheven, of
− vertrek− en aankomsttijden wijken af van planning.

De prestatieniveaus in de situaties zullen variëren tussen: 5%, 7%, 9% en 11%.

*Bijvoorbeeld: wanneer "het percentage treinen waarvoor planningswijzigingen nodig zijn" 5% is, betekent dit dat, gemiddeld genomen, de tijdsplanning van 1 op de 20 treinen (tijdig) gewijzigd moet worden. Maar: bij het overige deel, 19 van de 20 treinen, kan de trein rijden volgens planning.*

***3: Kosten door gebruiksvergoeding***
Deze prestatie heeft betrekking op de kosten die betaald moeten worden aan ProRail voor het gebruik van de railinfrastructuur. Deze kosten zijn direct verbonden met de hoogte van de gebruiksvergoeding, waarin de volgende kosten al verwerkt zijn: het aantal gereden kilometers, het gewicht van het treinstel, kosten voor elektrische energie en kosten voor gebruik transfer (stations) en emplacementen.

De prestatieniveaus in de situaties zullen variëren tussen:
− Afname van 5%
− Geen verandering
− Toename van 5%
− Toename van 10%

***Veiligheid***
U moet ervan uitgaan dat de veiligheid van de railinfrastructuur (systeemveiligheid) in elke situatie gewaarborgd is en niet van elkaar verschilt.

***Rapportcijfer***
Zoals al eerder aangegeven wordt u gevraagd om elke situatie te waarderen met een rapportcijfer. Dit cijfer kan varieren van 1 tot en met 10, en moet geïnterpreteerd worden als de wenselijkheid van de situatie voor de organisatie waar u werkzaam bent.
1 = Minst wenselijk
2−4 = Tussenliggend
5 = Licht onwenselijk
6 = Licht wenselijk
7−9 = Tussenliggend
10 − Meest wenselijk

***Corridor***
De bovengenoemde prestaties hebben betrekking op een fictieve corridor. Deze corridor moet u zien als een spoortraject waar uw organisatie veel gebruik van maakt. De fictieve corridor heeft een lengte van 130 kilometer en kunt u vergelijken met bijvoorbeeld:
− Rotterdam naar Zevenaar grens
− Amsterdam naar Eindhoven
− Amsterdam naar Roosendaal grens

Het percentage gehinderde treinen wordt beïnvloed door de lengte van de fictieve corridor. Mocht uw organisatie niet actief zijn op een corridor met een soortgelijke lengte, dan is dit geen probleem en kunt u deze aantallen voor de beeldvorming evenredig verminderen zodat deze in verhouding staan met de lengte van het traject waarop uw organisatie actief is.

*Bijvoorbeeld: wanneer uw organisatie actief is op een traject met een lengte van de helft van de fictieve corridor, dan kunt u het percentage gehinderde treinen door storingen én door gepland onderhoud, voor de beeldvorming, ook halveren.*

De onderstaande situatie geeft de prestaties in de huidige situatie weer.

Houdt a.u.b. in gedachte dat alle situaties betrekking hebben op een corridor van ca. 130 km lengte, waar uw organisatie veel gebruik van maakt.

En nogmaals:
− Het "percentage gehinderde treinen door storingen" heeft betrekking op de ***ongeplande*** onbeschikbaarheid van de railinfrastructuur, waardoor een bepaald aantal treinen een tijdsvertraging van meer dan 3 minuten zal oplopen.
− Het "percentage treinen waarvoor planningswijzigingen nodig zijn" houdt in dat deze wijzigingen ***vroegtijdig*** kunnen plaatsvinden, omdat deze ***geplande onbeschikbaarheid*** ruim van tevoren bekend wordt gemaakt.
− De "kosten door gebruiksvergoeding" zijn de financiële vergoedingen die door de vervoerder aan ProRail betaald moeten worden voor het gebruik van het spoorsysteem.

Met welk rapportcijfer zou u de huidige situatie beoordelen?

| ***Huidige situatie*** | |
|---|---|
| | |
| % gehinderde treinen door storingen | 19% |
| % treinen waarvoor planningswijzigingen nodig zijn | 7% |
| Kosten door gebruiksvergoeding | Geen verandering |

**Rapportcijfer voor de huidige situatie:**

1
2
3
4
5
6
7
8
9
10

Houdt u bij de waardering van alle onderstaande situaties rekening met de verschillen in prestatieniveaus. Uw bovenstaande waardering van de huidige situatie zou u als vergelijkingspunt kunnen nemen voor de beoordeling van onderstaande situaties.

*(Voorbeeld: iemand waardeerde de huidige situatie met een 8. De nieuw te waarderen situatie wordt beoordeeld door* ***alle prestatieniveaus goed af te wegen****. De persoon vindt de prestaties in deze situatie minder wenselijk dan in de huidige situatie, maar beschouwt deze toch als voldoende of "licht wenselijk". De persoon waardeert de nieuwe situatie met een 6)*

Met welk rapportcijfer zou u de onderstaande situatie beoordelen?

| ***Prestatie*** | **Situatie 1** |
|---|---|
| | |
| % gehinderde treinen door storingen | 11% |
| % treinen waarvoor planningswijzigingen nodig zijn | 5% |
| Kosten door gebruiksvergoeding | Afname van 5% |

**Rapportcijfer voor situatie 1:**

1
2
3
4
5
6
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| *Prestatie* | Situatie 2 |
|---|---|
| | |
| % gehinderde treinen door storingen | 11% |
| % treinen waarvoor planningswijzigingen nodig zijn | 7% |
| Kosten door gebruiksvergoeding | Geen verandering |

**Rapportcijfer voor situatie 2:**

1
2
3
4
5
6
7
8
9
10

Met welk rapportcijfer zou u de onderstaande situatie beoordelen?

| *Prestatie* | Situatie 3 |
|---|---|
| | |
| % gehinderde treinen door storingen | 11% |
| % treinen waarvoor planningswijzigingen nodig zijn | 9% |
| Kosten door gebruiksvergoeding | Toename van 5% |

**Rapportcijfer voor situatie 3:**

1
2
3
4
5
6
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Met welk rapportcijfer zou u de onderstaande situatie beoordelen?

| *Prestatie* | Situatie 4 |
|---|---|
| | |
| % gehinderde treinen door storingen | 11% |
| % treinen waarvoor planningswijzigingen nodig zijn | 11% |
| Kosten door gebruiksvergoeding | Toename van 10% |

**Rapportcijfer voor situatie 4:**

1
2
3
4
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6
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Met welk rapportcijfer zou u de onderstaande situatie beoordelen?

| *Prestatie* | Situatie 5 |
|---|---|
| | |
| % gehinderde treinen door storingen | 15% |
| % treinen waarvoor planningswijzigingen nodig zijn | 5% |
| Kosten door gebruiksvergoeding | Geen verandering |

**Rapportcijfer voor situatie 5:**

1
2
3
4
5
6
7
8
9
10

Met welk rapportcijfer zou u de onderstaande situatie beoordelen?

| *Prestatie* | Situatie 6 |
|---|---|
| | |
| % gehinderde treinen door storingen | 15% |
| % treinen waarvoor planningswijzigingen nodig zijn | 7% |
| Kosten door gebruiksvergoeding | Afname van 5% |

**Rapportcijfer voor situatie 6:**

Met welk rapportcijfer zou u de onderstaande situatie beoordelen?

| *Prestatie* | Situatie 7 |
|---|---|
| | |
| % gehinderde treinen door storingen | 15% |
| % treinen waarvoor planningswijzigingen nodig zijn | 9% |
| Kosten door gebruiksvergoeding | Toename van 10% |

**Rapportcijfer voor situatie 7:**

1
2
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4
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6
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Met welk rapportcijfer zou u de onderstaande situatie beoordelen?

| *Prestatie* | Situatie 8 |
|---|---|
| | |
| % gehinderde treinen door storingen | 15% |
| % treinen waarvoor planningswijzigingen nodig zijn | 11% |
| Kosten door gebruiksvergoeding | Toename van 5% |

**Rapportcijfer voor situatie 8:**

| *Prestatie* | Situatie 9 |
|---|---|
| | |
| % gehinderde treinen door storingen | 19% |
| % treinen waarvoor planningswijzigingen nodig zijn | 5% |
| Kosten door gebruiksvergoeding | Toename van 5% |

**Rapportcijfer voor situatie 9:**

1
2
3
4
5
6
7
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9
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Met welk rapportcijfer zou u de onderstaande situatie beoordelen?

| *Prestatie* | Situatie 10 |
|---|---|
| | |
| % gehinderde treinen door storingen | 19% |
| % treinen waarvoor planningswijzigingen nodig zijn | 7% |
| Kosten door gebruiksvergoeding | Toename van 10% |

**Rapportcijfer voor situatie 10:**

Met welk rapportcijfer zou u de onderstaande situatie beoordelen?

| *Prestatie* | Situatie 11 |
|---|---|
| | |
| % gehinderde treinen door storingen | 19% |
| % treinen waarvoor planningswijzigingen nodig zijn | 9% |
| Kosten door gebruiksvergoeding | Afname van 5% |

