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EXECUTIVE SUMMARY OF THE THESIS

A Business Model For The Customization Of Advanced Maintenance Through Microservices

TESI MAGISTRALE IN MANAGEMENT ENGINEERING – INGEGNERIA GESTIONALE

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1. Introduction

Maintenance has always been considered as a not value adding activity, more specifically as the cost derived from the repair of the asset and time needed to achieve the physical restoration. Over last years, maintenance has assumed a relevant role in strategical activities of the company, due to a progressive amplification of its objectives, moving from the concept of maintenance as group of activities to repair an asset and restore its degraded status, to maintenance as key aspect to increase performances.

Nowadays companies are involved in big transformation that brings digital innovation inside companies' value chain: the era of "digital transformation" has begun. Digital transformation means to continuously looking for new competitiveness opportunities thanks to innovation and has happened in the context of the fourth industrial revolution also called "Industry 4.0".
It is with servitization and with the arrival of the fourth industrial revolution, also known as "industry 4.0", that maintenance started to be seen more and more as a business opportunity, radically changing the historical maintenance models. Servitization is a strategy emerged in the last years that consists in offering to clients high value-adding services related to the sold products. Such business model originally conceived, in the academic discussion, from Sandra Vandermerwe e Juan Rada in 1988 with an article entitled "Servitization of Business: adding Value by adding Services" [1].
Many manufacturing companies started to leverage on servitization to offer services linked to products to increase margins and, thanks to the information and data flow connected to those services, can receive feedbacks on the same services and products solved, optimizing products.

In this context, big data and analytics play a very important role, enabling new maintenance paradigms like predictive maintenance that, exploiting the main technologies of industry 4.0 (sensors, IIoT, Big data, Artificial Intelligence…), is able to detect and predict failures in evolution before they finally occur.

Additionally, with the evolution of the enabling technologies, especially those related to

application and the software development and application, the era of micro-servitization begun and with it new opportunities came thanks to their capability to confer lightness and flexibility to software platforms and tools.
Micro-servitization even if related more to IT perspective, can be leveraged on business level thanks to the business opportunities that can be generated, for which an explorative study is provided in this work.

2. Overarching Goal and Structure of the research

This thesis has, in its scope of work, the interest and goal to understand what characteristics of industry 4.0 can be embedded in advanced maintenance, especially looking at the potential of micro-services to develop advanced maintenance as business opportunity and foundation of a new business model.

In particular, the work has the following purposes:
1. To study the state-of-art in the literature for what concern advanced maintenance;
2. To discover new business opportunities related to advanced maintenance that can be enabled by micro-servitization;
3. To understand how advanced maintenance tools and techniques can assist in increasing the flexibility of manufacturing systems;
4. To propose a business model for advanced maintenance conferring more value to the existing e-maintenance one.

Considering the above said purposes, the whole work is divided into three main parts:

I. Systematic literature review
II. Business Model proposal & validation
III. Conclusions & future developments

3. Literature Review and findings

Systematic literature review has been carried with the purposes to examine the state of art of advanced maintenance, servitization and micro-servitization in literature and to search for eventual gaps in literature that need to be filled with the objective to contribute with a starting point for future studies.

The methodology used in this work for systematic literature review is the one proposed in [2].

In particular, accordingly to the reference, the literature review was divided into two main sections:

- Primary studies: it consists in the "quantitative analysis" of the papers found in repositories aimed at revealing **interesting trends**.
- Secondary studies: it consists in an accurate reading of the most relevant papers present in literature with the aim to discover the state of art of analyzed topics and the main gaps in literature. It is fundamental since it provides different information that will be then transformed into "**insights**". In this thesis, this part will be called "**qualitative analysis**".

Quantitative analysis followed a 3-layered approach aimed to evaluate the results given by the intersection of 3 different topics. In particular, level 0 was aimed to analyze the number of outputs about the topics of predictive maintenance, servitization and micro-servitization considered as individual argument; research at level 1 was aimed, instead, to study two combinations of keywords, in particular: predictive maintenance and servitization from one side and servitization and micro-servitization on the other side; level 2, finally, represented the most important research part since allowed to address one of the core research objective of the review , that is to understand if in literature the possibility to apply micro-servitization to advanced maintenance has ever been explored.

