Tendering / Procurement of safety systems: A general approach to effective contracting

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Abstract

Calling for tenders in the railway business is a major task and it determines highly the costs and benefits of the later safety systems. Special attention is paid to these early phases because
  o There are new company alliances for operation and maintenance (sometimes involving companies new in the railway business);
  o Comprehensive business cases are required including evaluation of all costs and benefits during the system lifecycle;
  o The evaluation of new, low-cost systems becomes necessary;
  o Change of legal frame due to new standards and laws.

For this reason the procurement phases, analysing feasibility and specifying the requirements are sometimes long lasting due to revisions and re-specifications. If the tendering documents and specifications are very comprehensive and unspecific, this will lead to additional costs for legal support, bidding, and re-specification.

To cope with these problems we present a general process that contributes to a more structured way to specify requirements. Tailoring the process leads to effective contracting. Key indicators - like safety and availability - are clearly specified and contractual agreed.
1 Procurement process documents

A procurement process usually comprises a lot of documents. When starting such a process they can be structured in a way to plan and manage the necessary activities. In general there are two major tasks:

1. Definition of the requirements, which is a task chiefly based on knowledge about the operation of the safety system (for example Interlocking Systems);
2. Preparation of the procurement documents, which leads to the contract, which is mainly based on legal and commercial knowledge.

We will look at the process documents and problematic fields in this chapter. In chapter 2 we will look at the process optimisation that helps to find solutions and in chapter 3 we will describe some methods for them.

1.1 Definition of requirements

Starting with the Feasibility Studies (see Figure 1), the target is to make a decision. Besides business planning, based on forecasts of usage, there are already a lot of technical requirements and assumption concerning the future system. Next there will be some activities to define the legal structure. Here, the agreements are made on the work that has to be done and the overall obligations of the parties that are involved are determined. Further on a decision has to be made on the business plan and the budget, which goes with a general decision on the kind of the contract and its content documents. The technical requirements and assumptions made by doing these business decisions need to be based on solid data. For example, the Dutch ERTMS system was specified early in its expectations to increase the capacity of the railways as one of the most important success factors. Other examples are safety interlocking and control systems for man less train operation (MTO) where the decision on this operation is usually done early assuming a lot of technical details.

Based on the legal structure the roles and responsibilities of the parties that will be involved in the contract are defined in detail. Here we need to be sure that the parties are really capable to take the responsibilities, as the suppliers are usually not involved in this phase. Besides that, ownership of every responsibility must be clear and it should always be clear who decides in cases of disagreement or indecision.

That leads us to further define the Management Requirements of the contract. Here the future project is defined as detailed as necessary to contractual requirement: the schedules of the project, the management documents, the reporting lines, the test and acceptance procedures and requirements to configuration and quality management and the standards which have to be obeyed (e.g. Cenelec). Doing this for safety systems means that there are processes defined that implicitly describe a certain safety level of the future
system. For example if the acceptance process for a Control Center implies some safety functions, which are not specified elsewhere.

The **Technical Requirements** may deal with the interfaces at the boundary of the future system by defining this boundary clearly. Technical standards and location drawing are referenced. The basic functions of the future systems are defined. It is not easy to find the sufficient grade of detail. It may happen that we end up in a definition of certain products, which may exclude suppliers or create additional costs.

Depending on the kind of the contract **Operation and Maintenance (O&M) Requirements** are defined focusing sufficiently grade of detail. Mainly the scope of the service needs to be contractually defined and this may be linked to payment provisions.

All these requirements need to be cost optimized, clear, testable, feasible and they should have no contradictions. If this is not fulfilled, it will create serious additional work and delays of milestones in later phases.

<table>
<thead>
<tr>
<th>O&amp;M Requirements</th>
<th>schedules, payment, scope of service, downtimes, rules, diagnosis and displays, performance criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical Requirements</td>
<td>Interfaces, technical standards, functions, location drawings</td>
</tr>
<tr>
<td>Management Requirements</td>
<td>Schedule, documents, payment, reporting, test and acceptance, configuration, quality</td>
</tr>
<tr>
<td>Roles and Responsibilities</td>
<td>Definition of roles and responsibilities of all parties involved</td>
</tr>
<tr>
<td>Legal Structure</td>
<td>Binding definition of works and obligations, Decision on Business Plan and Budget, Decision on the kind of contract and content</td>
</tr>
<tr>
<td>Feasibility Studies</td>
<td>Prepare Business Plan, Decision on feasibility, Forecast</td>
</tr>
</tbody>
</table>

**Figure 1:** Documents for Requirements Definition
## 1.2 Preparation of procurement documents

<table>
<thead>
<tr>
<th>Contract</th>
<th>changes due to negotiations, binding requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tender Evaluation</td>
<td>decision process and roles, assessment criteria</td>
</tr>
<tr>
<td>Call for Tenders</td>
<td>procurement process, general requirements, compliance list, evaluation criteria, pricing forms</td>
</tr>
<tr>
<td>Prequalification Evaluation</td>
<td>decision process</td>
</tr>
<tr>
<td>Prequalification Document</td>
<td>suppliers data, selection data and criteria, procurement process</td>
</tr>
</tbody>
</table>

**Figure 2:** Documents for Procurement

The **Prequalification Document** (see Figure 2) is meant to list contractual binding data form suppliers to prepare for a decision process in the **Prequalification Evaluation**. It may be necessary to have specific assessments to get binding data. Additionally the tendering process needs to be generally specified, the selection criteria and the selection process are described. The number of qualified Tenderers may need to be cost optimised fitting the needs of actual future systems.