**Rapportcijfer voor situatie 11:**

1
2
3
4
5
6
7
8
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10

Met welk rapportcijfer zou u de onderstaande situatie beoordelen?

| *Prestatie* | Situatie 12 |
|---|---|
| | |
| % gehinderde treinen door storingen | 19% |
| % treinen waarvoor planningswijzigingen nodig zijn | 11% |
| Kosten door gebruiksvergoeding | Geen verandering |

**Rapportcijfer voor situatie 12:**

| *Prestatie* | Situatie 13 |
|---|---|
| | |
| % gehinderde treinen door storingen | 23% |
| % treinen waarvoor planningswijzigingen nodig zijn | 5% |
| Kosten door gebruiksvergoeding | Toename van 10% |

**Rapportcijfer voor situatie 13:**

1
2
3
4
5
6
7
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Met welk rapportcijfer zou u de onderstaande situatie beoordelen?

| *Prestatie* | Situatie 14 |
|---|---|
| | |
| % gehinderde treinen door storingen | 23% |
| % treinen waarvoor planningswijzigingen nodig zijn | 7% |
| Kosten door gebruiksvergoeding | Toename van 5% |

**Rapportcijfer voor situatie 14:**

1
2
3
4
5
6
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Met welk rapportcijfer zou u de onderstaande situatie beoordelen?

| *Prestatie* | Situatie 15 |
|---|---|
| | |
| % gehinderde treinen door storingen | 23% |
| % treinen waarvoor planningswijzigingen nodig zijn | 9% |
| Kosten door gebruiksvergoeding | Geen verandering |

**Rapportcijfer voor situatie 15:**

Met welk rapportcijfer zou u de onderstaande situatie beoordelen?

| *Prestatie* | Situatie 16 |
|---|---|
| | |
| % gehinderde treinen door storingen | 23% |
| % treinen waarvoor planningswijzigingen nodig zijn | 11% |
| Kosten door gebruiksvergoeding | Afname van 5% |

**Rapportcijfer voor situatie 16:**

1
2
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Zou u de volgende vier prestaties kunnen rangschikken op mate van belangrijkheid, waarbij
1 = de meest belangrijke prestatie, en
4 = de minst belangrijke prestatie.

Let u erop dat de prestatie "veiligheid" is toegevoegd.

(Het is hierbij de bedoeling dat elke prestatie een andere ranking krijgt toegewezen; een gedeelde plaats is niet mogelijk)

| | 4 (minst belangrijk) | 3 | 2 | 1 (meest belangrijk) |
|---|---|---|---|---|
| % gehinderde treinen door storingen | ○ | ○ | ○ | ○ |
| % treinen waarvoor planningswijzigingen nodig zijn | ○ | ○ | ○ | ○ |
| Kosten door gebruiksvergoeding | ○ | ○ | ○ | ○ |
| Veiligheid van de railinfrastructuur | ○ | ○ | ○ | ○ |

Tot slot volgen hier nog wat algemene vragen.

Bij welke organisatie bent u werkzaam?

Wat is uw functie binnen de organisatie?

Mocht u geïnteresseerd zijn in de uitkomsten van het onderzoek, vult u hieronder dan uw e-mail adres in

Wanneer u nog vragen en/of opmerkingen heeft, dan kunt u deze hieronder geven

Hartelijk dank voor uw medewerking!

Wanneer u op "Verstuur" klikt, worden de ingevulde antwoorden automatisch verzonden.

## Appendix O: Overview of Key Performance Indicators

Figure XXX shows ProRail's Key Performance Indicators which are based upon the Maintenance Concession (VenW, 2005) and is extracted from ProRail's Beheerplan 2009 (ProRail, 2008g).

| Zorgtaken in de Beheerconsessie | Kernprestaties in de Beheerconsessie (V&W) | Nadere prestatie-indicatoren (2008) | Kernprestatie-indicatoren (2009) | Grenswaarde 2009 | |
|---|---|---|---|---|---|
| Waardering door klant | | 1.1) Klanttevredenheid vervoerders<br>1.2) Klanttevredenheid overheden<br>1.3) Klanttevredenheid Publiek | 1.1) KPI Klanttevredenheid<br>1.2) KPI Contractopvolging Klanten<br>1.3) KPI Reizigerstevredenheid | | Klant |
| Leiden van het verkeer over de spoorweginfrastructuur | De kwaliteit van (bij)sturing | 2.1) Bijsturing conform afspraken<br>2.2) Aantal onregelmatigheden in de rijweginstelling | 2.1) Bijsturing conform afspraken<br>2.2) Aantal onregelmatigheden in de rijweginstelling<br>2.3) KPI Treinpad<br>2.4) KPI Herstelcapaciteit: Alternatief aangeboden treinpaden | V<br>V | Operational Excellence |
| | De kwaliteit van de informatievoorziening | 2.3) Informatievoorziening conform afspraken | 2.5) KPI Reizigerstevredenheid: Reisinformatie in verstoorde situaties<br>2.6) KPI Herstelcapaciteit: Informatievoorziening CTA melding bij verstoring | V | |
| Betrouwbaarheid en beschikbaarheid van de spoorweginfrastructuur | De beschikbaarheid en betrouwbaarheid van de spoorweginfrastructuur | 3.1) Beschikbaarheid<br>3.2) Onderhoud<br>3.3) Storingen | 3.1) KPI Punctualiteit<br>3.2) KPI Beschikbaarheid<br>- Geplande niet-beschikbaarheid (onderhoud)<br>- Ongeplande niet-beschikbaarheid (storingen)<br>3.3) KPI Realisatie Infra-projecten | V<br>V<br>V | |
| | De reinheid, sociale veiligheid en toegankelijkheid van de transfervoorziening | 4.1) Reinheid<br>4.2) Sociale veiligheid<br>4.3) Toegankelijkheid | 4.1) KPI Reizigerstevredenheid Reinheid<br>4.2) KPI Reizigerstevredenheid Sociale Veiligheid<br>4.3) KPI Toegankelijkheid Transfer | V<br>V<br>V | |
| Eerlijke, niet discriminerende verdeling van de capaciteit van de spoorweginfrastructuur | De kwaliteit van de capaciteitsverdeling | 5.1) Benutting<br>5.2)Geslaagde beroepen NMA | 5.1) KPI Capaciteitsverdeling Treinpad | V | |
| … binnen wettelijke kaders van veiligheid en milieu | | 6.1) Systeemveiligheid<br>6.2) Arbeidsveiligheid | 6.1) KPI Veiligheid: aantal botsingen trein-trein<br>6.2) KPI Veiligheid: Aantal ontsporingen<br>6.3) KPI Veiligheid: Aantal arbeidsveiligheidincidenten | | |
| … en op een zo efficiënt mogelijke wijze | | 7.1) Kosten per Treinkilometer<br>7.2) Overhead | 7.1) KPI Kosten per Treinkilometer<br>7.2) KPI Kosten per Tonkilometer | | Omzet & Kosten |
| **Intern** | | | | | |
| Medewerker | 8.1) Ziekteverzuim<br>8.2) Medewerkertevredenheid<br>8.3) RGB afspraken over leiderschap en kennismanagement<br>8.4) Interne benoeming op sleutelposities<br>8.5) Interne doorstroming (employability)<br>8.6) Competentiegericht, resultaatgericht en omgevingsgericht op/boven norm (RGB)<br>8.7) Percentage werknemers dat binnen 3 jaar weggaat | | 8.1) KPI Arbeidsmarktimago<br>8.2) KPI Medewerkersbetrokkenheid | | Medewerker |
| | 9.1) Innovatie | | | | |

# Appendix P: Model output in Optimizer+

## P1: Costs and unplanned downtime

| *Scenario* | *Sim.time* | *Reliability interval* | **Output** | | |
|---|---|---|---|---|---|
| | | | **Total maintenance costs** | **# Corrective maintenance** | **Av. Unplanned downtime** |
| 1: Present performance | 50 jaar | 90% | 60534316* | 43,1 | 167,9 |
| 2: Low cost-low performance | 50 jaar | 90% | 56.115.457 | 45,7 | 177,9 |
| 3: High cost-high performance | 50 jaar | 90% | 63.593.513 | 29,5 | 142,4 |

