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THE WAY TOWARD DIGITAL TRANSFORMATION IN ITALIAN SMEs. PROCESS DIGITALISATION AND PRODUCT DIGITALISATION: AN ITALIAN MANUFACTURING COMPANY CASE STUDY

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*"Punta sempre oltre le stelle in tutto ciò che pensi o che fai,
qualora fossi sfortunato e non riuscissi a raggiungere il tuo obiettivo,
potresti comunque centrarne una"*

- me stesso -

Abstract

According to European Investment Bank, 2021, as in other EU countries, Italian small and medium-sized enterprises (SMEs) have a pivotal role in the economy. There are about 4.3 million SMEs in Italy, 95% of which are micro-enterprises. They account for 80% of employment and 70% of value added. Their contribution to exports is larger than in other EU countries: 53% of exports in Italy vs. an EU average of 40%, and 25% in both France and Germany.

The productivity of Italian SMEs appears to be lower than the EU average and its closest peers (France and Germany). While part of that gap might be linked to different sectoral mixes, most of the difference in productivity remains unexplained. While there is also a regional divide, even Italy's best performing regions have a significant productivity gap compared to the rest of Europe.

According to several European metrics, the level of digitalisation of Italian SMEs is lower than in other countries. The lower level of digitalisation of Italian SMEs may play a crucial role. Given its relevance, the digitalisation of Italian SMEs is high on the Italian government's agenda.

The aim of this research work is to contribute in closing the knowledge gap that limits the ability of Italian SMEs to adopt digital solutions to improve their performances. The research activity has been focused on developing a simple guideline for practitioners with real examples through the case study of an Italian manufacturing small-medium enterprise and the related relevant results.

The present research work is structured starting from a question became recurring to the author: how to create value?
It is author's belief that in modern companies, value is created by means of the thoughtful integration between two important philosophies, Lean Six Sigma and Industry 4.0, respectively focusing on waste reduction, process-stability and digitalisation to further empower businesses.

The research starts with a literature review concerning the tools to understand business processes, diving deep in a recently studied tool called Makigami, that seems to be incredibly useful for transactional processes in particular, due to its flexibility and adaptability to particular cases as practitioners need.

Then, a complete overview of all the business processes is made in order to deeply understand their strengths and weaknesses and to have a clear vision about wastes and key-performance indicators to improve business.
After a careful analysis, criticalities are shown and discussed, and processes are re-engineered, using the same tool to continue having a clear vision on developments and improvements.

During the re-engineering of business processes, the author has interpreted and adapted digitalisation to the specific case study: both processes and business products have been digitalised, showing tools and the ancillary Lean-Six-Sigma activities needed in order to guarantee top performances and strong basis to evolve into a 4.0 company.

Finally, the outstanding results on business are shown and discussed and author proposes a generalisation of the procedure used, in order to provide with a simple guideline for practitioners and suggestions for further research.

Preface

I graduated *cum laude* in Mechanical Engineering (master's degree) at the University of Ferrara in July 2018. I characterised my engineering studies with some elements belonging to Industrial management and Economics in order to find synergies with the solid technical background.
During the graduation period I was hired by CT Pack, the company in which I worked as Program Manager and Business Process Engineer. Immediately, CT Pack and I decided to prepare a subject study useful for the company, that has been accepted by the University of Ferrara as a PhD project in collaboration with CT Pack, under the supervision of Professor E. Mucchi and Professor A. Chiarini.
The industrial doctorate in Engineering Science that I developed in these three years reinforces the existing exquisite collaboration between the academic environment and the industrial one of Ferrara, fundamental fact for transferring knowledge and advanced technical skills from the University to the society.

In the first year of my PhD, I have been involved in studying a methodology to streamline and map business transactional processes.
In particular, an innovative mapping tool oriented to transactional processes has been studied in depth. This led to a contribution to the exiguous literature on this matter, by two publications, consisting of a conference paper [1] and a journal paper [2].

[1] Gabberi, P., Chiarini, A. "In search of new tools for improving transactional processes. A manufacturing case study". Sinergie-SIMA 2020 Conference, Referred Electronic Conference Proceeding, Grand challenges: companies and universities working for a better society. 25-26 June 2020 University of Pisa – Sant'Anna School of Advanced Studies (Italy).

[2] Chiarini, A., Gabberi, P. (2020). Comparing the VSM and the Makigami tools in a transactional office environment: exploratory research from an Italian manufacturing company. *Total Quality Management & Business Excellence*.

