Chapter 26
On the Initial Spare Parts Assortment for Capital Assets: A Structured Approach Aiding Initial Spare Parts Assortment Decision-Making (SAISAD)

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Abstract In the capital-intensive industry, maintenance expenditures can add up to several times the initial investment. In order to be competitive in their business, owners and users of these capital goods have to take into account the total life cycle cost at investment (e.g. the lifespan of a capital is often more than several decades), the renewal decisions for their installations and the logistic management of the spare parts. Erroneous or unstructured initial spare parts assortment decision-making part of the logistic management can lead to undesired downtime and increases the risk of obsolete or unavailable components. Decision making is complicated by non-existent data in the early design phase and several information management problems. Based on a case study at Netherlands Railways (the largest maintainer of rolling stock in the Netherlands) and literature review a Decision Support Model to structure and improve the data gathering for more effective initial spare part assortment decision making is proposed.

26.1 Introduction

When a new capital asset is introduced there has to be made a timely decision on the initially needed spare parts to have the asset owner provide adequate, safe, reliable capital assets every day. The initial spare parts decision has not only to be made just but also in time because of the lead times. Research shows [8] this lead times can be variable and long and therefore need to be made before construction starts and often

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before reliable quantitative data is available. However ordering unneeded or wrong spare parts can lead to a significant increase in the spare part holding costs.

Having the right information at the right moment is however complicated by several challenging issues in data management. Therefore not only a good decision making model is needed but also a decision process which is adaptable to the available information. Having the right information at the right time is a serious challenge because of several data hand-over related problems: (i) fragmented information problems, (ii) high cost for gathering detailed information, (iii) information not easily provided due to strategic reasons of suppliers, (iv) content uncertainty with regard to the provided information and (v) future spare part availability uncertainty.

First of all the present paper will review the data requirements of existing models for spare parts assortment decision making and then will explore the information problems with the application of these models in practise based on a case study at Netherlands Railways. Secondly criteria and principles for the design of a decision support method will be discussed. Finally a decision support method will be proposed to structure initial data gathering and decision making.

26.2 Initial Spare Parts Management

Although there is plenty of literature on spare part management; they all assume the initial spare parts assortment as 'given'. According to Driessen et al. [4] there is no specific literature which can help to support the decision whether to add a spare part to the initial assortment or not.

However, closer analysis of the literature reveals that some literature sources discuss the (initial) spare parts assortment decision-making process without going much into detail.

Almost all quantitative methods are based on the Recommend Spare Parts List (RSPL), the failure rates λ or on the Mean Time Between Failure (MTBF). These data should be provided by the supplier or is based on operational experience.

The most prominent available quality method is the method of Jones [7] which uses Maintenance Task Analysis (MTA) to determine the spare parts assortment. However, for the initial spare parts decision making there is often not enough data available to make a detailed MTA possible and worthwhile in the initial stage.

Table 26.1 lists some of the identified literature and show the relevant keywords and the data used for the assortment decision making.

However as initial part decisions have to be made on time, the right characteristics have to be known or determined. Therefore the usability of the aforementioned methods is highly information and data dependent.

26.2.1 Spare Parts Characteristics

In order to successfully manage spare part inventories the maintenance department needs to know the different characteristics of every single spare part (or at least of

Table 26.1 Relevant data literature on the most common spare part decision models

Name of the method	Used input data
NEN-EN 13460 [10]	RSPL, MTBF[a]
Driessen et al. [4]	RSPL, MTBF, operational costs
Jones [7]	RSPL, λ, MTA[b]
Diallo et al. [3]	RSPL, λ, FMECA, reliability, availability[c]
Aït-Kadi et al. [1]	RSPL, criteria based on available data
Smit [11]	Similarity, criticality, MTBF, safety, holding costs, lead team, maintenance costs
Keywords used: documentation, maintenance, assortment management, decision, spare parts management, multi-criteria, spare parts, technical documentation	

[a]*RSPL* recommended spare parts list, *MTBF* mean time between failure
[b]λ failure rate, *MTA* maintenance task analysis
[c]*FMECA* failure mode, effect and criticality analysis

every spare part class) to classify parts in the decision-making model and to decide their stocking policy.