* wijkt af van getallen in artikel IEEE

## P2: Planned downtime

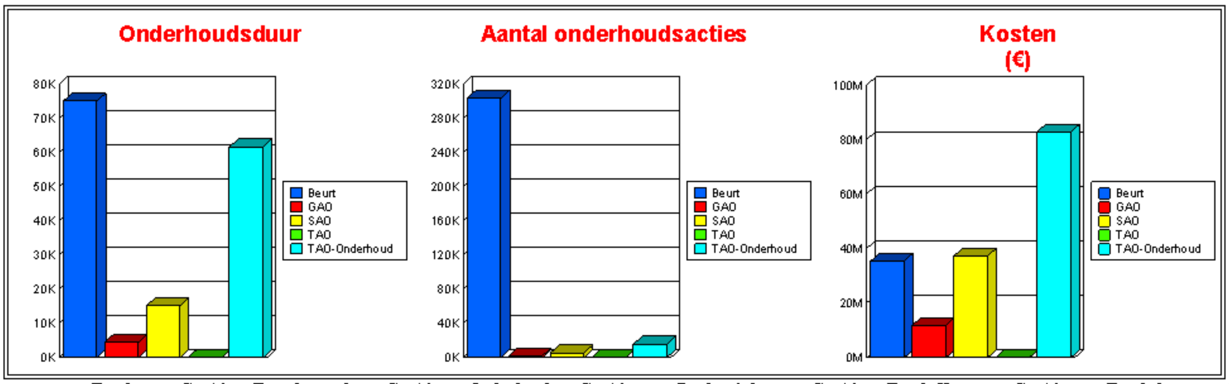
### *Scenario 1: Present performance*

ProRail

Print Datum : 7-4-2009

| Simulatie Parameters: | |
|---|---|
| Naam : | 01_Randy_Simulatie 02 |
| Sim. Periode:: | Jaren |
| #Perioden: | 50 |
| Max rekentijd (min.) :: | 30 |
| Behaalde Runs:: | 11 (Max : 0) |
| Behaalde Conf. Lvl.:: | 100% |

**Totaal Overzicht**
**Objectnaam: v2 MC Present performance -**




| Strategie | Totale duur(u) | *Gemid. Duur (u)* | Totaal aantal acties | *Gemid. Aantal* | Onderhouds kosten (€) | *Gemid. Kosten* | Productiederv. Kosten (€) | *Gemid. Kosten* | Totale Kosten | *Gemid. Kosten* | Totale kosten inc. Rend. (€) | *Gemid. Kosten inc.* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Beurt** | **75.032,34** | *1500,65* | **303.564,00** | *6071,28* | **11.687.491,00** | *233.750* | **0** | *0* | **11.687.491** | *233.750* | **35.472.515** | *709.450* |
| **GAO** | **4.502,65** | *90,05* | **2.029,82** | *40,60* | **4.679.740,00** | *93.595* | **0** | *0* | **4.679.740** | *93.595* | **11.779.642** | *235.593* |
| **SAO** | **15.095,55** | *301,91* | **5.340,82** | *106,82* | **11.992.888,18** | *239.858* | **0** | *0* | **11.992.888** | *239.858* | **37.263.971** | *745.279* |
| **TAO** | **0,00** | *0* | **0,00** | *0* | **0,00** | *0* | **0** | *0* | **0** | *0* | **0** | *0* |
| **TAO-Onderhoud** | **61.587,89** | *1231,76* | **15.595,18** | *311,90* | **32.174.196,36** | *643.484* | **0** | *0* | **32.174.196** | *643.484* | **82.822.153** | *1.656.443* |
| | **156.218,43** | *3124,37* | **326.529,82** | *6530,60* | **60.534.316** | *1210686* | **0** | *0* | **60.534.316** | *1210686* | **167.338.282** | *3346766* |

Optimizer+ Page 1 of 1 MaintControl

## *Scenario 2: Low costs – low performance*

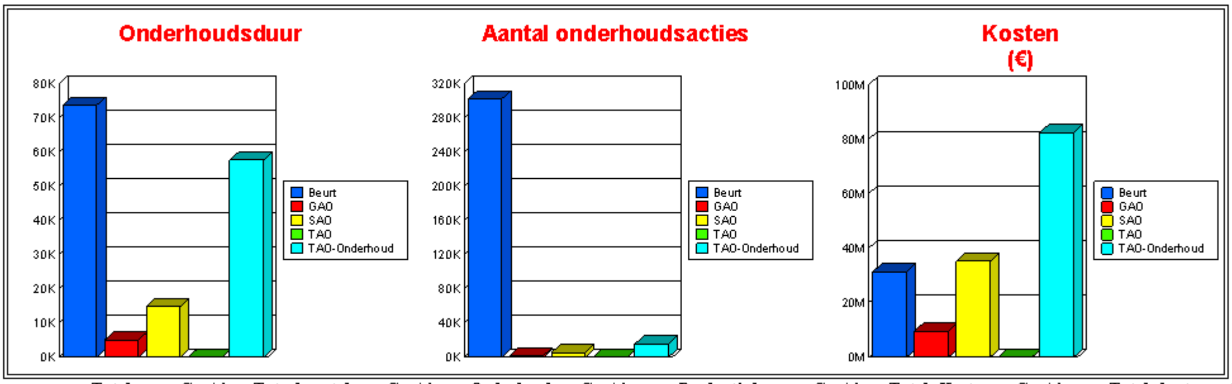
ProRail

Print Datum : 7-4-2009

| Simulatie Parameters: | |
|---|---|
| Naam : | 01_Randy_Simulatie 12 |
| Sim. Periode:: | Jaren |
| #Perioden: | 50 |
| Max rekentijd (min.) :: | 30 |
| Behaalde Runs:: | 11 (Max: 0) |
| Behaalde Conf. Lvl.:: | 100% |

**Totaal Overzicht**

**Objectnaam: v2 MC Low costs - Low performance -**




| Strategie | Totale duur(u) | *Gemid. Duur (u)* | Totaal aantal acties | *Gemid. Aantal* | Onderhouds kosten (€) | *Gemid. Kosten* | Productiederv. Kosten (€) | *Gemid. Kosten* | Totale Kosten | *Gemid. Kosten* | Totale kosten inc. Rend. (€) | *Gemid. Kosten inc.* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Beurt | 73.754,96 | *1475,10* | 302.289,00 | *6045,78* | 10.327.491,00 | *206.550* | 0 | *0* | 10.327.491 | *206.550* | 31.339.838 | *626.797* |
| GAO | 5.090,51 | *101,81* | 2.048,64 | *40,97* | 3.777.340,00 | *75.547* | 0 | *0* | 3.777.340 | *75.547* | 9.605.084 | *192.102* |
| SAO | 14.872,37 | *297,45* | 5.446,55 | *108,93* | 10.971.743,64 | *219.435* | 0 | *0* | 10.971.744 | *219.435* | 35.219.729 | *704.395* |
| TAO | 0,00 | *0* | 0,00 | *0* | 0,00 | *0* | 0 | *0* | 0 | *0* | 0 | *0* |
| TAO-Onderhoud | 57.666,07 | *1153,32* | 15.495,64 | *309,91* | 31.038.882,73 | *620.778* | 0 | *0* | 31.038.883 | *620.778* | 82.422.453 | *1.648.449* |
| | 151.383,91 | *3027,68* | 325.279,82 | *6505,60* | 56.115.457 | *1122309* | 0 | *0* | 56.115.457 | *1122309* | 158.587.103 | *3171742* |

Optimizer+ Page 1 of 1 MaintControl

## *Scenario 3: High costs – high performance*

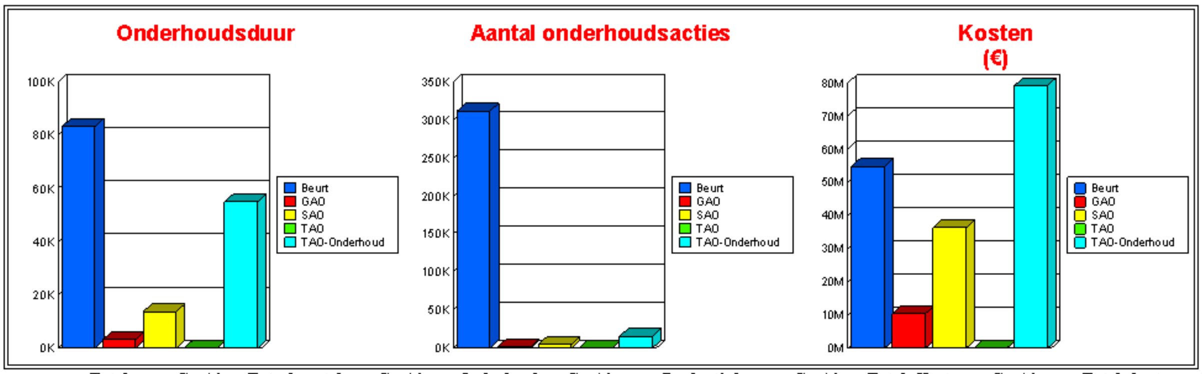
ProRail

Print Datum : 7-4-2009

| | |
|---|---|
| Simulatie Parameters: | |
| Naam : | 01_Randy_Simulatie 22 |
| Sim. Periode:: | Jaren |
| #Perioden: | 50 |
| Max rekentijd (min.) :: | 30 |
| Behaalde Runs:: | 11 (Max: 0) |
| Behaalde Conf. Lvl.:: | 100% |