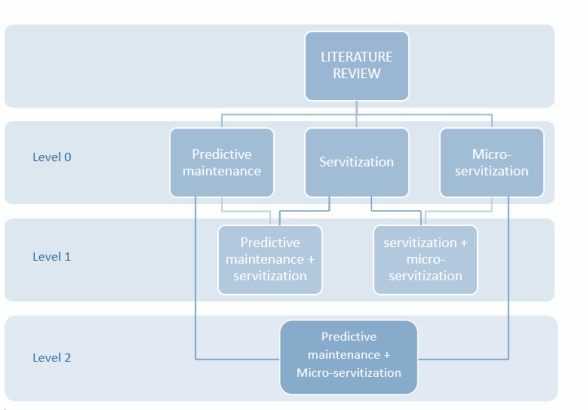

Figure 1 - Quantitative analysis research structure

Research protocol applied was basically an iterative process conducted on Scopus and IEEE Xplore (IEEEX). For each research, at the first iteration the output consist of all the results for a specific queried keyword or group of keywords; at the second iteration, output results with specific filters applied depending on the research question to be addressed.

Results from quantitative analysis brought to light that predictive maintenance has been deeply explored in literature and that the area of interest is mainly industrial one, but **research is expanding the scope to other areas.** Moreover, results confirmed an increase of scientific interest in **service-oriented perspective**, especially in manufacturing field and unexpectedly, the country that is demonstrating more interest about the topic is Italy. Amongst servitization examples, considering that it is mainly applied in manufacturing and industrial field, predictive maintenance plays an important role.
Another output of the quantitative research, is about micro-servitization that **has not been explored yet as a business opportunity**, and it is strongly related to IT field.
First analysis brought to light a first important gap: the possibility to confer modularity and flexibility to the existing e-maintenance business models has been considered interesting and to some extent explored, but it has not been associated to micro-servitization yet.

The second level of the analysis aimed to understand the reason of the poor interest in the study of micro-servitization for advanced maintenance. To find an answer to this question, three main hypotheses were formulated:

1. **Gains Distrust Barrier Hypothesis**: No interest on the topic since there is no significant improvement provided by the application of micro-services to advanced maintenance, in particular predictive maintenance;
2. **Feasibility Barrier Hypothesis**: The usage of micro-services in advance maintenance creates value but there are not enabling technologies to realize it or there are some possible barriers in isolating each phase of PHM process required for predictive maintenance;
3. **Value-transfer Barrier Hypothesis**: Micro-servitized advanced maintenance can add value to actual a-maintenance solutions and there are enabling technologies to realize it, but there is a lack of knowledge in understanding how to deploy such innovative business model and position it in costumers 'mind (what do make it desirable and innovative for costumer? Where is the value?).

Going through such hypotheses in the papers reading, it emerged that micro-services can help in solving some typical challenges of predictive analytics for many reasons: an example coming from [3] was provided to describe the main benefits provided by micro-services to a whole predictive analytics software. And also in [4], it emerged an interesting concept related to the evolution of predictive maintenance systems: micro-services enable to evolve and extend the architecture without costs of evolution, thanks also to the high replaceability.

Once first hypothesis was then neglected, research passed through a more technical study, moving on the feasibility plane. Also in this case, different findings from literature were mentioned to show, starting from real use cases, that advanced maintenance can be effectively developed using micro-services which is the demonstration that no feasibility barrier occurs.

Finally, last hypothesis was analyzed and it was presented an interesting paper proposed by J. Lee in 2009 [5] and offerings interesting insights on the conception of maintenance as "service function".

This paper under exam was very interesting from business point of view since it brought to light that it was needed to move from the conception of maintenance as "solution to a problem", towards the vision of maintenance as "value-adding and customized service". Moreover, the author proposed a systematic maintenance design able to provide a service business capable of adapting to changes in needs of clients that happen very frequently in nowadays dynamic environments.
Although the importance of this paper and its relevance from a scientific perspective, the approach presented a limitation: **customization, that is firstly considered as an important requirement to satisfy costumers expectations, is then reduced to the choice of the most suitable e-maintenance strategy among 3 proposed approaches.**
Finally, reference [3] suggested that actually a generic and scalable prognostics methodology does not exist, leading to following gaps in literature:

- Scalability dimension has not been considered in actual advanced maintenance business models
- But, on the other side, the need of scalable and reconfigurable systems for predictive maintenance exists.