As for the decision making on the rights spares, the literature provides an extensive list of common procedure for classifying spare parts; some of these procedures are now very briefly explained in order to make easier the comprehension of the next part of the research work.

26.2.1.1 Spare Parts Characteristics Decision Techniques

The following classification can be used as a starting point in the initial spare parts assortment decision making (Table 26.2).

Table 26.2 Relevant data literature on the most common spare part decision models

Name	Keywords	Description
FSN	Fast, slow, non-moving	Technique based on the usage rate of the spare parts; determining fast-moving parts help in deciding which parts need to be stocked close to the asset
SDE	Scarce, difficult and easy to procure	Technique based on procurement lead time. Scarce items are generally imported and require more than 6 months lead time
VED	Vital, essential and desirable	Technique based on the criticality of assortment. A vital part not available has a major effect on the production downtime
ABC	Always better control	Technique based on annual consumption value calculated with the Pareto analysis assigning all the spare parts to three categories
HML	High, medium, low unit price	Technique based on sorting the spare parts according to their unit price

As suggested by Huiskonen [6], forecasting and planning the demand, the procurement lead time, the criticality, the annual usage value and the unit price of the parts for complex capital assets like trains, could produce an unmanageable amount of classes. Therefore a choice on a combination of categories has to be made.

If more than two criteria are needed, multi-attribute classification models could be used [2, 5] assigning with an Analytic Hierarchy Process (AHP) relative priorities or weights to different criteria.

As a consequence, an important challenge for initial spare parts assortment decision making is gathering the proper information and the technical documentation to identify the most essential spare parts and then get the required information so that a part *can* be ordered if required in the future.

26.2.1.2 Spare Parts Characteristics Decision Techniques

Gathering technical information and documentation is vital to set up a correct spare parts management policy. In terms of resources saving, it could be preferable to spend time on collecting and maintaining technical information (criticality, redundancy, commonality, specificity, substitution, life span, position in the configuration and reparability) from the suppliers for spare parts relatively expensive, not easily available and important for controlling supplying risk and operational costs, than gathering technical information for relatively cheap and easily available parts.

Smit [11] presents a possible description of the documentation typology for spare parts. In Fig. 26.1 these characteristics are shown with the cross-references between the documentation.

Unfortunately, in practice even after extensive efforts it is not always possible to gather all presented information for reasons of confidentiality and marketing strategy related issues.

26.2.2 The Case Study: The Introduction of the Sprinter Light Train (SLT)

In our research we will use the introduction of the Sprinter SLT to research the specific context in which initial spare parts decisions are made and to research the specific problems with regard to data management.

The Sprinter Light Train (SLT) series, Fig. 26.2, was introduced in 2009 to replace the outdated Mat ‘64 train series. The SLTs are electrically driven train built by the Bombardier-Siemens consortium. Netherlands Railways needs to maintain 131 SLT’s: 69 four-carriage (SLT-IV) and 62 six-carriage (SLT-VI) trains for over 30 years. Therefore, a spare parts assortment decision-making process had to be defined.

