Data-Driven Maintenance Delivery Framework: Test in an Italian Company

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Abstract. Many manufacturing companies are now facing the transition towards the development of a structured service offering in the servitization fashion. Especially in the case of a service like maintenance, the definition of a coherent process, able to collect and exploit in the right way the data from the field for decision-making scopes constitutes the base to run an economically sustainable offering. The authors proposed a structured framework that, considering a dual perspective (asset and service), aims to address this problem and to improve the maintenance decision-making. The paper, using as a case study an Italian manufacturing company willing to accelerate its servitization process, addresses the testing and improvement of the framework. Company A service department's employees were interviewed in the scope of validating the framework and identify improvements for its structure and the related decision-making instruments.

Keywords: Maintenance · Decision-making · Product-service systems · Industry 4.0

1 Introduction

Manufacturing companies are widening their offering adopting the Product-Service System (PSS) business model, consisting of the joint offering of products and services to satisfy specific customer needs [1]. Researchers [2] expect that the introduction of the Industry 4.0 technologies inside production processes will also improve the service delivery to final customers, creating new revenue streams and solid bonds between users and vendors. Though, expanding the traditional offer with services, e.g. maintenance, does not guarantee additional profits [3], because of a lack of structured processes and tools [4] able to support proper operational decision-making and delivery [5]. Thus, decision-making tools are needed to offer services successfully [6]. Through Industry 4.0, new and unprecedented quantities of data can be exploited for decision-making purposes [7], even if manufacturing companies cannot create value without proper culture or skills [8]. To fill this gap, the authors proposed a framework [9] (Fig. 1) that, considering information from the asset and the field service, can support maintenance delivery as well as the continuous improvement of asset and service design. In this framework, blue rectangles represent phases, while ovals indicate tools and approaches under development (in orange), or already available (in blue)

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supporting specific steps. The framework is divided into three macro-areas (data collection and analysis, cross-analysis, and improvement) and adopts a dual perspective approach to support decision-makers, considering data from the asset and the maintenance.

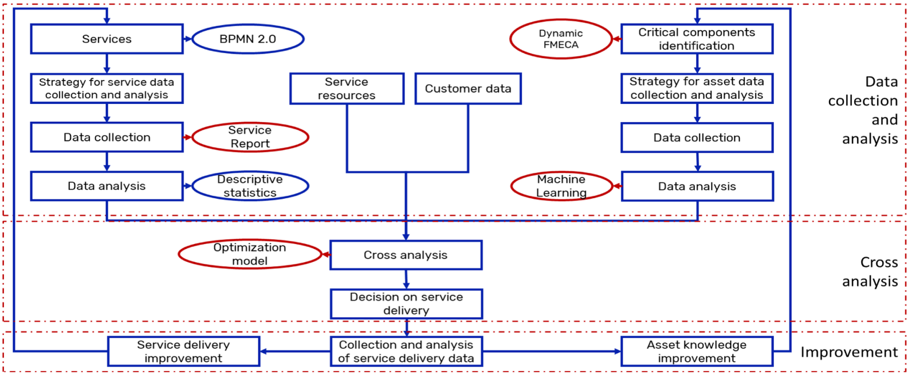

Fig. 1. The dual perspective framework for maintenance delivery improvement (Color figure online)

From the service perspective, the framework starts with a deep understanding of the actual service delivery processes that can be achieved by mapping activities, actors and data flows. Based on this, a strategy for the collection and analysis of service-related data should be defined and put in place. The service report [9] is the suggested tool to collect this data in a structured way. Regarding the asset, the first activity is the analysis of the components to identify the critical ones. This activity can be done through dynamic FMECA [10]. Once identified the critical components, the company should define a strategy for asset-related data collection, in terms of which data and how to analyse them. To this purpose, machine learning is suggested to determine the health status of the components. This activity is supported by a framework [11] for the selection of the algorithm based on. The novelty of this framework resides on the cross analysis of service and asset data to support service operations decisions, such as the selection of the maintenance policy and the intervention scheduling. To this purpose, an optimization model has been specifically developed. Once executed, the intervention's data are collected. The analysis of this data along with the asset information would allow the company to identify improvements at both the asset or the service level. The authors are now interested in testing the usefulness of the framework answering to the following research question: *How a data-driven decision-making framework for maintenance delivery should be structured?* This paper reports the results of an interview run in Company A, an Italian manufacturing company producing pumps for the Oil&Gas sector. Traditionally focused on its product-centred portfolio, the company is facing a servitization process, and aims at improving the maintenance service. After a short presentation of the research method (Sect. 2), the paper discusses the interviews (Sect. 3) and the improvements (Sect. 4) before delineating the next steps in the research (Sect. 5).

