Initiating an industrial machinery producer to digital servitization: a case study

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Abstract. Several manufacturing companies are coping with the need to change their business model, being compelled to provide smart, connected and servitized solutions to their customers to survive in the market. A strategic trigger and catalyst of such a transition is represented by digital technologies. Embedded on physical products, digital technologies enable knowledge-based services capable not only of monitoring but also of controlling and optimize, sometimes even at an autonomous level, the system provided to the customer. However, several hurdles (categorized in technical/technological, organizational, human resources-related, and customer-related) can be met along the digital servitization path. It is still not clear what should be implemented in a company internally realizing the need of implementing the digital servitization transition. This paper has the aim of conducting a strategic analysis to understand how to initiate to the digital servitization phenomenon a company producing machineries for the decoration of plastic objects and containers.

Keywords: digital servitization, machinery sector, Industry 4.0.

1 Introduction

Nowadays, several manufacturing companies are coping with the need to change their business model. Compelled to provide smart, connected and servitized solutions to their customers to survive in the market [1], [2], the profit of these companies no more depends on transactions linked to the sale of the possession of the physical products from the producer to the customer but is generated by the sale either of the use or of the result generated by the provision of the solution to the customer [3]. Generally, the provision of such solutions (named Product-Service Systems (PSS)) brings several benefits to both the providers and the customer, since they are able to increase providers' competitiveness on the market, to satisfy customer needs and to lower environmental impact than traditional business models [4]–[6].

A strategic trigger and catalyst of such a transition is represented by digital technologies [7]–[9] (gathered under the umbrella of Industry 4.0 (I4.0) [10]), whose adoption has been recently spread and pushed by a continuous evolutionary progress.

Embedded on physical products, digital technologies enable new knowledge-based services capable not only of monitoring but also of controlling and optimize, sometimes even at an autonomous level, the system provided to the customer [1]. Digital servitization [7]–[9] was recognized as a paradigm able to create new value, impacting not only on the whole business model of a company [11] but also its way of doing business [12]. Thanks to data generated and shared during the use phase of the solution, not only it allows to better manage the solution along its use phase (since the provider still owns it) but also strengthens the provider-customer relation (relieving the user from the commitment of supervising the status of the solution) [13].
However, several hurdles (categorized in technical/technological, organizational, human resources-related, and customer-related [14]) can be met along the digital servitization path by those companies that want to switch from a traditional product-based business model towards a PSS-based one. Hence, to navigate towards servitization, manufacturers need to enact different multifaceted changes in their organizations, from a cultural transition [15], through assuming a more a customer centric perspective [16], [17], up to modifying the way they approach the design of these systems [18], [19].
Notwithstanding this, it is still not clear which are the first steps to be done by a traditional manufacturing company to navigate towards digital servitization. For this reason, this paper has the aim of conducting a strategic analysis to understand how to initiate to the digital servitization phenomenon a company, Company A (for confidentiality reasons), producing machineries for the decoration of plastic objects and containers. The research started with the evaluation of the AS-IS *status* of the company, to understand what has been done so far internally in the company (and if those action answer to specific market requests) and what the company would like to implement in the future. Several interviews were conducted with the aim of covering the majority of the roles involved in this transition in the organization (from the technical director, through both electronic and mechanical departments, up to sales, customer care and export manager) to grasp their perspectives related to the business model shift feasibility. Furthermore, an analysis of the extant company product portfolio was performed to detect the pilot case, based on products' physical characteristics and functional properties, that will lead the experimentation towards a digital servitization business model transition.
In this way, first of all, it has been codified how the need of business change was raised in the company. Second, the pilot machinery to be used to experiment and set the shift has been defined. Third, the functional departments to be empowered to foster the digital servitization shift have been detected. Finally, the main areas of criticalities to implement this change, perceived by Company A, were defined and assessed.
Therefore, the paper is structured as follows. Section 2 shows the research methodology adopted and introduces Company A and the pilot machine. Section 3 presents the results of this research that are then discussed in Section 4. Finally, Section 5 concludes the paper and delineates the future research.

2 Research Methodology

To achieve the research objectives and be able to explore the company's *status quo,* a single case study was conducted [20].