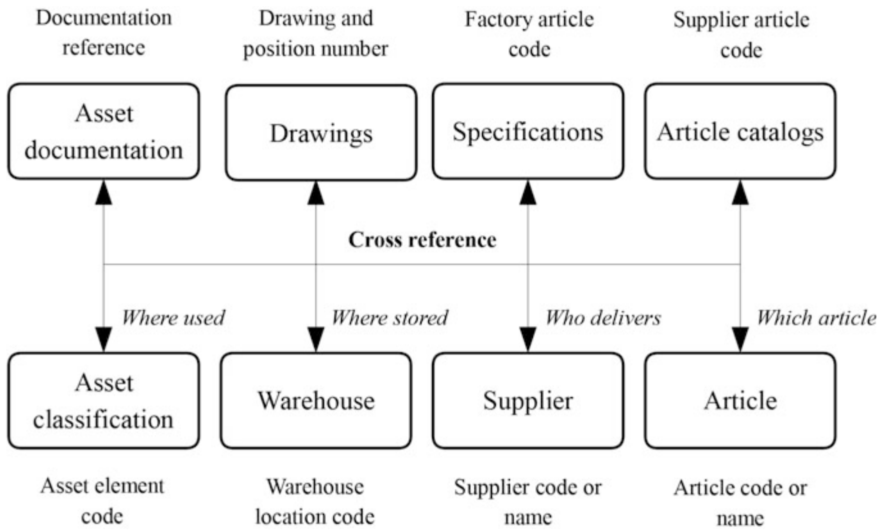

Fig. 26.1 Documentation typology for spare parts [11]

Fig. 26.2 Two Sprinter Light Train's at Netherlands Railways' workshop in Leidschendam, The Netherlands

26.2.2.1 The Sprinter Light Train Assortment Decision Making Process

The first 2 years after the introduction (start of transporting passengers), the supplier is responsible for spare parts management according to the warranty agreement. This means that the supplier has to deal with parts that fail unexpectedly, so-called infant mortality failures.

The Bombardier-Siemens Consortium positioned their engineers and placed their own spare parts in Leidschendam. Whenever a part had to be replaced or repaired because of warranty, the consortium engineers solved the problem.

But, after the warranty period Netherlands Railways takes over this responsibility with the possibility to obtain the spare parts that the Consortium still has on stock.

At Netherlands Railways, the maintenance-engineering department is responsible for the initial spare parts assortment decision making. Staff of this department decides on the assortment with the use of information obtained from suppliers and from own experience. After the initial spare parts assortment is determined, the procurement and logistics staff will decide to purchase parts or not and the amount of spare parts.

Because of Netherlands Railways has to maintain trains for over 30 years, the spare parts assortment is significantly different from the assortment decision made by the supplier for the first 2 years.

Manufacturer delivered spare parts recommendations, failure rates, unit price; minimal order quantity, yearly usage for preventive maintenance information are all potentially available for making the decision. The available information was reviewed by the maintenance engineer (ME) adding information, based on the experience, such as yearly corrective maintenance usage, part classification warranty status, common train series parts and external factors (water, snow and ice effects, vandalism acts etc.).

The initial assortment held about 1600 parts; after few months the assortment was updated to about 2100 parts according to new technical information gathered (part drawings, maintenance manuals and information on form, fit and function.

26.2.2.2 The Data Hand-over Problems and Uncertainties During the Sprinter Light Train Assortment Decision-Making Process

The problems and uncertainties in the spare parts assortment decision-making process of the SLT that arose, were mainly related to the difficult communication with stakeholders causing fragmented technical information and uncertainties about the quality of the gathered data and information:

Fragmented information problems (if Netherlands Railways wants to have more information from the suppliers, the consortium had to be contacted to send the request of information to the suppliers, Fig. 26.3) due the outsourcing [9] of the engineering design, the Netherlands Railways lost full control of the train technology and documentation, this influences lead-times and not always the 'right' quality of information is provided;

1. High cost for getting detailed information (gathering all the documentation in a detailed level is expensive causing additional work for the consortium and for the suppliers);

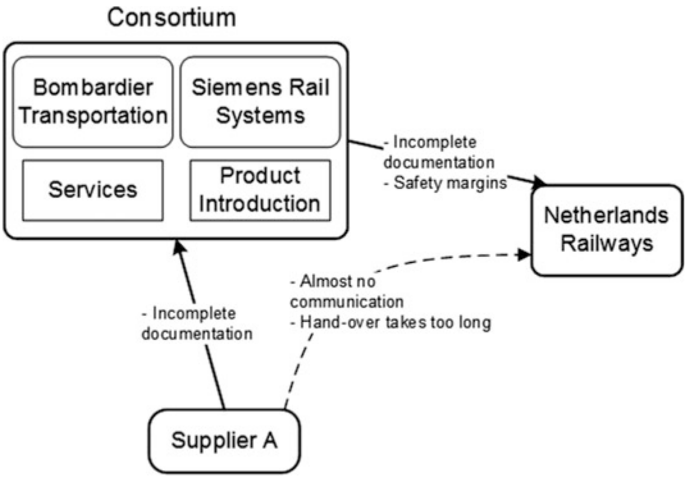

Fig. 26.3 Communication problem between consortium, suppliers and Netherlands Railways