Next the **Call for Tenders** will instruct the tenderers on the procurement process, it specifies exactly the information to be tendered, defines the requirements in sufficient detail and explains the tender evaluation criteria. Filled out pricing forms will later be part of the contractual agreement. This document should be open enough to enable low-cost-offers but it should also be clear about fundamental requirements.

The **Tender Evaluation Procedure** describes the decision process and assessment criteria. Often further negotiations are undertaken in this phase and the assessment criteria need to be carefully balanced while looking at the tenders.

These changes due to negotiations of contractual binding requirements will lead to a **Contract**. Negotiating the binding requirements one should focus on testability in order to be able to show that the future system is operating satisfactory.
2 Approach to effective contracting

All the efforts and documents for the procurement of a safety system need to be managed effectively, because they are major costs and can influence the time scale a lot. Therefore it is worth to think of new ways to increase efficiency in these phases.

2.1 Ranking key requirements

In some projects the planning is a key factor to success: if the system is implemented but the development is not entirely finished, it causes serious safety and availability problems. Another example can be the Dutch ERTMS systems: if it is not proven that the expected improvements will be reached, the government will probably not pay for the development anymore. Requirements, that are the key for a satisfactory future system, may be about management, performance criteria or payment but they all can be allocated to three categories: Safety, Availability, and Profit. These categories can be balanced in their priority and they are used as guide through the whole process.

The key requirements are defined in every phase of the procurement under the scope of the particular phase. For example a feasibility study should give brief definitions of: train punctuality, throughput of passengers, automatic degraded operations, risks of harm in case of accidents, compliance to standards at system interfaces, expected income from tickets sale, maximal cost of the installation due to a fixed budget.

Once the requirements have been identified in every phase, they will be ranked in their priority. According to this ranking the required level of detail for the requirement will be determined and it is planned in which phase it will be specified in detail. So, the stop criteria for a certain phase and the scope of its successor phase is always defined by this ranking and planning. By going through the procurement process, requirements may turn out to be almost covered by another one, so they can be combined. Also new requirements may be identified.

The ranking may be done starting numbering with the lowest priority up to the highest. First this is done for the requirements within one category. Secondly, it is done for all requirements (see brackets in Figure 3). The categories are ranked by the round mean value of the priorities within the category.

<table>
<thead>
<tr>
<th>Availability:</th>
<th>Safety:</th>
<th>Profit:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Punctuality:</td>
<td>Risk of injuries</td>
<td>Cost of installation</td>
</tr>
<tr>
<td>Throughput:</td>
<td>Standards</td>
<td>Income</td>
</tr>
<tr>
<td>Degraded operation</td>
<td></td>
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</tbody>
</table>

Figure 3: Example for ranking key requirements in Feasibility Study
Looking at the result helps to get a clear picture of the objectives of every phase. (Figure 3) shows an example for ranking key requirements in the Feasibility Study. Over here it may be sufficient to briefly define the train punctuality requirements to decide on feasibility. However the requirement itself is of high priority and will therefore be handled in a later phase. The income and the cost of installation are high-priority requirements as well. But to judge on the feasibility, they must be estimated in detail in this phase. The list of key requirements may change in its content, and the ranking may change as well, by going through the procurement process. The grade of detail is always the criterion to stop a phase and start with the next one (see Figure 4) or to start a parallel phase.

Figure 4: End criteria defining key requirements in Feasibility Study

2.2 Procurement process management

Figure 5: Example for effective procurement procedure using key requirements
Definition and ranking of key requirements can be used to plan and manage the procurement process. Starting with an initial list of key requirements it is planned for every phase how to detail them. By going through the phases the objectives may change, which results in detailing a certain requirement in a later phase when other information is available. Frequent revision of the ranking will result in revising the overall objectives as the process goes on. This helps to keep the focus on the necessary tasks. For example it may turn out during a feasibility study that the income of ticket sales forces NOT to specify train punctuality in detail, which has a lower priority, as this usually results in a higher investment. This fundamental change affects most of the tasks in the next phases reducing the originally planned efforts. (Figure 5) shows an example of a procurement process that is frequently revised and so optimised. At the end the phases contribute to the contract that comprises key requirements defined in sufficient detail.

3 Methods to define key requirements

The balance of the key requirements increases efficiency during the procurement phases. The key requirements determine the end criteria for each phase and the time to start the next phase. This is possible by applying appropriate methods that fit to the specification work on a high, abstract level during the procurement phases (Figure 6).