2.1 The case: Company A

The Company A has been established in 1967 for manufacturing dry-offset and silk-screen printing machines for the decoration of plastic objects and containers. Through the years the Company has gradually grown up and from small workshop covering nearly 200 square meters where just a few people were employed, it has reached the current configuration of nearly 6.000 square meters. During the years the Company A extended its range of equipment to include hot foil printers, multipurpose machines for flexible tubes and pails, heat transfer machines for digital printing (DDS: Digital Decorating System), all offering very high technology and quality. Today, the production range of the Company A includes over 40 basic models which, thanks to their modular structure and a wide selection of accessories, have the possibility of being extremely flexible and versatile thus to cope with the market's requirements. The Company A is present in over 100 countries spread all 5 continents, although it is particularly well established in developed markets such as Europe, Middle and Far East, South and North America. In the last year, to provide better services to existing and prospect customers from the North American market, the Company A decided to go one step further and open a subsidiary company in the US.
The choice of Company A was justified by the fact that this case is purposive, i.e. it is suitable to the particular problem or representative of a special population, bringing to a idiographic study, that is the intensive study of an individual case (Williamson 2002). Indeed, Company A represents the typical manufacturing company of small dimensions, designing and producing industrial machineries according to the traditional business model based on the selling of physical products to its customers. In the meanwhile, Company A was also starting to realize that, to survive in the market, it should have been compelled soon to change its business model and pursue the digital servitization transition. However, due to the lack of knowledge and skills, internal resources and external strategic collaborations, Company A needs a deep analysis and reorganization of both its structure (needing to be adequately filled with new resources) and product portfolio (needing an update of the products functionalities through the embedding of digital technologies enabling the provision of new services). Indeed, in the medium/long run, these actions would be oriented to enlarge the product/service portfolio of the company, create more continue revenues along the machineries' lifecycle and strengthen and make more long-lasting the relation with customers.

2.2 The interviews

Semi-structured interviews were used to collect qualitative data, allowing also to conduct discussions with the participants. Seven interviews were conducted, with a total duration of about 14 hours. Interviewees were all employees of Company A, which

was analysed in a pervasive way, both vertically in the Technical Department (involving the technical director, the Electronic Department Manager, one electronic department engineer and one mechanical department engineer) and horizontally (interviewing the Sales Department Manager, the Customer Care Department and the Export Manager).

A protocol was also prepared to guide the interviews (Table 1).

Table 1. Table captions should be placed above the tables.

Areas of investigations	Question
1. Triggers	• Why did you decide to invest (time, resources, etc.) in the creation of intelligent products (machines)?
2. Customer requirements and value analysis	• What are the characteristics (physical and functional) of the smart product required by your customers (sensors, data, services - e.g., maintenance, monitoring, etc)? • What is the value for the customer?
3. Changes implemented	• How has the concept of intelligent product been internalized and, consequently, what has changed (in terms of roles, organization, processes and product/service portfolio), to be able to achieve it?
4. Investments and risks	• Compared to what has been done so far and what is requested by the customer, what are the areas (internal organizational, business, related to product/service) in which further investments need to be made? (TO-BE) • What are the difficulties/opportunities envisioned along the transition?

3 Results

Through the conduction of the interviews described above it was possible to deepen four main areas of investigation in the company analysed (*Triggers, Customer requirements and value analysis, Changes implemented, Investments and risks*) and delineate guidelines to be followed in the future steps.

Looking at the first point, *Triggers*, the aim was to understand which were the drivers which triggered the need of undertaking the digital servitization transition. It seems that the proposal for a new business model to be used for the sale of Company A's machines arises from an internal need of the company, which intends, through this system, to differentiate its offer from its main competitors. However, to be effective, it is essential that the new business model must be perceived of value not only by the customer but also by the company itself.

The second area of investigation deals with the *Customer requirements and value analysis*. The aim is to detect in the extant product portfolio which are the potential

functionalities that could be added by digital technologies. To do this, a pilot machine to experiment the digital servitized transition needs to be detected. The different interviews led to the identification of two main options (shown in Table 2).

Table 2 Portfolio analysis and pilot machine selection

Machine	**Electronics on Board**	**New/Old Realization**	**Volumes**	**Main Customers**
Machine 1 (Screen printing)	High	New (3 years) already subject to technical improvements (direct drive on the engine and update of the loading system)	Medium-high	European (manufacturers of small tubes, bottles and mascara))
Machine 2 (Offset)	Medium-low	Old (standard machine)	High	Extra-European

Given their characteristics, the Machine 1 (Screen printing) has been detected as the best case of this project. Indeed, it represents one of the most recent conceptions and realizations in the Company A portfolio. Also for this reason, it has numerous electronic components on board and all the knowledge related to its conception, as for example the structure of the machine tree and its mechanisms, is completely known. Finally, despite its recent conception, this machine has already medium-high sales volumes (> 25% of the company's total sales).