2. Information is not easily provided due to strategic reasons by suppliers because with this information Netherlands Railways can eventually contact suppliers directly to buy parts for lower costs. For the initial assortment Netherlands Railways is however strictly bound to the consortium due to the terms of the contract;
3. Content uncertainty on the obtained information (the safety margins the consortium adds to the safety margins of suppliers cause inaccurate data. Lead times are too long, and parts become more costly than necessary);
4. Future spare part availability uncertainty (the possibility for spare parts included in the assortment to be never used during the lifecycle span of the train) but have to be purchased because there is sometimes only a single option to buy them.

It means that at the beginning of the use phase, the uncertainty on spare parts availability is considerably low; but, according to the lifespan of the train, the uncertainty on future spare parts availability will grow after the introduction.

26.3 Design of the SAISAD Model

In the following sections the SAISAD model will be introduced which is based on solving the aforementioned information management problems by using the earlier defined design criteria and design principles.

26.3.1 Design Criteria and Design Principles

There are some design principles proposed:

1. Gathering information based on asset criticality to reduce communication efforts (problem 1) and costs (problem 2). This also helps to be very focused on the right information at the suppliers, who are not so open in providing asset information (problem 3).
2. Structuring the decision-making process by using a multi-criteria analysis helps to make the process transparent and more fact-driven, thereby reducing cost (problem 2) and prevent issues caused by not including parts in the assortment, considered as the *reverse burden of proof*.
3. Using expert-based information sessions for gathering and selecting the right needed information, where the experts involved can handle content uncertainty (problem 4) and future availability uncertainty (problem 5). Thereby the decision making process becomes robust as it should support the initial spare parts assortment decision making when a relative great uncertainty in the decision phase is present.
4. Using a business case like approach to determine the expected investment and return of the gathered asset information (problem 2).
5. The decision making should be flexible and transparent to allow change when additional information is gathered (problem 4). The spare parts assortment might change a lot after a couple years. For example parts have to be added to the assortment during the using phase due to unexpected failure or difference in the Line Replaceable Unit (LRU)/Shop Replaceable Unit (SRU) level.

26.3.2 The SAISAD Model and Improved Decision Making Approach

To be able to set up a more suitable assortment, a Decision Support Model which combines some spare parts criteria together with a decision making approach is created. The suggested approach was inspired by the method proposed by Aït-Kadi et al. [1].

The SAISAD method, is composed by a logic decision tree approach to create a spare parts assortment, by an evaluation part to consider the Long Term Availability (LTA) and by a special part to take into account the different phase of the process. Hereby an additional step in process has been added (Fig. 26.4).

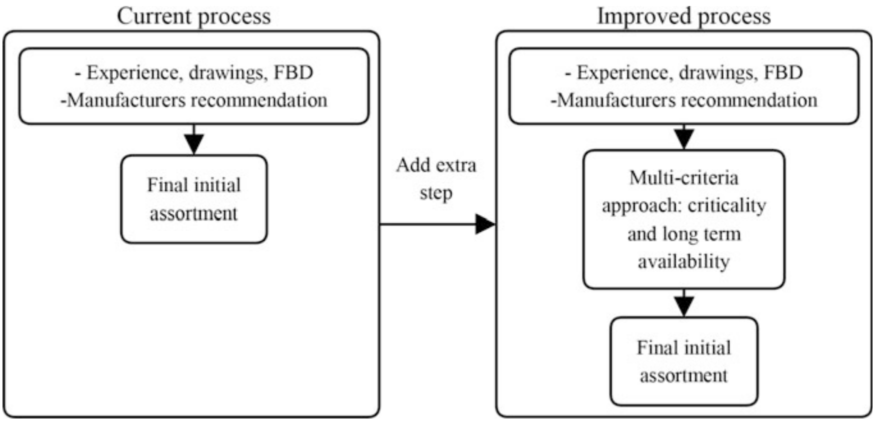

Fig. 26.4 Old approach versus new approach of initial spare parts decision making process

