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Creating value by integrating logistic trains services and maintenance activities

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Abstract

NedTrain is the Netherlands Railway's subsidiary responsible for rolling stock maintenance. Train sets are brought in for short-term routine maintenance after set intervals of some 75 to 120 days. When a major defect occurs, train sets are allocated to one of the three maintenance depots and are diagnosed and repaired. Removal from active service causes large amounts of withdrawal of trains. In the traditional production concept, major defects could not be repaired on spot by the service organization. A lack of knowledge and equipment forced the National Fleet Control Centre to send the trains to the maintenance depots. This led to the insight that an upgrade of the service process could lead to a substantial improvement of the availability of the fleet. NedTrain re-modelled the traditional production concept and decided to invest 25 million euros in 4 additional Technical Centres, strategically placed on major nodes in the train service operations. In these new Centres, major defects are repaired during the night. Also, the routing of empty trains to the depots is prevented. The Utrecht Technical Centre was opened in Spring 2014; the other Centres will start operations shortly. This investment will lead to an improvement of the fleet availability by over thirty cars (worth 60 million euros), savings that can be cashed in the next round of ordering rolling stock. This paper describes both the preparation of the service processes and the first results, measured in the Utrecht-case.

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1. Introduction

NedTrain is the Netherlands Railway's subsidiary responsible for rolling stock maintenance. Train sets are brought in at maintenance depots for short-term routine maintenance after set intervals of some 75 to 120 days. The relatively long maintenance intervals are due to the complex train operations schedule. In the Netherlands, most trains do not commute between fixed points but follow a complex path through the railway network. It takes a lot of effort to direct a train set to the workshop because of the train density on the rail network. Also, NedTrain has the policy to maximize the maintenance intervals, for long maintenance intervals are considered to be cost-effective.

The other side of the equation is a relative high number of unscheduled depot entries caused by train defects. These

depot entries are responsible for more than half of the maintenance withdrawal from train service operations. In the last 10 years however, NedTrain has significantly improved in the field of availability by taking preventive measures in the field of fleet reliability and the quality of the repair processes. The next step and subject of this paper is to describe how the corrective maintenance organization has recently been improved, i.e. how NedTrain has integrated the repair of complex failures into the train service operations by building four so-called Technical Centres. This was done by an innovation of the production concept for the unscheduled depot entries. The production concept determines what to do where, and is an often overlooked step between the maintenance concept and the maintenance execution.

2. The NedTrain maintenance network

2.1. Current maintenance locations

In the current production concept, two categories of train failures are known. Simple failures are handled nightly at 30 service locations, located at the Dutch marshalling yards. Complex failures are repaired at 3 large maintenance depots, for at the depots the highest level of mechanics is stationed. Directing defect trains to the large depots comes at the price of a reduced availability and is a time consuming job for the national fleet control Centre as well. Therefore, alternative ‘smart’ repair locations needed to be found, suitable for the building of Technical Centres.

2.2. Recent and future improvements

The decision to invest in Technical Centres for the repair of trains was preceded by some other important process improvements. These improvements laid the foundation for the new production concept described in this paper. Also, the new production concept will have to fit in to future improvements. Both past and future improvements are discussed in this chapter.

2.2.1. Improving fleet availability

In 2005-2010, preventive measures were taken to reduce the unplanned withdrawal for maintenance. A special Reliability Program was setup, targeting both the number N as well as the lead time L of the unscheduled depot entries was reduced by -25%, aiming at an amount of withdrawal $W = N * L = 75\% * 75\% = 56\%$. This finally led to a reduction of the unscheduled maintenance withdrawal of 57%, bringing > 200 extra cars into train service operations.

2.2.2. Improving work force skills

The capability of the repair process depends largely on the capability of the mechanics. Two factors were addressed: knowledge and experience. A ‘back to school’ program was initiated to bring 100 frontline mechanics to a higher educational level. The level of experience was lifted by appointing a selection of eight specialized service locations. These locations specialize on a maximum of three stock types. The national fleet control Centre directs each stock type to the fitting specialized location, thereby increasing the case flow and maximizing the speed of learning.

2.2.3. Standardization of the repair process

In recent years, analysis showed that the repair process suffered from repeating failures. Besides the aforementioned measures (education & speeding up the learning process), the ‘First Time Right’ process was introduced, standardizing the repair workflow process. Important elements were the checking of the repair-history of the train and the development of fault-trees to support the diagnostic capabilities of the mechanics. The standardization of the repair process led to a reduction of the amount of repeating failures by 50%.

2.2.4. Introduction of fleet teams

In 2010-2015 NedTrain took measures to improve the maintenance organization, introducing a dedicated fleet team for each stock type [1]. The teams operate cross the organization and direct all the fleet aspects. In this phase, the number of stranded trains was significantly reduced. The development of the production concept for complex train repairs, as described in this paper, also fits into the same period.