Switching to the last two areas of investigation (*Changes implemented*, and *Investments and risks*), the organizational areas in which it is needed to invest to implement the change towards digital servitization have been identified. Being the driver in this change the data generated by the machines operating in the customer's plants, three main actions have been defined to be implemented:

1. To identify the causes generating machine failures and downtimes and, consequently, improve its design elements:
   - creating data collection through a database (e.g. complaints, spare parts, components, etc. with tracking of the machines that require them);
   - collecting data on the causes of breakdowns, downtimes, loss of production capacity of the machines at the level of the individual critical components (through the adoption of the FMECA methodology [21]);
   - creating the behavioural model of the machine to understand where to act to improve its performance.

   The main criticality here has been detected in the lack of competences, of knowledge management during the machines design, and of data analysis skills.
2. To enhance the machine automation (waste reduction and performance optimization) based on the gathered data describing its operational and resource consumption behaviours (e.g. the machine self-adjusts in case of need for lubrication of one of its components, guarantees the temperature of the ink output so that the quality controls are minimized, etc.). However, this task needs to:

- identify the variables to be monitored;
- collect operating data of the machine components (e.g., ink output temperature);
- collect machine consumption data (e.g., gas or methane used, quantity of air in the pneumatic circuit, etc.);
- Create the behavioural model of the machine to understand where to act to improve its performance (e.g., create link between the component under an alarm status and the pieces to be considered as scraps),
- Implement technical modification introducing sensors on the machine;
- Implement software modification for data detection and machine self-regulation;
- Create a digital twin of the machine to be used for simulating and controlling the machine operation (e.g., optimization of the pick & place robot path, definition of machine operating times).

Related to these activities, multiple hurdles were detected. Not only it is complex to construct the operating model of the machines, to create an integrate with customer management systems and to implement a cloud technology for data collection, but in general in the company a shortage of strategic skills and know-how (modelling, data analytics, machine learning algorithms) was unveiled.

3. To provide new "product-based" services (e.g., condition-based remote maintenance, customer training on how to optimize the use of machines, etc.). The strategic tasks to enact this last point are to:
   - Identify the services that are intended to be flanking the sale of the machine;
   - Modify the machine design process to include the design for service [22].

4 Discussion

First of all, each of the areas of investigation explored in this research deserve a discussion.

Concerning the first, the triggers of the digital transitions, the analysis conducted to a first main suggestion to be provided to the Company A, i.e., to provide an adequate training to its employees to allow them to deeply understand the nature of this change. Once accomplished, the company needs also to understand how to effectively communicate the planned change to the customer. This is strictly linked to the following area of investigation, Customer requirements and value analysis. The Machine A (Screen Printing) needs to be used only as a pilot case to discover how to experiment the digital servitization path and to be able to provide a machine that is compliant with the customers' needs and expectations. The results obtained with the pilot case need then to be extended to the entire company's portfolio.

Finally, the last two areas led to a threefold discussion, each one connected to the three main actions to be implemented to complete the digital servitization transition in Company A. Indeed, three main criticalities were detected:

1. To further optimize the machine design process in the future, it would be suggested to gather, protocol and systematize in the company all the technical solu-

tions that along the time are proposed to meet each of the customers' requests/needs (so that they can be used in case of future designs of similar machines),

2. To speed up the machine improvement project and allow salespeople to better understand the technical functionalities of the machines and their components, it would be suggested to implement organizational and technological structures that could facilitate communication between the technical department and sales,
3. Since both a service department and a service-driven perspective are missing in the company so far, it would be useful in the medium-long run to both create a dedicated internal department and enlarge the external network around the company.

Wrapping up, an analysis of the criticalities inside the company has also been performed per each of the Company A's divisions (Table 3):

- Research & Development: the creation of a team (even just initially composed by a mechanic and an electronic engineer) would be required to improve applications, study innovative solutions, and pull the transition;
- Technical Department: not only the introduction of sensors on the machines would be required (asking for an analysis of which type of sensors to be put, where to place them and which standard protocol should be used to gather the data) but also an analysis of the data generated by their usage should support the definition of the machine operating models;
- Information Technology: a strategic activity to be done to allow the correct conduction of all the others is the data-base development. This should be flanked in a second phase by the cloud implementation, the implementation of systems integration (between the Manufacturers Execution System (MES) and the customers), and the development of machine learning algorithms;
- Human Resources: external training should be planned to further develop internal skills and new personnel with required skills should also be hired;
- Project Management: it would be necessary to introduce the figure of the project leader to coordinate the various actors involved in the management and development of the order in the company;
- Commercial Department/Post-Sales: customers' feedback and requests should be collected and analysed to grasp their sentiment about the solutions provided;
- Service: a service engineering function should be created. It would support the PSSs design following a service process perspective and promulgating their integration with the product development function. In addition, operators also need a consistent training to conduct specific services (e.g. installation, testing, etc.).