26.3.3 SAISAD Part 1: Logic Tree and Practical Principle

To reduce the number of parts to be analysed in the SAISAD model, a logic tree is used as first filter. To make the filter robust and reliable as much as possible the Pareto principle is considered. The Pareto principle states that in a group a significant 20% of the items contribute to 80% of the total problems and vice versa. Therefore in this case the logic tree should reduce the set of parts to be analysed with about 80%.

The logic tree is based on four decision points (Fig. 26.5):

1. parts that are not sufficiently similar to already known parts;
2. parts that are not decisively influenced by external factors;
3. parts that are significant and have a price higher than 250 €;
4. parts that are not significant and have a price higher than 10.000 €.

The technicians of Netherlands Railways will determine external factors, such as vandalism and risk of fire, during the assortment definition process.

They are not evaluated by the manufacturer because at the initial assortment definition there is no data about vandalism. The decision is then fully based on experience.

26.3.4 SAISAD Part 2: Evaluation Part for the Long Term Availability (LTA)

The evaluation part helps the decision maker to simplify a large complex decision problem into several smaller problems [13], combining Long Term Availability (LTA) of the spare parts identified during the logic tree phase with criticality

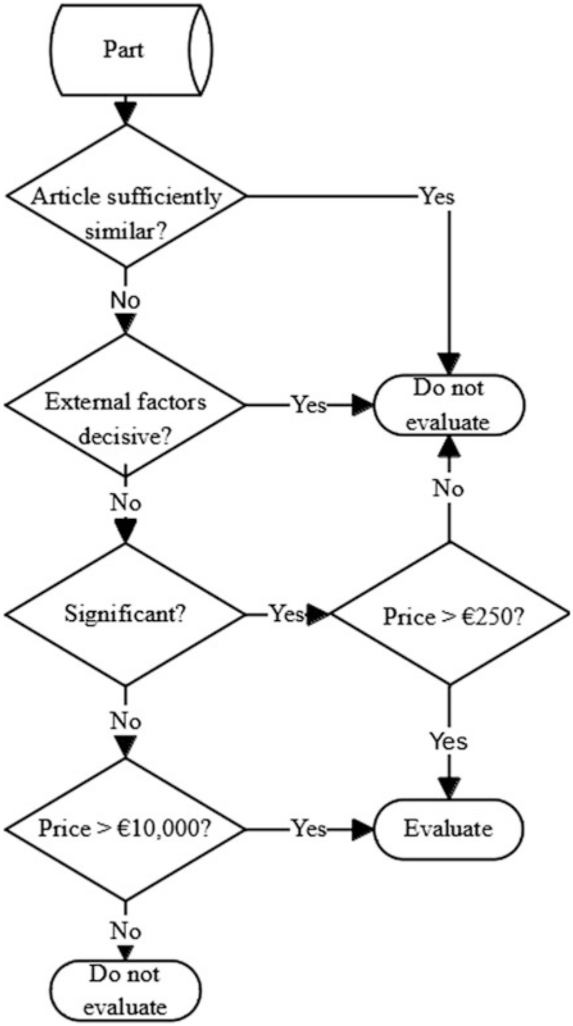

Fig. 26.5 Part 1: logic tree approach of the SAISAD model

categories. The criticality of the part is extracted from the available FMECA documentation related to the part.

The output of the evaluation part is an Importance Factor (1 important—3 least important).