2.2.5. Future improvements

Besides the implementation of the Technical Centres, NedTrain will focus in the period 2015-2020 on innovations both in the technical and the process field. Performance Centered Maintenance will lead to a more effective maintenance concept. Modularization of large maintenance blocks will make it possible to execute maintenance in off-peak hours. Real-time fleet monitoring will reduce the mean time to repair and improve the fleet reliability.

3. Problem statement

When major defects occur, train sets are allocated to one of the large maintenance depots, diagnosed and repaired. Removal from active service causes large amounts of withdrawal of trains, it usually takes 3 days to transport and repair a train. The main reason for the current lead time is the conflicting resource claim between regular maintenance of trains and the unscheduled repair of defect trains. Due to the unpredictable character of the defects workflow, increasing the workforce population or the number of depot lifting roads would lead to a significant increase of the depot inefficiency. Therefore, the question was raised whether it would be profitable to separate the repair of unscheduled depot entries from the regular maintenance process by executing these repairs at another location. As a consequence the project goal was set to develop a new production concept that would minimize the lead times of the repair of complex failures in order to increase the fleet availability.

4. Designing a new production concept for the repair process

The production concept design process would have to deliver a definition of the work package, a location selection, the requirements for the Technical Centres including a preliminary design and an impact analysis. Based on this, a business case would be delivered comprising different scenarios and supporting decision making.

4.1. Defining the work package

In the air force, maintenance is generally organized into three distinct levels of maintenance: the organizational (O) level, the intermediate level maintenance (ILM) and the programmed depot maintenance or overhaul maintenance (PDM). Most aircraft failures are handled on the flight line (O-level) by direct repair or by replacing line replaceable units (LRU's), returning the aircraft to mission-capable status

[2]. Almost all on-equipment servicing and repair is carried out at the O-level.

In rolling stock maintenance, on-equipment repairs are not only carried out at the O-level but also at the intermediate (ILM) level, keeping the rolling stock out-of-service. This raised the question whether in rolling stock part of the ‘ILM-repairs’ could be transferred to the ‘O-level’.

Analysis showed that train defects, handled by the train depots, could be separated into two groups: very complex defects and complex defects¹. The very complex defects, handled by specialized mechanics, turned out to be unique defects that seldom appear in higher frequencies. The complex defects however appeared more often and could be systematically categorized into groups, suitable for re-allocation to the service locations. Of the approx. 3500 defects, a 1000 defects could be labeled as ‘complex’ and assigned to a train system (e.g. brakes, climate, toilets). These defects were selected keeping in mind the educational level of the mechanics at the service locations. This group of complex defects was aimed for with the new production concept.

4.2. Location selection

4.2.1. Developing criteria

In order to select the right repair locations, several criteria needed to be developed. A new facility is usually an investment that has to remain in place for a long period of time. It is therefore important to select a location that will continue to be profitable for the facility’s lifetime [3]. Factors such as environmental impact and market trends have therefore be taken into account in order to find a robust solution. In our case, the main criterion was robustness. Robustness means that the production concept has to be robust for changes in the train service. This criterion was implemented by top-down selecting the largest service locations at important nodes in the rail network. When reshuffling the different stock types over the country, the chance to be able to repair different stock types would still be high and also these locations would not run out of work. Additional selection criteria were: the attainableness of the locations, the local space for shunting, the physical space for the building of the Technical Centres and the compliance to noise regulations. The locations were tested against these blow-off criteria by a group of specialists, resulting in a gross-list of preferred service locations. This list would be further narrowed down bearing in mind the work package, cost of investment, maintenance of workforce skills and the chance of arrival of the defect trains at a Technical Centre location.

4.2.2. Application to the location selection

Given the multiple criteria the location selection was not an easy task. It turned out to be an optimization problem. In literature, this type of problem is commonly known as a cost vs. routing problem. In general, a route is developed that facilitates a set of given locations and minimizes the cost. Sometimes the choice of locations is taken into account as

well. Daskin et. al [4] e.g. discuss that vehicle routing is commonly secondary to the choice of location as the location and construction costs are relatively high. In our case neither of these problem types apply. Firstly, in the NedTrain case the trains needed to be facilitated, not the locations. Secondly, the routing and landing of the trains was an input and could not be influenced. Thirdly, the exact routing of the trains was not known, only the chances of landing at a specific service location were given.

Therefore this problem requested a different approach. On the one hand the work package, the cost of investment and the development of workforce skill would suggest a bare minimum of repair locations. Based on these criteria alone, 2 repair locations would be fitting. On the other hand, the logistical probability for a train to arrive at night at a Technical Centre location would suggest a maximum of repair locations.