**Totaal Overzicht**

**Objectnaam: v2 MC High costs - High performance -**




| Strategie | Totale duur(u) | *Gemid. Duur (u)* | Totaal aantal acties | *Gemid. Aantal* | Onderhouds kosten (€) | *Gemid. Kosten* | Productiederv. Kosten (€) | *Gemid. Kosten* | Totale Kosten | *Gemid. Kosten* | Totale kosten inc. Rend. (€) | *Gemid. Kosten inc.* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Beurt** | **83.238,09** | *1664,76* | **311.775,00** | *6235,50* | **18.025.091,00** | *360.502* | **0** | *0* | **18.025.091** | *360.502* | **54.867.197** | *1.097.344* |
| **GAO** | **3.143,45** | *62,87* | **1.599,00** | *31,98* | **4.044.300,00** | *80.886* | **0** | *0* | **4.044.300** | *80.886* | **10.364.760** | *207.295* |
| **SAO** | **13.761,64** | *275,23* | **4.878,91** | *97,58* | **11.533.408,18** | *230.668* | **0** | *0* | **11.533.408** | *230.668* | **36.359.556** | *727.191* |
| **TAO** | **0,00** | *0* | **0,00** | *0* | **0,00** | *0* | **0** | *0* | **0** | *0* | **0** | *0* |
| **TAO-Onderhoud** | **54.970,31** | *1099,41* | **15.666,91** | *313,34* | **29.990.713,64** | *599.814* | **0** | *0* | **29.990.714** | *599.814* | **79.219.748** | *1.584.395* |
| | **155.113,49** | *3102,27* | **333.919,82** | *6678,40* | **63.593.513** | *1271870* | **0** | *0* | **63.593.513** | *1271870* | **180.811.261** | *3616225* |

Optimizer+

Page 1 of 1

MaintControl

## Appendix Q: Attribute level calculation of 2 maintenance scenarios

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | **All maintenance costs** | | | **Downtime due to technical malfunctions** | | **In- and outside opening hours** |
| | Maintenance costs | **%Diff. From Pres. Perf.** | | Average annual downtime (in hours) | **Average unplanned downtime per day in minutes** | Average annual maintenance time in hours | **Average planned maintenance time per day in minutes** |
| **Model output** | | | | | | | |
| Present performance | 57943 | 0,00% | | 167,9 | 27,58 | 2822,46 | 463,65 |
| Low cost-low perf | 56115 | -3,15% | | 177,9 | 29,22 | 2730,23 | 448,50 |
| High cost-high perf | 63593[134] | 9,75% | | 142,4[135] | 23,39 | 2827,04[136] | 464,40 |
| **Attribute values** | | Change in financial tariff | % change in technical downtimefrom present perf. | % change in total downtime | % of hindered trains by unplanned downtime | % change in total maintenance time (= similar to change in time within opening hours as the assumption is that the ratio ramains the same) | % of hindered trains by planned downtime |
| Present performance | | **0,00%** | 0,00% | 0,00% | **18,60%** | 0,00% | **7,06%** |
| Low cost-low perf | | **-1,40%** | 5,96% | 3,15% | **19,19%** | -3,27% | **6,82%** |
| High cost-high perf | | **4,34%** | -15,19% | -8,03% | **17,11%** | 0,16% | **7,07%** |
| Influence factor: maintenance costs to use-rate (normative variable costs) 44,4983%[137] | | Average % of technical malfunction time in reference to the total malfunction time 52,85147%[138] | | Percentage of unplanned hindered trains on corridor in average situation 18,6035%[139] | | Percentage of planned hindered trains on corridor in average situation 7,0550%[140] | |

134 From Fischer et al. 2008

135 From Appendix P1

136 Calculated from the model output results of the 3 scenarios on the previous pages: = "Totale gemiddelde duur in uren (=per jaar)" minus "SAO (Situatie Afhankelijk Onderhoud), which is corrective or unplanned maintenance time"

137 Calculated from "Tariefberekening Gebruiksvergoeding Nieuwe Stijl": see also next pages of Appendix V.

138 Based on the average malfunction time which resulted in hindrance over the last 3 years (=limitation data availability), extracted from the KPI Beschikbaarheid (ProRail, 2009b); see also next pages of Appendix V.

139 Calculated based on historical data of 3 existing corridors extracted from the KPI Beschikbaarheid (ProRail, 2009b); see also next pages of Appendix Q.

140 See previous footnote.

## Appendix R: Individual conjoint stakeholder models

| Rating model: Veolia Cargo | | | | | | |
|---|---|---|---|---|---|---|
| | | **Average rating** | **Part-worth utility** | **p-value** | **Range** | **Relevance** |
| **Overall utility (constant)** | | 2,375 | | 0,000 | | |
| | | | | | | |
| **% Hindered trains** | | | | | | |
| 11 | | 4,25 | 1,875 | 0,000 | 2,75 | 50,0% |
| 15 | | 2,25 | -0,125 | 0,635 | | |
| 19 | | 1,5 | -0,875 | 0,013 | | |
| 23 | | 1,5 | -0,875 | | | |
| | | | | | | |
| **% Trains needing re-planning** | | | | | | |
| 5 | | 2,75 | 0,375 | 0,184 | 0,75 | 13,6% |
| 7 | | 2,5 | 0,125 | 0,635 | | |
| 9 | | 2,25 | -0,125 | 0,635 | | |
| 11 | | 2 | -0,375 | | | |
| | | | | | | |
| **% Change in usage rate** | | | | | | |
| -5 | | 3,5 | 1,125 | 0,004 | 2 | 36,4% |
| 0 | | 2,75 | 0,375 | 0,184 | | |
| 5 | | 1,75 | -0,625 | 0,047 | | |
| 10 | | 1,5 | -0,875 | | | |
| | | | | | | **Check** |
| **R Square** | 0,941 | | **Total Range:** | | 5,5 | 100,0% |
| **Adjusted R Square** | 0,852 | | | | | |

| Rating model: ERS Railways | | | | | | |
|---|---|---|---|---|---|---|
| | | **Average rating** | **Part-worth utility** | **p-value** | **Range** | **Relevance** |
| **Overall utility (constant)** | | 2,438 | | 0,000 | | |
| | | | | | | |
| **% Hindered trains** | | | | | | |
| 11 | | 3,75 | 1,312 | 0,022 | 2,499 | 41,7% |
| 15 | | 2,25 | -0,187 | 0,677 | | |
| 19 | | 2,5 | 0,062 | 0,889 | | |
| 23 | | 1,25 | -1,187 | | | |
| | | | | | | |
| **% Trains needing re-planning** | | | | | | |
| 5 | | 2,5 | 0,062 | 0,889 | 0,501 | 8,4% |
| 7 | | 2,75 | 0,313 | 0,493 | | |
| 9 | | 2,25 | -0,188 | 0,677 | | |
| 11 | | 2,25 | -0,187 | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **% Change in usage rate** | | | | | | |
| -5 | | 4,25 | 1,812 | 0,005 | 2,999 | 50,0% |
| 0 | | 2,75 | 0,313 | 0,493 | | |
| 5 | | 1,5 | -0,938 | 0,071 | | |
| 10 | | 1,25 | -1,187 | | | |
| | | | | | | **Check** |
| **R Square** | 0,86 | | **Total Range:** | | 5,999 | 100,0% |
| **Adjusted R Square** | 0,65 | | | | | |

| **Rating model: NS Reizigers** | | | | | | |
|---|---|---|---|---|---|---|
| | | **Average rating** | **Part-worth utility** | **p-value** | **Range** | **Relevance** |
| **Overall utility (constant)** | | 2,75 | | 0,000 | | |
| **% Hindered trains** | | | | | | |
| 11 | | 5 | 2,25 | 0,000 | 4 | 80,0% |
| 15 | | 3 | 0,25 | 0,207 | | |
| 19 | | 2 | -0,75 | 0,005 | | |
| 23 | | 1 | -1,75 | | | |
| **% Trains needing re-planning** | | | | | | |
| 5 | | 3 | 0,25 | 0,207 | 0,5 | 10,0% |
| 7 | | 2,75 | 0 | 1,000 | | |
| 9 | | 2,75 | 0 | 1,000 | | |
| 11 | | 2,5 | -0,25 | | | |
| **% Change in usage rate** | | | | | | |
| -5 | | 3 | 0,25 | 0,207 | 0,5 | 10,0% |
| 0 | | 2,75 | 0 | 1,000 | | |
| 5 | | 2,75 | 0 | 1,000 | | |
| 10 | | 2,5 | -0,25 | | | |
| | | | | | | **Check** |
| **R Square** | 0,973 | | **Total Range:** | | 5 | 100,0% |
| **Adjusted R Square** | 0,932 | | | | | |