From the second year, my studies focused on introducing digitalisation in the company: a variety of projects have been defined, studied, and implemented starting from standardisation and modularisation of products, through a completely revised cost management, introduction of new products to the market, introduction of new tools in the company and new features in products, embracing digital transformation. This work led to interesting considerations about digitalisation in SMEs, aiming to contribute to the scarce literature on the matter of digital transformation and to provide with a detailed case study as a general guideline that could help practitioners.

This brief summary regarding the work I carried out in the last three years leads me to express sincere gratitude to CT Pack S.r.l., in particular to F. Cocchi and G. Cocchi for having invested in my potentialities. A special thank goes to my advisors, Prof. E. Mucchi, and Prof. A. Chiarini, for the help and the time they dedicated to me throughout this experience.

Contents

1. Introduction

How to create value?
This is the main question I have thought about before starting the work contained, and summarised to some extents, in this thesis.
I have focused all my efforts for the last years on trying to answer to this question and provide with evidence that proved that waste reduction and digitalisation are the two most impacting factors on which a company should work in order to create value nowadays.
Please, do not misrepresent what I am sentencing: a good product or service is a must have for a modern company in order to develop its business, however, in the global market where we live every day, we fight with skilled competitors from all over the world with comparable products or services, so it is the chance to create value that tips the balance in favour of floridity instead of struggles.

This thesis work's aim is, indeed, to show how value can be created in a company focusing the efforts and the middle period strategy on waste reduction and digitalisation, by means of a case study that involves an Italian manufacturing SME: CT Pack.
It is author's belief that the process followed in this case study could be generalised and repeated for any SME interested, with small adaptation to the specific case.

In order to better understand the following contents, it is fundamental to introduce some more concepts: in particular, what is intended with digitalisation and what is CT Pack, the subject of this case study.

Digitalisation is a word became very common in business environment with the introduction of the concept of Industry 4.0, to streamline the variety of work done on processes and products that are behind cyber-physical systems.
Industry 4.0 is a trend of Industrial Automation that gather some technologies to improve working conditions and increase productivity and quality of plants.
Industry 4.0 defines its being through the concept of "smart factory" built by the combination and the integration of the following three elements:

1. Smart production: new manufacturing technologies that bring collaboration between all the elements of manufacturing, as operators, machineries and informatic tools.
2. Smart services: informatic infrastructures and technologies that allow to integrate systems and processes, all the infrastructures that allow, in a collaborative way, to digitalise and integrate companies between themselves and with external infrastructures (suppliers, customers, employees, institutions, environment).
3. Smart energy: care about energy consumption, sustainability, ecology, green economy, building more and more performant systems and eliminating waste.

The focal point of Industry 4.0 are indeed cyber-physical systems, so physical systems perfectly connected with the informatic ones, digitalised indeed, that can interact and collaborate with other cyber-physical systems.

In this thesis work the focus is mainly on the first two elements of Industry 4.0 reported above.

As far as CT Pack is concerned, the company is essentially the realisation of an ambitious thought: to bring a complete packaging system to the market, a perfectly integrated process that did not need anything else.

Figure 1: CT Pack's logo.

CT Pack was founded by Mr. Gino Cocchi at the beginning of the new millennium with the aim of creating a leading company in the food packaging sector.
To pursue this ambitious project, the first step was the acquisition of three companies, Mopa, Otem and Vortex Systems, which could boast the experience of world leaders in their sector, to implement as a second step an integration process that would lead to the possibility, and opportunity, of propose a new concept to the market, that is, fully integrated, customised, turnkey packaging systems.
Certainly, an atypical birth, but which brought a particularly innovative concept to the international market for those years, namely the possibility for the customers to substantially buy a complete, integrated and totally customised system, for a part of their plant, from the end of the internal production process to the complete boxing for shipping or storage.

Figure 2: logos of companies merged in CT Pack.

Founded in 1971, Mopa is specialised in the design and creation of feeding systems for delicate products that must be transported to buffers, small warehouses within the production line, and to high-performance packaging lines.
Mopa has experience and a presence on the market worldwide, with over 500 units installed in the five continents.
This makes Mopa one of the most qualified and constantly updated companies in the food sector.

The main products of Mopa are:

- Feeding systems for flows of envelopes and innovative systems to feed one or more flow-wrapper machines: these systems are mainly suitable for products such as chocolate bars, sweets, biscuits, chocolates and are equipped with recirculation stations to reuse products not taken from the envelopes flow and buffer stations to temporarily manage excessive flows of products.
- Product aligners: machines for aligning and sliding small products of different shapes (round, square, rectangular) in order to arrange them in a single line, such as to feed flow-wrapper machines at high speed.
  Initially products arrive in a more or less random way from their production process, on approach belts, then a series of belts and devices that work at different speeds ensuring the correct positioning of the product.
  Only motorised belts are used at this stage of the process, as fixed or vertical guides can damage delicate products.