Table 3 analysis of the criticalities inside the company per each Company A's division

Company A's Division	Activity to be done	Aim of the activity
Research & Development	To create a team (even just initially composed by a mechanic and an electronic engineer).	To improve applications, study innovative solutions, and pull the transition.
Technical Department	To introduce sensors on the machines, asking for an analysis of which type of sensors to be put, where to place them and which standard protocol should be used.	To gather the data.
	analysis of the data generated by their usage	Support the definition of the machine operating models.
Information Technology	To develop a data-base.	Strategic activities to allow the other ones.
	To implement a cloud infrastructure, systems integration (between the Manufacturers Execution System (MES) and the customers), and machine learning algorithms.	
Human Resources	Planning of external training. Hiring of new personnel with required skills.	To further develop internal skills.
Project Management	To introduce the figure of the project leader.	To coordinate the various actors involved in the management and development of the order in the company.
Commercial Department/Post-Sales	To collect and analyse customers' feedback and requests.	To grasp their sentiment about the solutions provided.
Service	To create a service engineering function.	To support the PSSs design following a service process perspective and promulgating their integration with the product development function.
	To perform a consistent training to operators.	To conduct specific services (e.g. installation, testing, etc.)

5 Conclusions

Through the conduction of a single case study, this paper provided a practical evidence of what should be implemented in a manufacturing company that internally realizes the need of implementing a transition of its business model from a pure product-based towards a digital servitized one. Therefore, Company A was selected, a B2B ETO company developing and producing machineries for the decoration of plastic objects and containers. A strategic analysis of the company was performed inter-

viewing several employees covering the majority of the roles involved in the digital servitization transition of the organization (from the technical director, through both electronic and mechanical departments, up to sales, customer care and export manager) with the aim of grasping their different perspectives related to the business model shift feasibility. Four main areas of investigation of the digital transition (*Triggers, Customer requirements and value analysis, Changes implemented, Investments and risks*) were detected and investigated through the definition of an interview's protocol.

As a result, Company A has been assessed evaluating the criticalities occurring inside each of its division. The analysis led to formulate and provide several managerial guidelines to the company to cope with the risks occurring along the digital transition path. In addition, an analysis of the Company A's extant product portfolio was performed to detect a pilot case, based on products' physical characteristics and functional properties. Machine 1 (Screen Printing) was selected. Its future analysis, up to the level of the individual critical components, will lead the experimentation in Company A towards a digital servitization business model transition.

Indeed, based on the guidelines provided with this strategic analysis, several activities have been planned to be implemented in the Company A on Machine 1 (Screen Printing) to push forward this research. First of all, after decomposing the machine in all its components based on its bill of material, a FMECA analysis will be implemented to detect the main failure causes on the machine and to detect the most critical components. Once prioritized, each component will be analysed to evaluate which sensors could be embedded to improve its monitoring and control functionalities. Per each of these possible actions to be implemented, the requirements of the needed data should be defined (description of the type of data required, detection frequency, unit of measure of the detection, standard interface to be used, warning and fault range settings, rules to be used to implement the related control, difficulty/cost of the intervention). Furthermore, a set of performance measurement of machines (e.g. Overall Equipment Effectiveness (OEE)) will be developed and used to be able to associate the possible tracked and monitored losses of times due to the failures analysed before, with the specific components of the OEE (i.e. availability, performance and quality). Last, to enable the actual implementation of all these previous actions on the machine, allowing the gathering of the tracked data coming from the machines' operation, a database, and a cloud platform (hardware and software architecture) will be implemented. A sensor ontology, proposed in literature by [23] as a part of common knowledge repository, can support the conduction of this method, also fostering the semantic interoperability between involved actors and tools and providing engineers the necessary knowledge to reuse facilities during the IPSS design.

In addition, it has also to be highlighted what is really lacking in literature in the field of digital servitization methodologies. Indeed, several research projects, as ICP4Life [24] and DIVERSITY [19], proposed a real PLM approach for PSS systems but the extant state of practice in the domain is still far to present a consolidated adoption of such methods, tools, and platforms. The authors think that if manufacturing companies, like Company A, are able to follow the steps proposed in this paper, then

the adoption of such systems will be eased, also facilitating the management of smart PSS along their entire lifecycle.

Finally, this research is not free from limitations since it is based on qualitative analysis, and it is applied on one single application case. After the completion of this first case, the entire research method (involving also the next steps to be conducted in Company A) will be integrated in a unique methodology to be then applied in a systematized way in other companies willing to pursue the digital servitization transition.

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