| **Rating model: NS Hispeed** | | | | | | |
|---|---|---|---|---|---|---|
| | | **Average rating** | **Part-worth utility** | **p-value** | **Range** | **Relevance** |
| **Overall utility (constant)** | | 4,188 | | 0,000 | | |
| **% Hindered trains** | | | | | | |
| 11 | | 5,5 | 1,313 | 0,001 | 2,751 | 50,0% |
| 15 | | 4,75 | 0,563 | 0,035 | | |
| 19 | | 3,75 | -0,438 | 0,079 | | |
| 23 | | 2,75 | -1,438 | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **% Trains needing re-planning** | | | | | | |
| 5 | | 4,25 | 0,063 | 0,773 | 0,752 | 13,7% |
| 7 | | 4,5 | 0,313 | 0,182 | | |
| 9 | | 4,25 | 0,063 | 0,773 | | |
| 11 | | 3,75 | -0,439 | | | |
| | | | | | | |
| **% Change in usage rate** | | | | | | |
| -5 | | 5,5 | 1,313 | 0,001 | 2,001 | 36,4% |
| 0 | | 4,25 | 0,063 | 0,773 | | |
| 5 | | 3,5 | -0,688 | 0,016 | | |
| 10 | | 3,5 | -0,688 | | | |
| | | | | | | **Check** |
| **R Square** | 0,955 | | **Total Range:** | | 5,504 | 100,0% |
| **Adjusted R Square** | 0,887 | | | | | |

| **Aggregated rating model: ERS Railways and Veolia Cargo** | | | | | | |
|---|---|---|---|---|---|---|
| | | **Average rating** | **Part-worth utility** | **p-value** | **Range** | **Relevance** |
| **Overall utility (constant)** | | 2,406 | | 0,000 | | |
| | | | | | | |
| **% Hindered trains** | | | | | | |
| 11 | | 4 | 1,594 | 0,002 | 2,626 | 46,7% |
| 15 | | 2,25 | -0,156 | 0,619 | | |
| 19 | | 2 | -0,406 | 0,222 | | |
| 23 | | 1,375 | -1,032 | | | |
| | | | | | | |
| **% Trains needing re-planning** | | | | | | |
| 5 | | 2,625 | 0,219 | 0,491 | 0,501 | 8,9% |
| 7 | | 2,625 | 0,219 | 0,491 | | |
| 9 | | 2,25 | -0,156 | 0,619 | | |
| 11 | | 2,125 | -0,282 | | | |
| | | | | | | |
| **% Change in usage rate** | | | | | | |
| -5 | | 3,875 | 1,469 | 0,003 | 2,501 | 44,4% |
| 0 | | 2,75 | 0,344 | 0,293 | | |
| 5 | | 1,625 | -0,781 | 0,040 | | |
| 10 | | 1,375 | -1,032 | | | |
| | | | | | | **Check** |
| **R Square** | 0,918 | | **Total Range:** | | 5,628 | 100,0% |
| **Adjusted R Square** | 0,795 | | | | | |

| Rating model: NS Hispeed --> CORRECTED FOR PLAUSIBLE PREDICTIONS | | | | | | |
|---|---|---|---|---|---|---|
| | | | Original worth utility | New part- part-worth utility | Range | Relevance |
| **Overall utility (constant)** | | 4,188 | | 4,188 | | |
| | | | | | | |
| **% Hindered trains** | | | | | | |
| 11 | | 5,5 | 1,313 | 1,313 | 2,751 | 50,0% |
| 15 | | 4,75 | 0,563 | 0,563 | | |
| 19 | | 3,75 | -0,438 | -0,438 | | |
| 23 | | 2,75 | -1,438 | -1,438 | | |
| | | | | | | |
| **% Trains needing re-planning** | | | | | | |
| 5 | | 4,25 | 0,063 | **0,313** | 0,752 | 13,7% |
| 7 | | 4,5 | 0,313 | **0,062** | | |
| 9 | | 4,25 | 0,063 | **-0,188** | | |
| 11 | | 3,75 | -0,439 | **-0,439** | | |
| | | | | | | |
| **% Change in usage rate** | | | | | | |
| -5 | | 5,5 | 1,313 | 1,313 | 2,001 | 36,4% |
| 0 | | 4,25 | 0,063 | 0,063 | | |
| 5 | | 3,5 | -0,688 | -0,688 | | |
| 10 | | 3,5 | -0,688 | -0,688 | | |
| | | | | | | **Check** |
| **R Square** | 0,955 | | **Total Range:** | | 5,504 | 100,0% |
| **Adjusted R Square** | 0,887 | | | | | |

| Rating model: Provincie Gelderland | | | | | |
|---|---|---|---|---|---|
| | Average rating | Part-worth utility | p-value | Range | Relevance |
| **Overall utility (constant)** | | 4,188 | 0,000 | | |
| | | | | | |
| **% Hindered trains** | | | | | |
| 11 | 4,25 | 0,063 | 0,585 | 0,501 | 25,0% |
| 15 | 4,5 | 0,313 | 0,028 | | |
| 19 | 4 | -0,188 | 0,134 | | |
| 23 | 4 | -0,188 | | | |
| | | | | | |
| **% Trains needing re-planning** | | | | | |
| 5 | 4,5 | 0,313 | 0,028 | 0,751 | 37,5% |
| 7 | 4,5 | 0,313 | 0,028 | | |
| 9 | 4 | -0,188 | 0,134 | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 11 | | 3,75 | -0,438 | | | |
| **% Change in usage rate** | | | | | | |
| -5 | | 4,5 | 0,313 | 0,028 | 0,751 | 37,5% |
| 0 | | 4,5 | 0,313 | 0,028 | | |
| 5 | | 4 | -0,188 | 0,134 | | |
| 10 | | 3,75 | -0,438 | | | |
| | | | | | | **Check** |
| **R Square** | 0,915 | | **Total Range:** | | 2,003 | 100,0% |
| **Adjusted R Square** | 0,789 | | | | | |

| **Rating model: Provincie Overijssel** | | | | | | |
|---|---|---|---|---|---|---|
| | | **Average rating** | **Part-worth utility** | **p-value** | **Range** | **Relevance** |
| **Overall utility (constant)** | | 3,938 | | 0,000 | | |
| **% Hindered trains** | | | | | | |
| 11 | | 4,5 | 0,563 | 0,002 | 1,501 | 54,5% |
| 15 | | 4,5 | 0,563 | 0,002 | | |
| 19 | | 3,75 | -0,188 | 0,134 | | |
| 23 | | 3 | -0,938 | | | |
| **% Trains needing re-planning** | | | | | | |
| 5 | | 4,25 | 0,313 | 0,028 | 0,751 | 27,3% |
| 7 | | 4,25 | 0,313 | 0,028 | | |
| 9 | | 3,75 | -0,188 | 0,134 | | |
| 11 | | 3,5 | -0,438 | | | |
| **% Change in usage rate** | | | | | | |
| -5 | | 4,25 | 0,313 | 0,028 | 0,501 | 18,2% |
| 0 | | 4 | 0,063 | 0,585 | | |
| 5 | | 3,75 | -0,188 | 0,134 | | |
| 10 | | 3,75 | -0,188 | | | |
| | | | | | | **Check** |
| **R Square** | 0,958 | | **Total Range:** | | 2,753 | 100,0% |
| **Adjusted R Square** | 0,895 | | | | | |

## Appendix S: Analysis design using effect coding

| Profielnr | storing1 | storing2 | storing3 | plan1 | plan2 | plan3 | kosten1 | kosten2 | kosten3 |
|---|---|---|---|---|---|---|---|---|---|
| holdout | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 |
| 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| 2 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| 3 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 4 | 1 | 0 | 0 | -1 | -1 | -1 | -1 | -1 | -1 |
| 5 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| 6 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| 7 | 0 | 1 | 0 | 0 | 0 | 1 | -1 | -1 | -1 |
| 8 | 0 | 1 | 0 | -1 | -1 | -1 | 0 | 0 | 1 |
| 9 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 |
| 10 | 0 | 0 | 1 | 0 | 1 | 0 | -1 | -1 | -1 |
| 11 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| 12 | 0 | 0 | 1 | -1 | -1 | -1 | 0 | 1 | 0 |
| 13 | -1 | -1 | -1 | 1 | 0 | 0 | -1 | -1 | -1 |
| 14 | -1 | -1 | -1 | 0 | 1 | 0 | 0 | 0 | 1 |
| 15 | -1 | -1 | -1 | 0 | 0 | 1 | 0 | 1 | 0 |
| 16 | -1 | -1 | -1 | -1 | -1 | -1 | 1 | 0 | 0 |

| Levels: | Four levels | | |
|---|---|---|---|
| 0 | 1 | 0 | 0 |
| 1 | 0 | 1 | 0 |
| 2 | 0 | 0 | 1 |
| 3 | -1 | -1 | -1 |
| | ▼ | ▼ | ▼ |
| Parameters to be estimated | $\beta_1$ | $\beta_2$ | $\beta_3$ |

## Appendix T: Motivation non-response ROVER

Beste Paul,

Helaas vond ik niet eerder tijd om te reageren. Sorry daarvoor. Overigens wil ik je wel als mijn ervaring meegeven dat het mij een veelvoud van 10 minuten kostte om mij de gevraagde afwegingen eigen te maken en serieus te overdenken. (Dat kan natuurlijk ook aan mij liggen.)