2 Research Method

In the scope of testing and improving the framework, the authors carried out a series of semi-structured interviews in Company A. As proposed by [12], a questionnaire was prepared while, during the interviews, questions have been added or modified according to the situation and the role of the respondents. Employees were selected with the help of the Business Development Manager to cover all the aspects of the maintenance delivery process. Four figures have been interviewed: the Business Development Manager, for its comprehensive vision on the services offered by Company A; a Field Service Engineer, for its experience on the field; a Service Engineer with the role of planner, for its competences in terms of intervention allocation; a Service Engineer in charge of supporting the Field Service Engineer remotely during the maintenance intervention, for its competencies in terms of information retrieving and management. Due to the small size of the service department, each of the interviewed people has experience with what concerns the different parts of the maintenance delivery process even not being specialized in all the tasks. The interviews lasted around 1.5 h each and were divided into two parts. In the first part, the respondents were asked to describe their activities related to the maintenance delivery process as well as the data collected and used to make decisions related to maintenance delivery. This phase of the interview allowed highlighting the current gaps in terms of data usage and sharing, tools and activities in the process. In the second part, based on the problems identified in the first part of the interview, the framework and the related tools were presented, and benefits and barriers related to their implementation were discussed. This phase allowed identifying how the implementation of the framework could improve the current maintenance delivery process in Company A and allowed listing a set of requirements necessary for the correct implementation and exploitation of the framework. All the interviews were recorded and transcribed to favour the following analysis. The authors categorized the information retrieved from the transcripts depending on their relationship with the framework to clarify the list of gaps that emerged during the interviews, identifying commonalities between the ones described by the respondents. In the following section, the authors discuss the results of the interviews.

3 Results

3.1 Company A

Company A is a manufacturing company headquartered in the northern part of Italy working in the Oil&Gas sector. Originally characterized by a strongly product-oriented portfolio, the company has recently started an internal reorganization introducing a servitization perspective in its business model. Company A has been chosen due to its interest in the development of a proper maintenance offering. The current maintenance delivery process in Company A is structured as follows. The planner receives, via email or phone, a claim from the customers or the vendors on the field. In half of the cases, it is possible to identify the problem immediately and sort it to the right person. In the remaining half, more information from the customer are collected. Once identified the problem, the request is sorted out to a technician on the base of their competencies. First, the owner of the request tries to solve the problem via telephone; otherwise, an intervention is scheduled with the support of the planner. Once the intervention is scheduled, the technician goes to the field and tries to solve the problem. If possible, the problem is solved in a unique session, otherwise, the technician schedules additional sessions. A report, used mainly for the final billing, is written at the end of the intervention. Once the bill is sent to the customer, the report is stored in an internal database.

3.2 The Framework

The respondents were asked to discuss how, from their perspective, the framework and the tools could contribute in solving the current gaps considering benefits and barriers connected to its implementation. The interviewees agreed on the structure of the framework and its content. Regarding information sharing among departments, the field service engineer said *"We are trying to restructure the way information is shared between R&D and service department. [...] The framework is aligned with what we are intentioned to create here."* Similarly, the Service Engineer said *"Data sharing would be really useful, even though we need to understand how to handle the situation on the asset side due to the privacy concerns of the customers"*. Some suggestions for the improvement were collected from the respondents. Firstly, it is relevant to deepen the asset monitoring aspect since, as the Business Development Manager said, *"The main barrier to the implementation is in the introduction of real-time monitoring technology in the Oil&Gas plants [...]. Moreover, currently, we don't have a historical database to run preventive maintenance"*. Also, the Service Engineer stated: *"Something that should be clarified is who is in charge of the infrastructure maintenance. The customer or us? It is something that has to be defined in the contract"*. Thus, the framework can be useful to overcome the problem of data collection and exploitation (i.e. for preventive maintenance purposes) and information sharing. In the following, the main areas of the framework are discussed.