<table>
<thead>
<tr>
<th>Safety</th>
<th>Availability</th>
<th>Profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>CADM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Life Cycle Costing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prelim. Risk Analysis</td>
<td></td>
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<tr>
<td>Brainstorming</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benchmarking</td>
<td></td>
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</tbody>
</table>

Figure 6: Some methods to define key requirements

Benchmarking and brainstorming are methods to define all kinds of requirements and they are especially helpful when appropriate requirements are already defined elsewhere, for example in standards or other contracts.

Benchmarking is a method looking at other, comparable systems to derive requirements from it. The requirements can be tailored to the specific needs using the ranking process of chapter 2.1.
Brainstorming is a structured way to specify requirements where a number of experienced people bring in their knowledge. It is important that this method is guided well by a moderator, to prevent ending up in discussions. It is possible to use methods like the Failure Modes and Effects Analysis (FMEA) to give the brainstorming a better structure. For safety requirements the Hazard & Operability Analysis (HAZOP) review method is also based on brainstorming.

A Preliminary Risk Analysis helps to define specific requirements that belong to the safety category [3]. Besides, CENELEC requires such an analysis in the early project phase to set up the overall safety requirements specific for a project [4], [6]. Applying this method in procurement phases prohibits to go too much into technical details that are specific to certain products. Sometimes it is only possible to define the safety requirements in a qualitative, verbal manner because we not always can deal with quantifiable safety targets. However, this method can be tailored to the particular needs of the procurement phases.

The steps for Preliminary Risk Analysis are:
1. Hazard Identification on system level
2. Description of the hazard consequences and linking to the overall safety targets (e.g. safety performance of other systems in operation);
3. Description of the hazard-causes as detailed as possible;
4. Allocation to safety requirements as much as possible to subsystems, operation, maintenance (e.g. SIL, wrong side failure rates);
5. If it was not possible to define requirements entirely by the Casual Analysis then the Tolerable Hazard Rate will be specified
6. If the Tolerable Hazard Rate can not be specified due to lack of quantifiable overall safety target then the Consequence Analysis will lead to a qualitative overall safety requirements (e.g. using standards).

Figure 7: Exemplary Preliminary Risk Analysis in procurement phases

It is the aim to completely specify the top-level safety requirements for the project in the procurement phases. When we use the Preliminary Risk Analysis to do this, we will try to go through the entire process including Causal Analysis and allocation of safety requirements to operation, maintenance or Safety Integrity Levels (SIL) of subsystems. When this is not possible, because for
example the causes cannot be determined and the subsystem shall not be defined in procurement, then the safety requirement will be Hazard Rates. If even this is not possible, because the tolerability cannot be quantified, we will end with verbally defined safety requirements that result from the hazards consequences (see Figure 7).

The monetary aspects, and therefore the balance with requirements in the profit category, become clear when using this method for different alternatives and comparing the cost/benefit (for example in the Tender Evaluation Phase).

There are various methods to define availability requirements. One is especially appropriate for the procurement phases due to its short duration and capability for investigating costs, the Cost affective Availability Design Method CADM [1], [2]. To enable optimisation of the requirements the failure characteristic are converted to the system's performance requirements such as train delays which are connected to terms such as 'mean time between failures' (MTBF) and 'mean down time' (MDT). The input data consists of the functions of the future system and its associated reliability model, maintenance strategy, failure management and configuration of railway network including traffic data. The method agglomerates maximal expert knowledge to specify performance targets for the overall system. Applying CADM provides input for life-cycle-cost calculations. As the technique is relatively comprehensive in its scope but fast and easy to apply, it provides support for defining system safety, reliability, maintenance concepts, and helps to optimise requirements according to the costs.

Optimise the requirements to operator's needs

Determine probabilities, e.g. train delays

Investigate effects of failures

Define system's failure characteristics

Specification of the target benefit for procurement phases

Figure 8: CADM to define availability requirements in procurement phases

Life Cycle Costing helps to investigate the costs of the future system and in combination with income estimations it gives opportunity to optimise requirements according to the future profit. As it makes sense to apply this to
most of the requirements, the LCC may be used broadly in the procurement phases. The method is well known [2].

In the Tender Evaluation Phase it may be applied like the following: The Call for Tenders document specifies a cost breakdown structure and the cost model is set up for investment, preventive maintenance, corrective maintenance, spare parts, operation. First the data for LCC comes from the tenderers (e.g. equipment cost, maintenance hours), second this data is translated into a general level (e.g. investment, labour costs). Then a LCC calculation helps to evaluate tenders. All the data used is never fixed, it can vary under different circumstances, and therefore a sensitivity analysis should be done with LCC.

4 Conclusion

When going through a procurement process of a small or a big project it is always worth to think about a structured way to define and manage the requirements. Every requirement should be categorised to safety, availability, and profit and then ranked by their priority before starting detailing it. The level of detail of requirements is the stop criterion for every phase during procurement. Defining key requirements and ranking, in combination with powerful, easy to apply methods, makes it possible to plan and manage the whole process of procurement efficiently.

References