Na overdenking kom ik helaas tot de conclusie, dat de vraagstelling te ver verwijderd is van het domein van reizigersbelangen om door ROVER te kunnen worden beantwoord. Ik zal dat hieronder toelichten.

De afweging die je ons vraagt te maken gaat tussen drie dingen: 1) meer of minder door storingen vertraagde treinen, 2) meer of minder geplande buitendienststellingen met treinhinder en 3) meer of minder gebruiksvergoeding (te vertalen in een duurder of goedkoper treinkaartje). Op zichzelf vind ik het een prima gedachte om ons allerlei varianten van zo'n afweging voor te leggen, maar dan zouden we als reizigersorganisatie ook zicht moeten hebben op de consequenties van de variabelen (1) en (2) voor de treinreizigers. Je vraagt immers ook om afwegingen tussen de variabelen (1) en (2): de ene een beetje beter, de andere een beetje slechter of omgekeerd (en dat dan ook in relatie tot de prijs van het treinkaartje).

Voor de relatie tussen ProRail en vervoerders is het percentage (gehinderde) voertuigbewegingen ongetwijfeld een relevante grootheid. Voor de vervoerders is dit een belangrijke 'input' voor hun dienstverlening aan de reizigers. Voor ons als reizigers is echter niet de 'input' van de vervoerders van belang, maar de 'output': welk percentage van de reizigers is (redelijk) op tijd naar zijn bestemming gebracht, en hoe ernstig was de hinder voor de reizigers die met vertraging of vervangend vervoer te maken kregen? Het verband tussen input en output is allerminst eenduidig. Het effect op de verplaatsingen van reizigers wordt immers in belangrijke mate bepaald door de grootte van het reistijdverlies (waarop o.a. treinfrequenties en omgang met aansluitingen van invloed zijn), de kwaliteit van vervangend vervoer, de dikte van de betrokken reizigersstromen en effecten op de betrouwbaarheidsperceptie van de spoorwegen in de markt (bijv.: "in het weekend kun je beter niet met de trein gaan want er zijn altijd stremmingen"). Dat zijn allemaal appels en peren die in de afweging horen te worden betrokken.

Ook in een geabstraheerd model, zoals in jouw vragenlijst, is daardoor een onderlinge outputvergelijking van de variabelen (1) en (2) voor mij niet mogelijk. Ik zou daarmee aan knoppen gaan draaien zonder inzicht in het uiteindelijke effect voor de reizigers. Dat doe ik dus niet. Tenslotte is de output van het hele vervoerproces (voor reizigers en verladers) toch datgene waar het in de spoorsector om gaat.

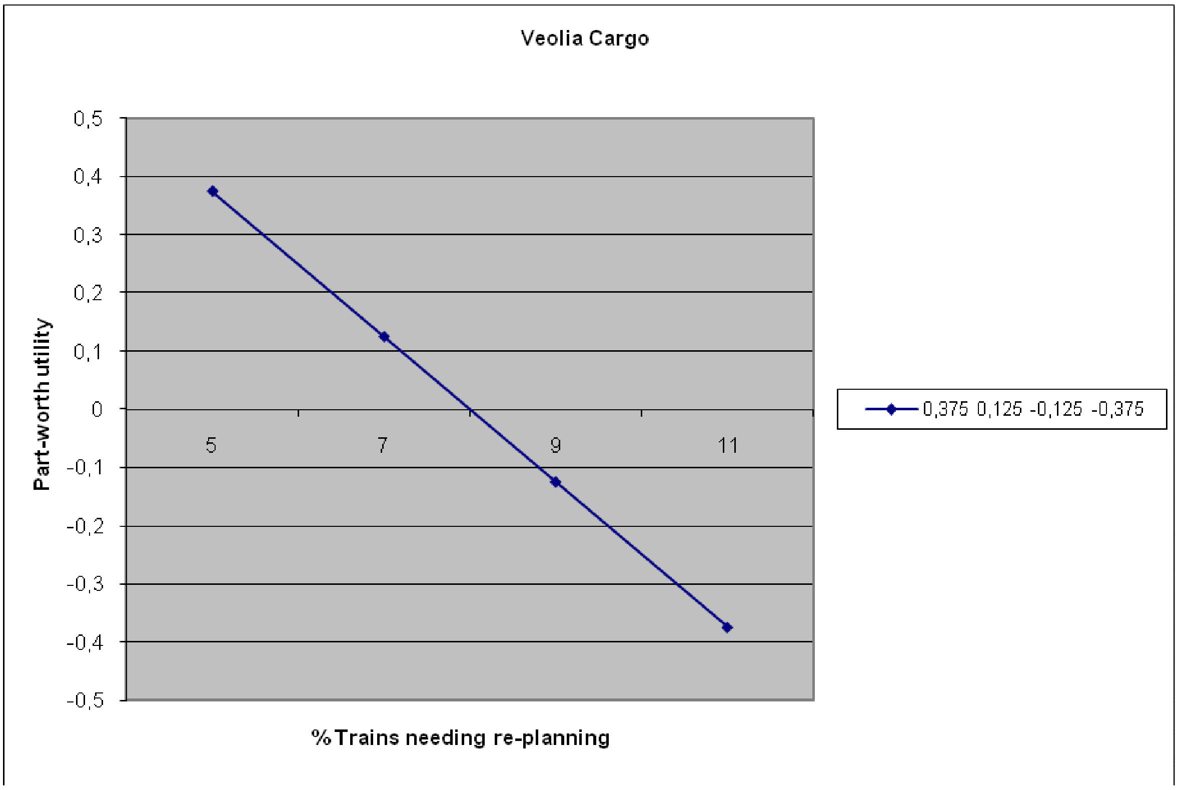
Ik ben graag bereid tot een nadere toelichting. Je kunt me daarvoor eventueel ook bellen.

Met vriendelijke groet,
Tim Boric

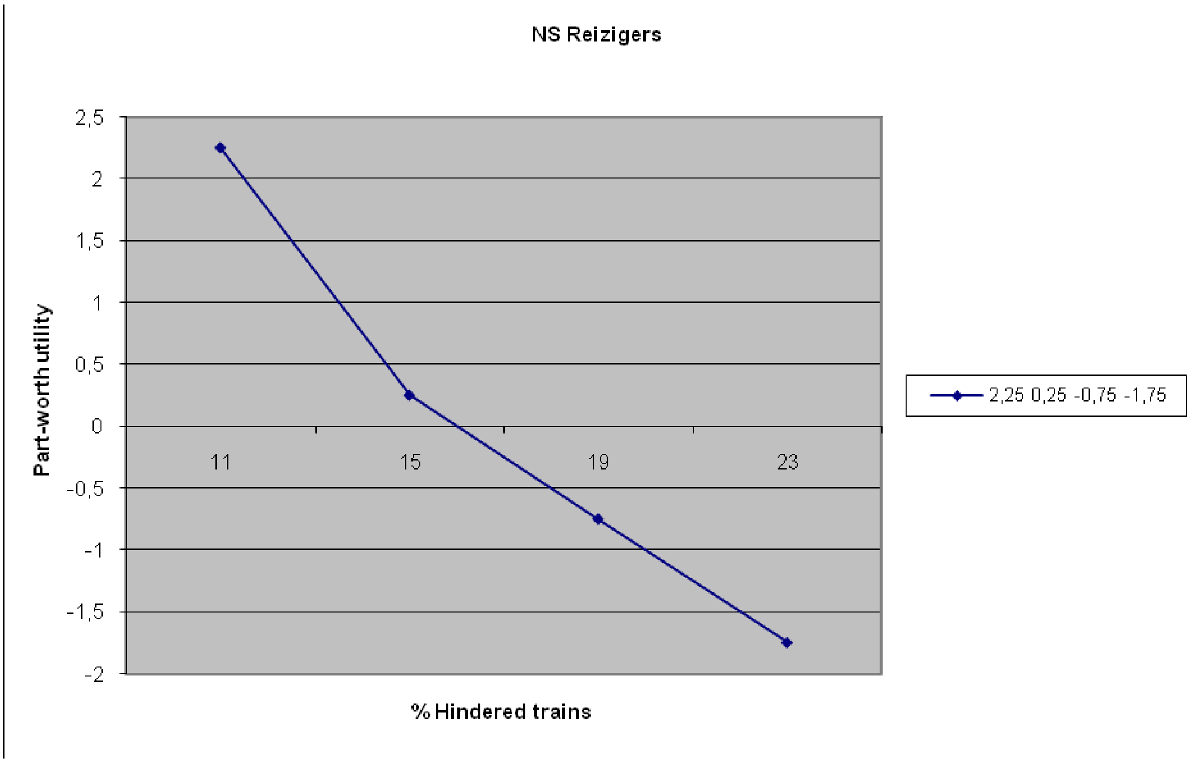
## Appendix U: Relation part-worth utilities and attribute level values

(These are examples of three different types of relations)