Finally, calculations showed that 4 locations would be sufficient. This can be explained as follows. In Holland, physical trains are not directed to or assigned to physical locations. The chance of arrival of a specific train at a certain service location can be expressed as a probability percentage. Given the probability p for a specific train to arrive at a service location with a Technical Centre, the chance q that a train with a complex failure can be repaired within x days is: $q = 1 - (1-p)^x$. For example, when the probability of the arrival of a specific train at a service location with a Technical Centre is 60% and the lead time allowed is 3 days, the success rate is: $q = 1 - (1-60\%)^3 = 94\%$. Given 1000 repairs per year, 940 trains will arrive on time at a suitable service location and 60 trains need to be actively redirected to such a location. This last number is important in the Netherlands. The number of active logistical train adjustments in our country needs to be minimized due to severe congestion on the rail network. Therefore the number of active redirections required was an important criterion. In order to achieve a sufficiently high success rate with only 4 service locations, the production concept was tweaked by adding smart ‘train swaps’, meaning low effort exchanges of identical trains within each others proximity but planned in different directions. These train swaps lifted the change for defect trains of arriving at a service location with a Technical Centre with tens of percent’s.

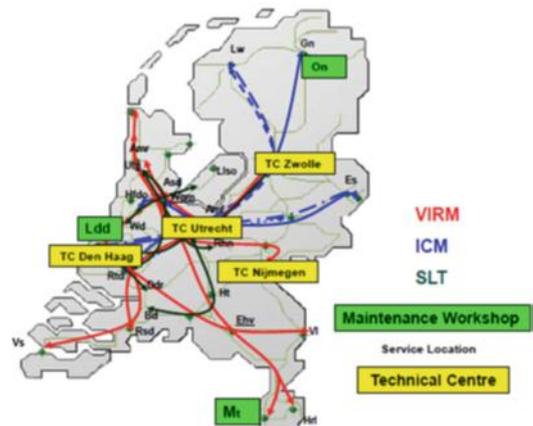


Fig. 1: The projected Technical Centres in the Netherlands

¹ Specialized equipment-bound defects were neglected in the analysis

The selection process resulted in the choice of the following locations (see Fig. 1): Utrecht, Den Haag, Nijmegen and Zwolle.

4.3. Requirements for the Technical Centres

Together with a team of specialists, the functional and technical requirements for the Technical Centres were setup. All the Centres would fit a common design, and all Centres would facilitate all of NedTrain's train sets. The length of the Centres would be 190 m, being able to service 90% of NedTrain train stock. The width of the Centres would be such that a fork lift truck at both sides of the track could change large train parts. The height would be such that working on top of the trains would be possible, since modern trains contain a lot of systems on the roof. Furthermore, the Centres would be low energy consuming, saving both cost and the environment. The requirements mentioned were necessary to facilitate the defined work package and create a personnel friendly working environment. Based on a preliminary design, a cost estimate for the design and building of the Centres was made.

4.4. Impact analysis

Consulting a group of production managers, the risk of not attaining the marshalling yards from the passenger platforms was seen as the highest risk especially in Utrecht, the ultimate node and logistically complex heart of the rail network. Future plans to a. guide the Utrecht train movements through separated corridors and b. to increase the train frequency on certain lines from 6 to 12 trains per hour made the situation even more complicated. A specialized engineering consultant was ordered to thoroughly investigate the impact of 2 extra shunting movements per hour on the timetable delay in an already disturbed environment. The investment decision as a whole depended on the outcome of this study which took 3 months. The outcome of the simulation study showed clearly that there was no significant increase of train delays. This freed the way for decision making at top level.

4.5. Conclusion

A subset of locations was chosen such that chances to handle the train failures, given the train service, would be sufficiently high. The requirements for the Technical Centres were set and a preliminary design was made to estimate the building costs. The building of 4 Technical Centres alone would not lead to the desired results. It was necessary to look at additional requirements in the field of people, parts and processes as well. These requirements are discussed in the paragraph on implementation.

5. Setting up the business case for decision making

The primary business case driver was the increase of availability of the six major fleets of Netherlands Railways. All together, the new production concept would be able to deliver 30 additional cars for the train service, representing an

investment-avoidance in new trains of 60 million Euros. This result could be reached by a reduction of the lead time of the repair of complex defects. As explained above, the lead time reduction was made possible by re-allocating the train repairs from the maintenance depots to newly built Technical Centres on 4 service locations at strategically nodes in the rail network. Secondly the redirection of 1000 defect trains to the workshops was cut out of the process, delivering 1 million Euros per year. Thirdly, the closure and sale of an empty old workshop serving as spare production space was made possible by the building of the 4 Technical Centres. Fourthly there was a reduction of maintenance costs by not buying 30 additional new cars. The building and implementation costs of the 4 Technical Centres was estimated at 25 million Euros.