Overall, the search for a customized advanced maintenance, built on flexible and scalable resources appear a significant need.

4. Business Model for Customized Advanced Maintenance

Starting from the literature findings, it was decided to contribute to literature with proposal of a business model depicted in a correspondent canvas designed for conferring conferring to advanced maintenance the possibility to be customized.

➢ Costumer Segments

This business idea was addressed mainly to three main costumer segments for which is here provided a definition and the typical need:

- **Manufacturing Business**: business that uses raw materials, parts, and components to assemble finished goods (B2C). Typical need of a manufacturing business is increasing productivity by reducing downtime, increase product quality and machines availability.
- **Service Enterprise**: business that generates income by providing services instead of selling physical products. Identified need is improving decision making process or offering new analytics services to clients
- **Industrial machinery company**: possibility to sell specific services to others producers of industrial machinery for (B2B). Typical need is to provide to their costumer adding-value services customized on the products and collect data direct from the costumer's plant.

To enable a focused approach, the business model here presented has been built only a main costumer segment amongst ones identified: manufacturing business.

➢ Value Proposition

General value promise of the business model in object to this thesis is providing the possibility to customize specific advanced maintenance services and adapt them to clients requirements.

Customization is realized thanks to micro-services and confer to the new paradigm higher scalability and higher flexibility of solutions proposed.

Value proposition was better described defining value map and costumer profile. Value map contained gain creators and pain relievers of the idea proposed, describing also the product & services. On the other side, costumer profile aimed to define costumer jobs and principal gains provided by the idea and pains resolved. A resume of the main items can be found in the picture below:

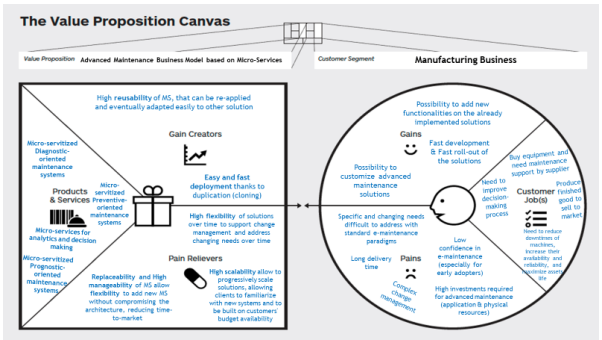

Figure 2. Value Map and Costumer Profile of Business Model Canvas

➢ Key Activities, Key Partners and Key Resources

To realize what is expected by value proposition, it is important to consider the key activities that industrial machinery manufacturers should perform in order to ensure to their customers the value promises. Amongst the main key activities, in the business model the followings were considered:

- Adopting Agile framework and changing development culture (DevOps Model adoption)
- Identify customers' expectations and approach and select the most suitable advanced maintenance strategy
- Componentize maintenance strategy into micro-services and then focus on integration
- Migration from monolithic systems to distributed ones

Key resources have been divided into three main categories: financial, for which it has been considered costumer budget availability; human resources, for which were included mainly expertise in IT/ICT, network specialist, data security experts and solution architects. In particular, between the main key partners were identified Cloud services providers & Cloud experts: Container-based environments and microservices make companies look for engineers who are hands-on with Google Cloud Platform (GCP), Amazon Web Services (AWS).

Finally, the idea includes as main key physical resources, first of all the micro-services themselves for which the list of basic modules for PHM was provided; the cloud, fog and edge computing needed for running an application for predictive/advanced maintenance deployed using micro-services and finally, DevOps as the ensemble of tangibles (tools, codes, etc.) and intangibles (procedures, standards, etc.) needed for a successful development of micro-services architectures.