In Fig. 26.6, a Vital criticality and a Vital LTA final importance factor is calculated. The Vital criticality always gives an importance factor 1. When a part is critical, the LTA does not matter: the importance will be high. For parts which have an Essential criticality the LTA does matter; a Vital LTA will yield an importance factor 1. Similarly, Essential and Desirable LTA's will yield an importance factor 2. When the criticality is categorized as Desirable, the LTA can give importance factor 2 (for Vital and Essential LTA) or 3 (Desirable LTA).

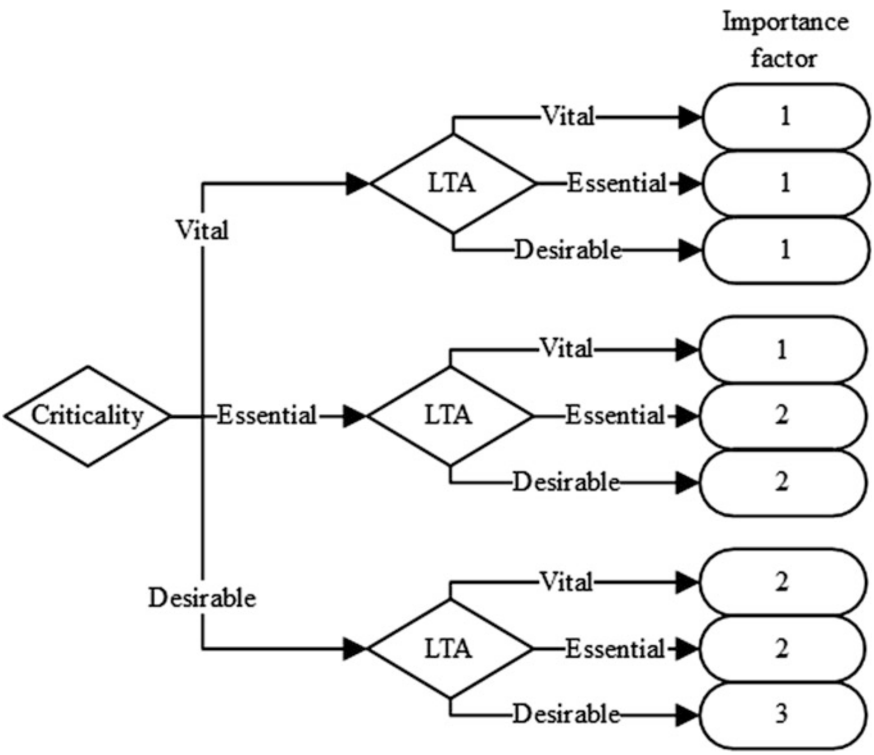

Fig. 26.6 Part 2: long term availability (LTA) combined with vital criticality of spare parts

For each of the important factor decisions, policies are created and assessed in the third part of the SAISAD model.

26.3.5 SAISAD Part 3: Spare Parts Assortment Decision Making

The improved spare parts assortment decision making is formed by an evaluation moment and an expert session.

26.3.5.1 Evaluation Moment

The evaluation moment is created to gather the last information to manage the uncertainty in the initial spare parts assortment decision making. In Fig. 26.7 the advised policy at the first evaluation moment is shown. Parts with importance factor 1 are added to the assortment to be ordered. Parts with importance factor 2 are not