All the systems can be customised according to customer needs.

Otem was founded in 1958 as a branch of a leading Italian company in the ice cream sector.
The company initially specialised in the production of ice cream flow-wrapper machines and is now a leader in other high-speed applications as well.
In 1965, Otem designed a semi-automatic feeding system for wrapping machines, which allowed it to enjoy constant growth, successfully selling wrappers all over the world, satisfying the demand of the most diverse industries.
In the 1970s and 1980s, Otem became a world leader in the ice cream and high-speed packaging sector and today boasts more than 5,000 units installed in global markets.
The main products of Otem are a wide range of automatic wrapping machines, successfully used for a variety of different products: from frozen pizzas to chocolate bars, from food products to pharmaceutical and cosmetic products.
Otem machines represent the best solution in terms of reliability, high capacity and safety and meet the highest standards of quality and hygiene.
Horizontal packaging machines, even with multiple lanes, are designed and customised according to customer needs, meet the standards of medium and high production capacity and simultaneously manage a wide range of different products (solutions up to 12 lanes are available).

Finally, Vortex Systems, founded in 1967, brings its experience in high-speed handling, boxing and cartoning systems for different types of products.
The company is confirmed as a leader thanks to innovative end-of-line, mainly composed of robot manipulators with two, three, four and six controlled axes, for the management of large production volumes of different types of products in the food and non-food sector.

The strategic and industrial design of CT Pack is therefore based on the union of the best Italian experiences in the fields mentioned above, in order to offer its customers fully integrated packaging lines, designed and built by a single team of people with multidisciplinary skills.

CT Pack is a possible response to the new needs of the market, since it has gathered know-how and skills for all the machines that make up a packaging line, which are designed and built entirely by the various company divisions.

Figure 3: Representation of CT Pack's core business.

In addition to the evident synergistic advantages due to the union of three companies into one, customers can appreciate the after-sales assistance structure offered by a single company division, which takes care of the machines produced by the three divisions, proposing itself as a single interlocutor, hence simplifying the relationships.

However, the merger of the three companies has safeguarded one of the prerogatives that have made Mopa, Otem and Vortex Systems famous in the world: customised design based on customer specifications.
Not only CT Pack does offer itself to the market with a standard product catalogue, but also is mostly aimed at customers looking for customised packaging solutions, often carrying out ad hoc projects.

CT Pack belongs to Aretè&Cocchi Technology Group, an industrial holding characterised by the distinctive element that is common to all the companies of this group: innovation & technology at the state of art, in each of the sectors into which the group operates.

Now that premises and the company have been briefly framed, the path related to the development of this thesis work can be better understood.

In order to create value by digitalisation and waste reduction, the main purpose of the work done in CT Pack in these years, the first step to take was to understand how the company worked, what were the processes, the procedures and the interactions between departments.
With this target clear in mind the mapping activities started: as a first step the most suitable tool to develop the project was researched and studied.

Literature provides with a variety of materials, tools and methodologies concerning manufacturing processes' mapping activity, the Value Stream Map (VSM) is the well-known example. However, almost nothing was existing in literature related to transactional processes, so it was decided to elaborate on a recent concept related to the lean thinking and apparently perfect for the purpose: the Japanese-born Makigami.
This tool offered the chance to investigate and to study in depth something oriented to company's needs, since most of the processes are transactional.
By means of this research, the first step of the whole project, not only have Chiarini and Gabberi (2020) found a valuable tool for the project, but also they contributed to the literature putting the spotlight on something that, even more in these years, will be useful for many practitioners dedicated to digitalisation and waste reduction.

Chosen the mapping tool, a first global map was drawn, without a high level of detail, just in order to have the big picture of the puzzle to be developed.
Then, a detailed map (as-is state) was created for each department, where all the transactions, all the interactions and all the possible failures were clearly visible. The possibility to chase time by time the level of detail for each process is indeed one of the valuable features of the researched mapping tool Makigami highlighted by Chiarini and Gabberi (2020).
From the so called as-is--state Makigamis, each one with its indicators and notes, criticalities have been outlined and investigated to clarify the situation of the company and to suggest possible improvements.
Therefore, a huge work in terms of dialogue, investigation and design have been developed with the managers of the company in order to define the new shape of

business processes: all the detailed future-state maps considering the possibility of digitalisation as recommended to streamline flows.

In the meantime, a variety of strategic initiatives started and have been carried on in different areas of the business: product standardisation and new products cost management for pricelist were the main ones. Then, even more digital features to products have been studied and implemented, including a brand-new family of horizontal continuous-motion cartoner machines, a new flow-wrapper machine, smart products and smart services.