Putting the figures together in a business case resulted in a net present value of > 40 million Euros. A sensitivity analysis was carried out, showing that the net present value was still positive at -30% re-allocated complex failures and + 50% higher costs. The business base was presented in the board of directors of the BU's NedTrain and NS Reizigers and finally accepted by the executive board of Netherlands Railways. The decision making process was speeded up by an excellent collaboration between NedTrain and NS Reizigers from day one. The business case contained scenarios for less than 4 Technical Centres as well as scenarios for smaller Technical Centres. Determining the right amount of Technical Centres was primarily a question of calculating. The size of the Technical Centres was determined by taking into account future work packages. The board decided upon the larger variant being able to take in 6-car train sets as a whole, instead of 4-car lengths.

6. Implementing the new production concept

Building new workshops does not automatically lead to results if the complementary processes are neglected. After approving the business case, two related projects were started: a building project for the 4 Technical Centres and a process-project. Besides a lack of equipment in the form of Technical Centres, the service locations also suffered from a lack of specialized knowledge and other constraints. An investigation was setup to examine the requirements for empowering the front line service process: people, parts & processes. From these elements, knowledge transfer (people/process) stood out as the most critical factor.

6.1. Building the Technical Centres

As planned, the Centres were built 190 m long and 12 m wide, suitable for taking in train sets of 6 cars long in a day and night process². The Centre are made up of a hall with a lifting road and elevated work platforms to allow for the easy access to the equipment on the roof of and underneath the trains. The Centres are low energy consuming buildings, receiving a 4 star rating according to the international BREEAM classification standard.

² See also: <https://youtu.be/LAGwPJwun1w>

The Utrecht Technical Centre (see Fig. 2) was opened in Spring 2014; the other Centres will start operations shortly.



Fig. 2: Pictures of the Utrecht Technical Centre

6.2. Process implementation

A process project was started to arrange for the development and implementation of the requirements for a successful repair process. In the repair-field, a lot of knowledge is tacit knowledge or knowledge gained by experience. This type of knowledge is not easily transferred from the back to the front of the service chain. Therefore Network teams were setup bringing together the professionals working in the service chain. They were given the task to develop so called failure response plans that would guide the future repair processes in the right direction.

Response plans are the counterpart of the regular maintenance plans. They contain the best knowledge available in the service chain in a standardized format. Response plans are meant to support decision making in each step of the service chain, starting with the train driver calling the national fleet control Centre and ending with the mechanic filling in his repair report.

The Network teams were led by team leaders with a situational leadership style. The teams were experienced by most team members as the ‘Columbus egg’ meaning the perfect solution to a problem no one ever thought of.

7. Discussion of the first results

Since the Utrecht Technical Centre has opened, the first results could be measured. These results are encouraging: the Centre is performing according to expectation. The amount of complex defects repaired in the first three months is already on target and the lead time is on target as well. The gain in transportation time is even higher than expected. The actual lead times are shown in the table below.

Table 1. Actual lead times Technical Centres vs. Depot

| | Transportation time (days) | Production time (days) | Total lead time (days) |
|-------------------|----------------------------|------------------------|------------------------|
| Maintenance depot | 1.9 | 2.3 | 4.2 |
| Technical centre | 0.5 | 0.8 | 1.3 |

In the Utrecht case, the gain in lead time led to a availability gain of 5 cars/year. Since the reference lead time of the maintenance depot had decreased from 3.1 to 2.3 days, the resulting gain in number of cars was lower than predicted.

The first results brought to light a surprising difficulty: when re-allocating complex defects to the service locations, the lead time of the remaining depot defects decreases significantly, slowly absorbing the business case results. This can be explained by a simple rule of factory physics, telling us that the lead time of a production plant increases exponentially when a production facility is occupied more than 80%. This means the other way round that a small decrease of the degree of depot-occupation from e.g. 95% to 70% leads to a significant decrease of the production lead time. This positive side effect has a negative influence on the business case review, when comparing the actual lead times of the depot and the Technical Centre. Nevertheless is the remaining performance gain sufficient to justify the new production concept.

8. Summary and conclusion

This paper describes how the fleet availability is optimized by integrating the repair process of train defects into the train service. Besides discussing the criteria for the selection of the Technical Centre locations, the requirements and process preparations for the operation of the Technical Centres are described as well. The first results measured in the Utrecht case are being presented and appear to justify the business case. This leads to the conclusion that investing in the service chain creates value indeed when corrective maintenance and the train service operations are properly integrated.

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