Data Collection and Analysis

Currently, data collection and analysis in Company A are carried out in an unstructured way. Even when data is collected properly, it is stored in different databases, making more complex the analysis. Information indexing is one of the main problems the company is suffering, resulting in the inability to offer more advanced services, e.g. preventive maintenance. Since service reports are text-intensive and any natural language process algorithms are used, data collected during the interventions are not analysed, preventing the information extraction. The framework proposes the introduction of an approach to data collection and analysis, aimed at favouring the retrieval of useful information when it is needed, e.g. making decisions for maintenance delivery. As depicted in Fig. 1, first, the company should decide what data and how to collect them. Analyses are performed using techniques able to extract information and determine, for example, the machine health status. Regarding the asset data collection, the Business Development Manager stated *"The problem is that our products are tested for 4 hours internally and then we have no process data. We have no historical database supporting services like preventive maintenance"*. The usefulness of such an approach for data analysis has been confirmed by the Field Service Engineer: *"It would be useful to have unique software to handle data, making it easier the information research"* and by the Planner: *"Service Reports are just stored on an internal database, not analyzed because of the lack of a standard format. The structure that you propose for the data collection and analysis is good. […] It would be useful to have a historical database of what happened to the machine, it would facilitate the identification of the problem."*

Cross Analysis

Currently, the Planner is in charge of filtering the requests and assigning each one to the most suitable technician. This work is done only with the calendar, without the support of specific software or a database with information on technicians or past interventions, due to the limited number of service resources available in Company A. When this figure is not available, no one in Company A has the competencies to fully substitute him. To address this issue, the framework proposes an optimization model that integrates the information on service (e.g. list of available interventions, skills required to execute the intervention) and asset (e.g. component health status), the information related to the service department (e.g. resources, schedule, competencies) and to the customer (e.g. location, Service Level Agreement) making it possible to base decisions on historical and field data. The company completely agreed with this. The Planner said: *"It could be very useful to have something like this when I am occupied with other activities. Having data on the usual length of the interventions would facilitate the job for the person who has to substitute me"*.

Improvement

Currently, due to the lack of a structured approach to data collection and analysis, Company A is not using the data from service reports to identify the main problems in products and services. Information sharing is still limited nowadays, whit only a few meetings organized until now. The framework is built in a continuous improvement fashion. It aims at combining the data from maintenance intervention reports and from the asset (if available) as sources of information to identify improvements both for the service (e.g. service reengineering) and asset sides. This approach to data management is considered beneficial, since, as reported by the Field Service Engineer, *"Recently we had a meeting with the R&D to discuss the problems related to the machine design and the ones related to the incorrect machine usage. […] The identification of these problems could be one mean to reduce the frequency of these failures and shorten the resolution time"*.

3.3 The Framework Tools

The interviews were useful to collect suggestions for the improvement of the tools as described in the following.

Dynamic FMECA

Currently, Company A is not keeping track of a structured way of the most problematic components in its machines. This, and the lack of analysis on maintenance interventions, complicates the definition of proper maintenance plans for the machines. The Service Engineer stated: *"I think it is a good idea to update it with new information."* However, he suggested: *"Something that I would improve is the way components Risk Priority Number (RPN) is updated. A component that frequently fails not necessarily fails because it has a problem. The failure could be caused by another component's wrong behavior. So, I would suggest introducing a Root Cause Analysis (RCA) to identify the failure cause of a component and be sure to update the right RPN."*