➢ Channels & Costumer Relationship

The building block "Channels" of the business model canvas describes how the supplier can establish a point of contact with its customers segments and how the communication is established. The most important identified channel for this business model was the **product** itself: the asset sold to costumer for which a customized advanced maintenance solution should be designed. Other channels identified are:

- **Periodical Meetings** to present to customer new value-adding micro-services to be integrated in the previous sold solution (channel for continuous delivery)
- **Presentation of historical data and achieved results**
- **Monitoring and alerting systems** to support customers during post-purchase of the microservices, facilitating maintenance interventions.

In is also important, from supplier perspective, to clarify which kind of relationships should be established with costumers accordingly with the costumer strategy. To this regard, 3 kinds of relationships have been identified:

- **Co-Creation:** to be established during the design phase costumer should be involved in order to transfer him the new value of the new advanced maintenance model;
- **Collaboration:** in this phase it is important to check if services delivered at this point as minimum viable services (following agile perspective) are responding to costumers needs or requirements changed or not perfectly fulfilled
- **Continuous Delivery & Continuous Improvement**: it regards the after-sale phase, needed to keep the contact with the clients.

➢ Costs Structure and revenue Streams

Finally, in the thesis the cost structure and revenue streams of the model were defined. In particular the main expected benefit of the presented idea is an overall increase of profitability. Given by:

1) **Costumer-base growth**: the business model can be extended not only to the main identified costumer segments, but also to other costumers thanks to the customization that allows;

2) **Margins increase**: thanks to customization as value-adding characteristics for analytics and predictive systems;

3) **Enlarge services portfolio:** supplier can offer entire the e-maintenance solutions, or simply specific analytics functionalities provided through micro-services.

For what concerns cost structure of the proposed business model, It is necessary to consider following costs:

- Costs for the acquisition of human key resources
- Migration from monolithic to distributed systems & legacy system integration: it refers to the costs to sustain in order to transfer the whole application to a newer hardware and software infrastructure.
- Infrastructure Costs & 24/7 (always-on) services

5. Validation process and Results

The business model Canvas was then tested using the method proposed by Alex Osterwalder in 2021 [6] and based on 3 main steps:

a) Key Hypotheses formulation
b) Experiments
c) Key insights generation

The main idea behind, is to transform the whole business model into hypotheses that cover mainly three **types of risks (desirability – viability – feasibility)** to be eliminated for achieving a successful implementation of the business idea.

After each assumption made in the business model was transformed into a hypothesis, such hypotheses were then prioritized and treated following the Osterwalder's procedure.

It was built a so-called "**assumptions map**" composed by 4 quadrants, obtained by crossing two axes: importance (y-axis) and evidence presence (x-axis). Each assumption was then positioned in the map according with its importance and the presence/lack of evidences to support the hypothesis. Following pictures show how the assumptions are collocated in the assumption maps, , starting from the proposed business model canvas:

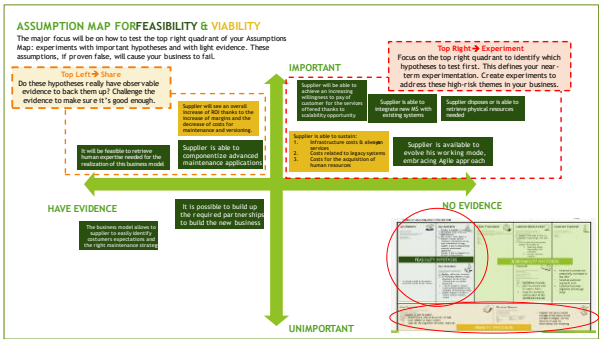

Figure 3 - Assumption Map for Feasibility and Viability Hypotheses

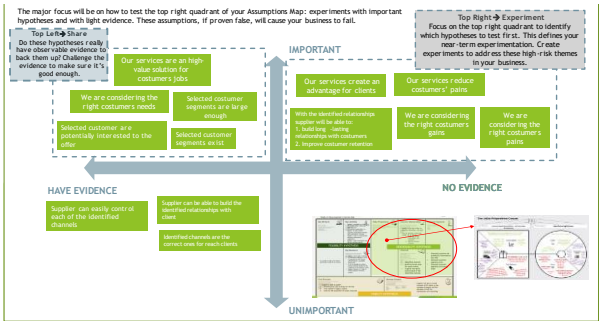

Figure 4 - Assumption Map for Desirability Hypotheses

According to the reference, the major focus has to be put on the top right quadrant of each assumption map: characterized by an high important and an absence of evidences.