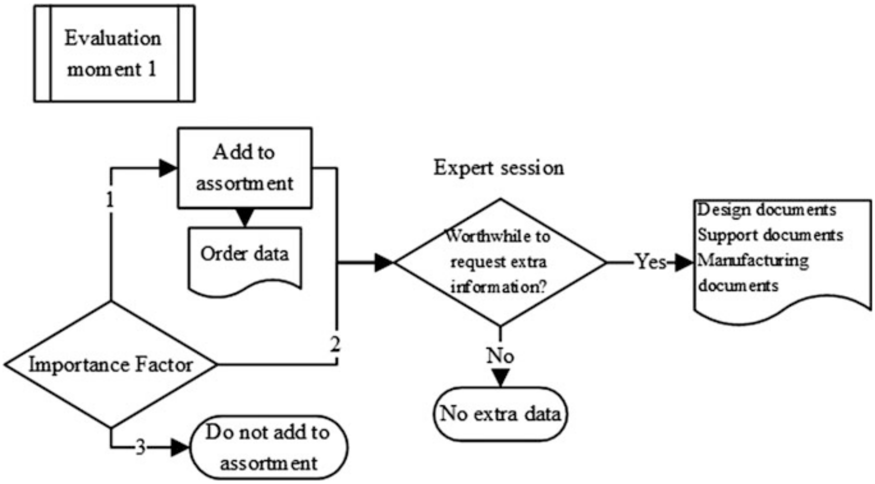

Fig. 26.7 Evaluation moment

added to the assortment at this moment due to the level of uncertainty; the available data is inconclusive on the assortment decision making. Those parts have to be evaluated in an expert session to investigate to require extra information from the supplier and which information has to be requested. Parts with the lowest importance factor (3) are not added to the assortment; no data is gathered because these parts have a low criticality and LTA.

26.3.5.2 Expert Session

To decide on the parts with importance factor 2 the expert session will take place. The maintenance organization needs to have the right technical documentation available reducing and preventing future spare parts unavailability. The people involved in the initial spare parts assortment decision-making process are maintenance engineers and spare parts assortment experts. As discussed in the Sect. 19.2.1 and according to Watts [12], there are several groups of technical documentation could be helpful during an assortment decision making. Due to the complexity of the asset to maintain, the expert session have to take into account different aspects to reduce the uncertainty on the spare parts assortment. The Table 26.3 underlined the documents required during the expert session.

Table 26.3 Technical documentation taken into account during the expert session for the spare parts with importance factor 2

Technical documentation	Description
Sales document	Mostly logistic information about the parts. Lead time, minimum order quantity, storage conditions etc.
Design documents	Design documents define the product or critical process elements. These documents include part drawings, product specifications, parts lists, material specifications, etc.
Support documents	Support documents define the information necessary to install, use or maintain the product. These documents are the product description manual, maintenance manual and installation instructions
Manufacturing documents	Manufacturing documents define the manufacturing process. The tool/fixture drawings, inspection process documents and routing/process sheets. These documents give the needed information to either re-manufacture the parts or to choose external producers to manufacture them

26.4 Conclusions

The design of a structured approach for gathering spare part information in the pre-operational phases is vital to improve the actual spare-part decision making of a typical complex capital asset formed by thousands of parts.

This is hindered by several information management problems which make it necessary to focus efforts. A decision making process is therefore proposed to improve the control on the initial spare parts assortment decision-making process, reducing the number of parts for which data needs to be gathered with a decision tree approach and classifying them according to their criticality and to the Long Term Availability (LTA). The presented SAISAD model is focused on a number of design principles: (1) Gathering information based on asset criticality to reduce communication efforts and costs. (2) Structuring the decision-making process by using a multi-criteria analysis helps to make the process transparent and more fact-driven, thereby reducing cost and prevent issues caused by not including parts in the assortment. (3) Using expert-based information sessions for gathering and selecting the right needed information, with the experts involved can handle content uncertainty and future availability uncertainty. (4) Using a business case like approach to determine the expected investment and return of the gathered asset information. (5) The decision making should be flexible and transparent to allow change when additional information is gathered.

Research Limitations

The LTA is a quantitative estimation of the future availability of the parts and of the supplier affected by an uncertainty. For these reasons, the knowledge of the maintenance experts is of significant value and is acquired during the expert session. The maintenance organization should in addition find ways to decrease the future uncertainty of the spare parts and on the other hand increase the maintainability of the assets ensuring a more dynamic spare parts assortment and long-term availability by optimized contracts with suppliers. Netherlands Railways is therefore planning a new management approach for the introduction of new "Next Generation Trains" on the Netherlands railways. Based on knowledge sharing and cooperation during the planning phase, the aim is to realize a for maintenance and operations designed asset, supported by a reliable spare parts assortment during the life cycle of the asset, delivering the highest value to all involved stakeholders.

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