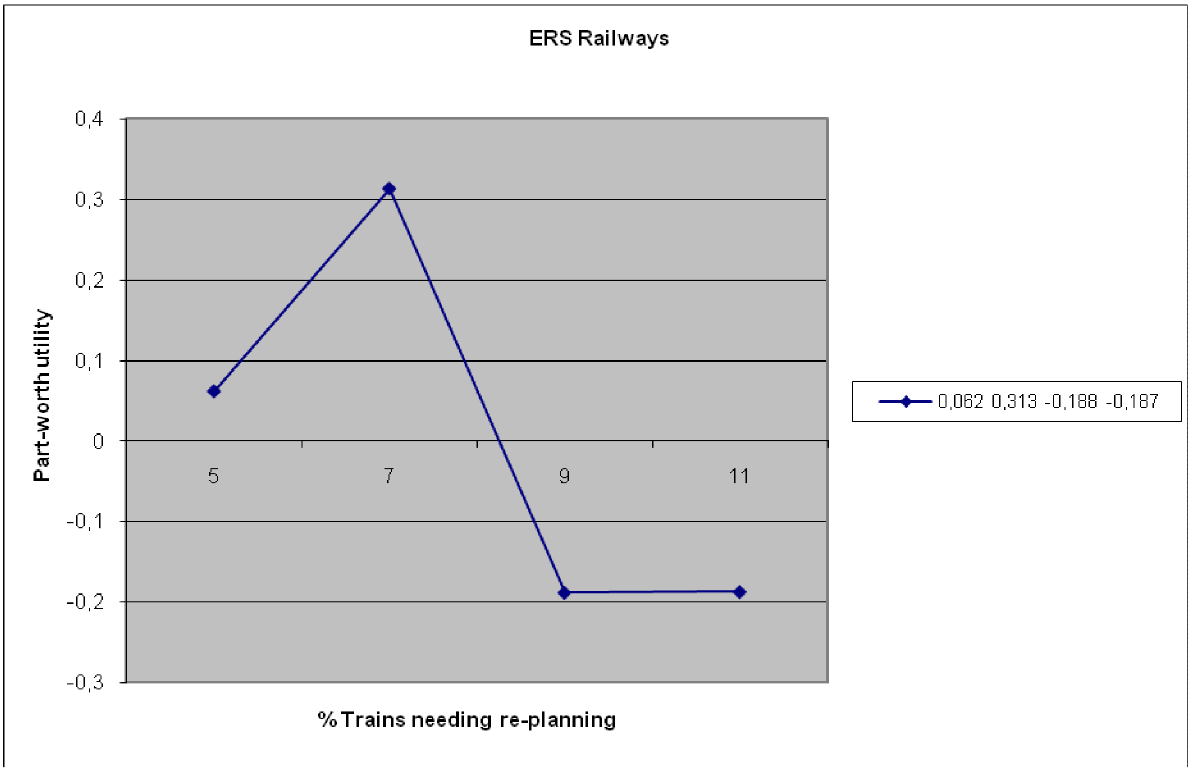
**Linear:**




**Non linear :**



**Inconcistent/Unexpected:**



## Appendix V: Background information for attribute range determination

### *Attributen m.b.t. de geplande onbeschikbaarheid van de corridor*

| | # WBIs 2007 | Gem lengte WBIs 2007 | # WBIs 2008 | Gem lengte WBIs 2008 |
|---|---|---|---|---|
| **R'dam - Zev grens (126 km)** | 32 | 12,6 | 21 | 27,1 |
| **A'dam - Eindhoven (A2 corridor) 119km** | 25 | 16,2 | 35 | 22 |
| **A'dam - Roosendaal grens (145 km)** | 50 | 8,1 | 22 | 24,8 |
| **Landelijk (netlengte = 2896 km)** | 231 | 18,1 | 304 | 17,1 |

### *Attributen m.b.t. de ongeplande onbeschikbaarheid van de corridor*

| | 2006 | 2006 | 2007 | 2007 | 2008 | 2008 |
|---|---|---|---|---|---|---|
| | # storingen | Gemiddelde FHD | # storingen | Gemiddelde FHD | # storingen | Gemiddelde FHD |
| **R'dam - Zev grens (126 km)** | 853 | 140 | 1071 | 137 | 1029 | 131 |
| **A'dam - Eindhoven (A2 corridor) 119km** | 1163 | 98 | 1466 | 75 | 1321 | 76 |
| **A'dam - Rosendaal grens (145 km)** | 1257 | 108 | 1570 | 87 | 1350 | 115 |
| **Landelijk (netlengte = 2896 km)** | 9061 | 101 | 10280 | 86 | 10304 | 103 |

### *Average malfunction information from KPI Beschikbaarheid*

| | **Storing categorie** | **Aantal storingen (met hinder)** | **FHD in uren** | **Gem duur p st in uren** | **Gem FHD per storing in minuten** | **% storingstijd door techniek** | **% storingsaantal door techniek** | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | **Gem aandeel techniek over 3 jaar (storingstijd)** |
| Landelijk 2008 | Alles | 10304 | 17629 | 1,71 | 102,65 | 57,31% | 41,80% | 52,85% |
| | Techniek (primair) | 4307 | 10103 | 2,35 | 140,75 | | | |
| Landelijk 2007 | Alles | 10280 | 14722 | 1,43 | 85,93 | 52,99% | 39,86% | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Techniek (primair) | 4098 | 7802 | 1,90 | 114,23 | | | |
| Landelijk 2006 | Alles | 9061 | 15306 | 1,69 | 101,35 | 47,58% | 40,25% | |
| | Techniek (primair) | 3647 | 7282 | 2,00 | 119,80 | | | |

### *Real corridor information for basing hypothetical corridor*

| | | |
|---|---|---|
| Lijnen: | | **R'dam - Zev grens (126 km)** |
| | 44 | Rotterdam Westelijke splitsing - Moordrecht aanslu |
| | 96 | Moordrecht aansluiting - Gouda |
| | 38 | Gouda - Utrecht |
| | 99 | Utrecht Lunetten aansluiting - Utrecht - Blauwkape |
| | 16 | De Haar - Arnhem |
| | 89 | Arnhem - Velperbroek aansluiting |
| | 93 | Velperbroek aansluiting - Zevenaar |
| | 67 | Zevenaar - Zevenaar grens |
| Lijnen | | **A'dam - Eindhoven (A2 corridor) 119km** |
| | 55 | Amsterdam Sloterdijk - Amsterdam Muiderpoort (excl |
| | 31 | Amsterdam Muiderpoort - Utrecht |
| | 99 | Utrecht Lunetten aansluiting - Utrecht - Blauwkape |
| | 47 | Lunetten - Den Bosch |
| | 94 | Den Bosch - Vught aansluiting |
| | 20 | Vught aansluiting - Boxtel |
| | 91 | Boxtel - Eindhoven |
| Lijnen | | **A'dam - Rosendaal grens (145 km)** |
| | 31 | Amsterdam Muiderpoort - Utrecht |
| | 38 | Gouda - Utrecht |
| | 44 | Rotterdam Westelijke splitsing - Moordrecht aanslu |
| | 43 | Schiedam - Rotterdam Lombardijen |
| | 46 | Rotterdam Lombardijen - Dordrecht |
| | 78 | Dordrecht - Lage Zwaluwe |
| | 50 | Lage Zwaluwe - Roosendaal Grens |

### *Realistic range of 3 existing corridors*

| **Openingstijden zijn 20 uur per dag** | | | |
|---|---|---|---|
| **corridor = 240 treinen per dag = elke 5 min een trein** | **min** | **max** | **gem** |
| Range storingstijd per dag in minuten | 277 | 426 | 351 |
| Storingstijd per rijrichting | 176,18 | 270,94 | 223,24 |
| Aantal gehinderde treinen | 35,24 | 54,19 | 44,65 |
| % gehinderde treinen | 14,68% | 22,58% | 18,60% |
| Punctualiteit (= plausibel bij check actuele punctualiteitsdata) | 85,32% | 77,42% | 81,40% |
| Range onderhoudstijd per dag in min | 66,1 | 126,31 | 84,66 |
| Range aantal treinen gehinderd door gepland onderhoud per dag | 13,22 | 25,262 | 16,932 |
| Range percentage treinen gehinderd door gepland onderhoud | 5,51% | 10,53% | 7,06% |

### *Kosten*

In de praktijk wordt de hoogte van de gebruiksvergoeding bepaald op basis van zogenaamde normatieve variabele kosten; dit zijn kosten die pas ontstaan wanneer er treinen gaan rijden. Volgens Europese regelgeving moet het op deze manier gebeuren. Echter, hoe je het aandel variabele kosten bepaald is niet zo eenvoudig. Binnen de instandhoudingskosten (focus onderzoek) onderscheid men: kleinschalig onderhoud (KO), grootschalig onderhoud (GO) en vernieuwingen. Op het moment kent zowel KO als GO een percentage variabele kosten, echter de verniewingsinvesteringen worden als geheel vast gezien, dat wil zeggen dat men ervan uitgaat dat het rijden van treinen geen invloed heeft op deze investeringskosten. Dit is op zijn minst eigenaardig omdat de drie instandhoudings-onderdelen nauw met elkaar verbonden zijn. Er zijn experts op dit gebied die het tegenovergestelde beweren: het spoor kan in principe oneindig blijven liggen als er geen treinverkeer plaatsvindt. Dit zou betekenen dat vernieuwingskosten 100% variabel zijn. Het zal voor de bepaling van de range behoorlijk uitmaken hoe je hiernaar kijkt. Ten eerste omdat de ranges per jaar verschillen tussen KO-GO en KO-GO-vernieuwing en ten tweede omdat de invloed van de instandhousingskosten op de hoogte van de gebruiksvergoeding verandert.