For testing the hypotheses, three main methods were chosen:

- **Costumer survey**: this method was addressed to digital manufacturing department of a B2C company, worldwide leader in the Tobacco field with the aim to confirm an effective interest on the solution from costumer and to address the main value proposition's hypotheses. Costumer survey is considered to be low-cost, quick and according to the mentioned reference, it provides a weak evidence. To increase the strength of output evidences, also the stakeholders interview were associated to address desirability hypotheses.
- **Marketing & Sales Department and experts stakeholders Interviews**: two different roles were involved from R&D department (or expert stakeholders) and marketing & sales departments of a leader company in the

production of automated machines for packaging were interviewed to eliminate the identified relevant risks on feasibility and viability side, providing an high level of evidence strength and requiring an high run time.

The results of this research phase definitively confirmed the need, emerged from literature review, of a customizable and scalable advanced maintenance both from supplier and costumer perspectives, adding some other important insights.

First of all, from interviewees emerged that the supplier, in this case, was ready enough to switch to the new business model strategy, especially from a mindset and resource acquisition point of view and recognised the importance of digitalization and servitization. Both costumer and supplier involved in the research, has invested a lot in technologies and capability for industry 4.0.
Another relevant result is characterised by the confirmation of the main assumptions made in the business model Canvas, in particular:

a) **Integration** is considered by the supplier, as expected, one of the most difficult key activity to deal with when advanced maintenance solutions are developed via micro-services;
b) Supplier interviews confirmed the expected benefits mentioned in the value proposition: including the fact that **cost for the addition of new functionalities can be reduced** thanks to reusability of micro-services;
c) Both supplier and costumers confirmed **scepticism** and difficulties in advanced maintenance solutions adoption;
d) Both supplier and costumers affirmed that **delivery time is a very important aspect** when speaking about advanced maintenance.
e) An important confirmation arrived from costumers side: suppliers are not able, with actual maintenance business models, to follow company's changes and they would receive a more "customizable" offer in maintenance and even welcome, analytics. Additionally, clients would have an **higher level of flexibility of advanced maintenance**;
f) Relationships with clients for such business model are fundamental for both costumers and suppliers. Costumer must be involved in all the phase of the projects and to engage him and stimulate its interest is necessary, as affirmed by supplier, to provide him short-medium-long period visions.

6. Conclusions & Future Developments

This work aimed to explore the interest on the possibility to improve actual advanced maintenance business models using the potential of micro-services. Moreover, the ultimate purpose of this thesis was to try to fill gaps found in literature about this topic, by proposing an innovative business model for advanced maintenance development.

This work can be intended as an early exploration of the topic that could be used as starting point for the development of more structured business models.
For this reason, also the validation purposes of this work have been more focused on the reduction of the main identified feasibility, desirability, viability risks than their elimination. Indeed, this is an exploration that must be contextualized in its "discovery" phase, for which weak and medium evidences are sufficient, according with Osterwalder's perspective, to discover if the general direction of this work is right and to produce useful insights that could be confirmed with further stronger tests.

For this reason, one possible future development suggestion, is to test again the presented business model exploiting the iterative process suggested by Osterwalder. In this way, at each iteration and changing also experiments methods and people involved, it will be possible to enrich the idea of other hidden elements that could emerge.
In this work, in fact, supplier involved presented a certain readiness on that matter and for this reason, the majority of key activities, resources and partnerships were already put in place. It could be interesting to conduct other interviews with suppliers that have not the same level of readiness in order to evaluate more precisely if new difficulties can arise. Similarly, also costumer involved had an high maturity level in industry 4.0 and relatives, living in a advanced step of digital transformation and having high budget availability to invest in digital projects. It could be

useful to contribute to this initial work, involving also small and medium enterprises to test their interests and needs and see if micro-services can boost the digital transformation process and support them in changing their maintenance paradigm.

7. Bibliography

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