Service Report

Data collection is critical for Company A, especially during maintenance delivery. The proposal of a standard format for service reports was interesting for the respondents, who appreciated its structure and gave suggestions for improvement. For example, the Field Service Engineer said: *"I think it has a good format. Depending on the type of service, a report like this could be really useful. […] It would be good to have the chance to print only parts of the report depending on the situation and necessity."* Similarly, for the planner *"The logic behind the report structure is good. It would be useful to specify the day of execution for each activity. It would help in understanding their length and impact. It would also be useful to have the length of the single activities, to know what are the simplest ones and the most complex. Sometimes the customer is the cause of a considerable amount of time lost during the intervention because he is not ready. It would be useful to have information like this"*. To facilitate the filling phase for the technicians, the structure of the asset identified through the dynamic FMECA (e.g. groups, subgroups, and components) is replicated into the service report.

Optimization Model

As emerged from the interviews, there is only one Planner in charge of the scheduling; the other employees do not have enough competencies to substitute him. Thus, the proposal of a tool able to support the task allocation, in conjunction with the idea of creating a competencies database and collect data on the intervention length, was approved by the Planner, who stated: *"The logic behind the model is very similar to the one I use. Sometimes there are contingency factors causing delays to the original schedule. It would be useful to have something that also considers that information."*

4 Summary of Improvements

The interviews allowed to validate the structure of the framework and collect information on further improvements. The results are depicted in Fig. 2.

The general structure of the framework received positive feedback and, thus, no modification was necessary. Despite this, suggestions were collected about its implementation barriers (e.g. contractual clauses) and the benefits.

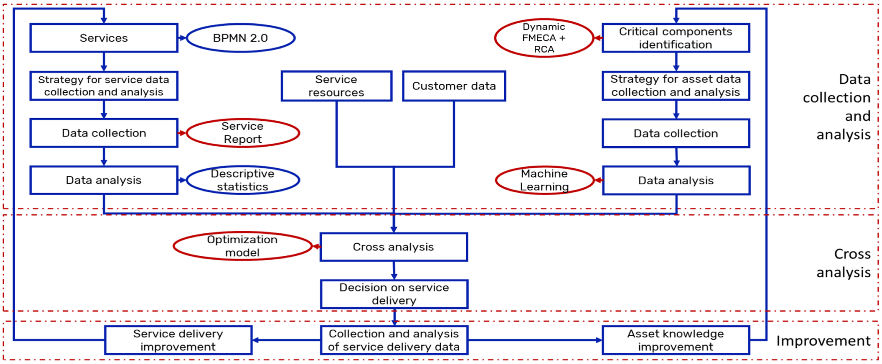

Fig. 2. The updated framework

The main suggestions for improvement were focused on the internal structure of the tools rather than on the structure of the framework. For example, the RCA has been integrated into the process of updating the RPN in the dynamic FMECA. Other changes have been integrated into the tools despite being not visible in the framework since related to their internal structure. Specifically, the Service Report has been modified in the structure considering the possibility to specify time losses causes and add more information related to the activities performed.

5 Conclusions

The establishment of a structured approach to data collection and analysis is necessary if companies want to offer an efficient maintenance service to their customers. In the scope of validating and improving the framework proposed in [9], this work describes the results of a set of semi-structured interviews run in an Italian manufacturing company operating in the Oil&Gas sector which is currently facing a servitization process. The data collected during the interview demonstrated the possible benefits achievable from the implementation of the framework and of the related instruments. Despite this, also suggestions on improvement actions related to both the framework and the instruments were collected (e.g. joint use of dynamic FMECA and RCA to improve the RPN update). The main contribution of the framework resides in the approach that considers the asset and service perspectives jointly with a focus on operational decision-making. As discussed in [5] and [6] there is a lack of approaches focused to maintenance decision-making at the operational level. The framework wants to cover this gap working at the operative level (e.g. technician selection and scheduling, maintenance typology) and on the strategic and tactical levels through the improvement phase (e.g. redesign of asset or service, re-definition of maintenance policies, spare parts management). Barriers related to the acceptance of the new approach should be discussed to explain the employees its benefits and make them participate in the company improvement journey [8]. Suggestions will be used to improve the whole framework and new interviews will be run to validate the framework and the instruments.

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