We hebben besloten dat de praktische relevantie belangrijker is dan een eventuele “eerlijkere” berekening van de gebruiksvergoeding. De hoogte van de gebruiksvergoeding wordt dus niet beïnvloed door vernieuwingskosten, maar alleen kosten voor KO en GO.

Dan kom ik tot het volgende en laatste puntje. In het paper van Fischer et al. (2008) zijn o.a. twee scenario's doorgerekend: een low en high cost variant waarbij de range varieert van -3,0% tot +9,8% (alle instandhoudingskosten).
In de realiteit ligt de range over de afgelopen 6 jaar tussen:
-3,8% en +23,9% (op basis van KO + GO)
-5,7% en +14,2% (op basis van KO + GO en vernieuwing)

Het is duidelijk dat een daling in kosten minder sterk is dan een stijging en de range zal hiermee rekening moeten houden. De grootte van de range is, zoals hierboven aangetoond, wat minder eenduidig. Uit gegevens over de tariefberekeningen van de gebruiksvergoeding (zie pagina hieronder) kan worden afgeleid dat 10% kostenstijging in KO en GO zou moeten leiden tot 4,50% stijging in de hoogte van de gebruiksvergoeding (aangenomen dat het treinverkeer gelijk blijft).
Wanneer de range bepaald wordt op basis van -3,8% en +23,9%, betekent dit voor de range van de gebruiksvergoeding: tussen: -1,7% en +10,8%. Om 0%[141] als attribuut-level mee te nemen in de profielen kan het aantal attribuut-levels van “kosten” verhoogd worden van 3 naar 4 (zonder dat het aantal benodigde profielen toeneemt).

**De range van “de gebruiksvergoeding per treinkilometer”**
**-5%, 0%, +5%, +10%.**

Dit betekent dat de 10,8% buiten de range valt. Echter, het is hoogstwaarschijnlijk dat de stijging van 23,8% in onderhoudskosten (waarvan de 10,8 is afgeleid) beïnvloed is door de toename in

[141] De aanwezigheid van 0% als attribuut level zal de waardering van de huidige situatie vergemakkelijken.

treinverkeer, en hiermee zal de 10,8% stijging in de hoogte van de gebruiksvergoeding in werkelijkheid lager hebben gelegen. Ik acht het dus geen probleem.

Het is erg lastig om een concreet getal te noemen bij deze kosten, omdat:

- De kosten per treinkilometer in werkelijkheid zeer van elkaar verschillen (variërend van ongeveer €1,23 tot €3,24 of hoger; afhankelijk van gewicht trein en bij reizigerstreinen ook het type station dat gepasseerd wordt). Het toevoegen van een “voorbeeldtarief per gereden kilometer” zal in veel gevallen sterk afwijken van de tarieven die men op het moment betaalt. Het risico bestaat dat de respondenten het getal niet serieus nemen.
- Het aantal afgelegde kilometers verschilt sterk per vervoerder, waardoor het noemen van een vast bedrag in termen van “kosten aan gebruiksvergoeding per maand” ook wellicht slecht te interpreteren is voor vervoerders.

→ Daarom kunnen de attribuut levels m.b.t. de gebruiksvergoeding beter in termen van procentuale veranderingen, in plaats van abslute getallen.

Table 33: Normative variable costs in "Tariefberekening Gebruiksvergoeding Nieuwe Stijl"

**Aandeel variabele kosten in "Niet verder afglijden".**

(bedragen * € 1,0 miljoen; pp 2004)

| | Beheer | Grootschalig onderhoud | Kleinschalig onderhoud | Lonen en salarissen | Transfer | Totalen |
|---|---|---|---|---|---|---|
| | Absoluut | Absoluut | Absoluut | Absoluut | Absoluut | |
| **Pakket 1** | | | | | | |
| Beveiliging, posten, overwegen en telecommunicatie | 3,23 | 4,49 | 15,64 | 2,79 | 0,00 | 26,15 |
| Baan en kunstwerken | 7,36 | 15,86 | 46,59 | 8,25 | 0,00 | 78,06 |
| | | | | | | 0,00 |
| **Pakket 2** | | | | | | 0,00 |
| Energievoorziening | 0,97 | 4,10 | 5,33 | 1,08 | 0,00 | 11,49 |
| Stationscomplex | 0,00 | 0,00 | 0,00 | 1,61 | 19,53 | 21,14 |
| Vrachtterminals | 0,01 | 0,01 | 0,06 | 0,00 | 0,00 | 0,08 |
| Rangeerstations (reizigers) | 0,01 | 0,03 | 0,07 | 0,01 | 0,00 | 0,11 |
| Rangeerstations (goederen) | 0,15 | 0,18 | 0,65 | 0,13 | 0,00 | 1,11 |
| Vormingsstations | 0,51 | 0,34 | 0,97 | 0,22 | 0,00 | 2,03 |
| Remisestations (reizigers) | 0,06 | 0,04 | 0,05 | 0,05 | 0,00 | 0,19 |
| Remisestations (rgoederen) | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| Onderhoudsinfra (reizigers) | 0,02 | 0,03 | 0,18 | 0,02 | 0,00 | 0,26 |
| Onderhoudsinfra (goederen) | 0,00 | 0,01 | 0,00 | 0,00 | 0,00 | 0,01 |
| Totaal Railinfrabeheer: | 12,31 | 25,09 | 69,54 | 14,16 | 19,53 | 140,62 |
| Kosten treindienstleiding RVL | | | | | | 34,40 |
| Kosten NCBG (RVL) | | | | | | 5,33 |
| Kosten toedeling | | | | | | 1,54 |
| Heuvelprocesleiding | | | | | | 0,23 |
| Transport Railinfrabeheer | | | | | | 30,55 |
| | | | | | | 212,66 |
| **Buiten beschouwing** | | | | | | |
| Onderhoudsinfra | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,01 |
| Bentheimer Eisenbahn | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| SUN-lijn | 0,01 | 0,13 | 0,24 | 0,03 | 0,00 | 0,42 |

***Calculation of impact maintenance costs in financial tariffs by using the table on the previous page***

**Table 34: Impact maintenance costs on financial usage rate**

| | 0,00% | 10,00% | 20,00% | 30,00% | 40,00% | 50,00% |
|---|---|---|---|---|---|---|
| Kosten KO variabel | 69,54 | 76,494 | 83,448 | 90,402 | 97,356 | 104,31 |
| Kosten GO variabel | 25,09 | 27,599 | 30,108 | 32,617 | 35,126 | 37,635 |
| Kosten onderhoud variabel | 94,63 | 104,093 | 113,556 | 123,019 | 132,482 | 141,945 |
| | | 9,463 | 18,926 | 28,389 | 37,852 | 47,315 |
| Aandeel onderhoud variabel | 44,50% | 46,86% | 49,03% | 51,03% | 52,88% | 54,60% |
| Kosten Totaal variabel | 212,66 | 222,123 | 231,586 | 241,049 | 250,512 | 259,975 |
| Stijging in variabel | | 4,45% | 8,90% | 13,35% | 17,80% | 22,25% |
| Per 10% | | | 4,45% | 4,45% | 4,45% | 4,45% |

## Appendix W: Validating the attribute importance

**Table 35: Calculated and direct ranking of performance indicators**

| Stakeholder | Performance Indicator | Estimated ranking | Direct ranking |
|---|---|---|---|
| ***NS Reizigers*** | Safety | N.A. | **1** |
| | Reliability | 1 | 2 |
| | Costs | 2 or 3 | 3 |
| | Availability | 2 or 3 | 4 |
| ***NS Hispeed*** | Safety | N.A. | **1** |
| | Reliability | 1 | 2 |
| | Costs | 2 | 3 |
| | Availability | 3 | 2 |
| ***ERS Railways*** | Safety | N.A. | **4** |
| | Reliability | 2 | 2 |
| | Costs | 1 | 1 |
| | Availability | 3 | 3 |
| ***Veolia Cargo*** | Safety | N.A. | **1** |
| | Reliability | 1 | 2 |
| | Costs | 2 | 1 |
| | Availability | 3 | 1 |
| ***Province of Gelderland*** | Safety | N.A. | **1** |
| | Reliability | 3 | 1 |
| | Costs | 1 or 2 | 4 |
| | Availability | 2 or 2 | 1 |
| ***Province of Overijssel*** | Safety | N.A. | **1** |
| | Reliability | 1 | 2 |
| | Costs | 3 | 4 |
| | Availability | 2 | 3 |