Finally, synergies related to all these actions together had, and currently have, an outstanding positive impact on business, as explained in Results and conclusions.

It is author belief that the original contribution of this thesis, over and above the definition of a new mapping tool for transactional processes, resides in a streamlined procedure created by tangible examples of the case study, that could help practitioners in introducing digital transformation in SMEs. Literature is indeed a bit confusing, and some contributions are too specific in one particular subject at time to be generic and helpful for the variety of companies and the complexity of a whole organisation.

The relevance of this research work, focused on Italian SMEs, is highlighted by the fact that although European initiatives are inclusive and aimed at multiple actors, there are still many differences in the state of digitalisation between the various Member States; one of the most well-known synthetic indicators is the DESI (Digital Economy and Society Index), calculated annually for each State of the European Union based on five factors: connectivity, human capital, use of Internet services, integration of digital technologies, digital public services. In 2018 Italy was in 24th position out of 27, whereas in 2021 20th out of 27, definitely far from the leading countries (Denmark, Sweden, Finland and the Netherlands) but also from the EU average, where the skills of human capital and the use of services Internet represent the areas of greatest weakness of the Italian system (European Commission, 2018, 2021).

Moreover, a research conducted by Brancati and Maresca in 2017-2018 confirms the greater propensity of large companies compared to SMEs to use the enabling technologies of the Fourth Industrial Revolution, in fact, in 2017 approximately 8.4% of Italian companies used at least one 4.0 technology, but the variability of adoption between micro (6.0%), small (18.4%), medium (35.5%) and large enterprises (47.1%) is very marked. Furthermore, large companies, in addition to being more inclined to activate innovative initiatives, make use of several technologies at the same time to exploit the synergies connected to these technologies (Brancati and Maresca, 2018).

This work after all shows in a simple way the methodology followed in a manufacturing environment for each of the themes developed, paying particular attention to transactional processes, in order to address the company (and covering matters that belong to almost the totality of the organisation’s structures) toward digital transformation and Industry 4.0.

Characteristics of the processes and projects implemented are common in general between the majority of the SMEs and, by means of this thesis considered as a general guideline support, author aims to contribute to organise practitioners' ideas and to propel digital transformation in any companies that could have been discouraged by the extent of the change and the necessary commitment.

This work, following author's opinion, provide with a global view of problems and action taken in an Italian SME, the perfect candidate for the aim of the research since it involves both manufacturing processes and transactional processes, that works both with completely customised products and standardised ones and offers a variety of cases, ideas and improvements belonging to all the department existing in the majority of companies (making easier the generalisation of the procedure), with the target of value creation by means of waste reduction, lean organisation and digitalisation.

2. Literature review

The pioneering proponents of the factory of the future found early on that inflexible and dedicated production lines should be exchanged with flexible machines and that computers will support this endeavour (Diebold 1952; Freeman 1988). The idea of an interconnected world has gained attention from the industry sector, and the vision of a fourth industrial revolution is emerging, popularly known as Industry 4.0 (Kang et al. 2016).

Starting out as a German government programme to increase the competitiveness of their manufacturing industry (Kagermann et al. 2013), Industry 4.0 was announced at the Hannover Messe in 2011 (Drath and Horch 2014). It is a cooperation project between the private sector, academia and the government (Kang et al. 2016), and it revolves around 'networks of manufacturing resources (manufacturing machinery, robots, conveyor and warehousing systems and production facilities) that are autonomous, capable of controlling themselves in response to different situations, self-configuring, knowledge-based, sensor-equipped and spatially dispersed and that also incorporate the relevant planning and management systems' (Kagermann et al. 2013). However, with time, the term Industry 4.0 has evolved into an overall label for describing the next era of manufacturing, and in this process, it has become a poorly defined buzzword for the future of production. Even though Industry 4.0 is one of the most frequently discussed topics among practitioners and academics in the last few years, no clear definition of the concept has been established; therefore, no generally accepted understanding of Industry 4.0 has yet been published (Brettel et al. 2014; Hermann et al. 2016; Rüttimann and Stöckli 2016; Hofmann and Rüsch 2017). Researchers and practitioners have different opinions regarding which elements compose Industry 4.0, how these elements relate to each other and where Industry 4.0 is applicable. Surveys show that few practitioners are able to provide a concrete definition of Industry 4.0 (Heng 2014). Some even claim that Industry 4.0 does not bring something new, that it merely combines existing technologies and concepts into a new package with a catchy marketing name (Drath and Horch 2014). This ambiguity and lack of a clear definition will lead to communication difficulties and complicate research and education on the subject (Pettersen 2009), as well as make it more difficult for companies to identify and implement Industry 4.0 solutions (Hermann et al. 2016). Recent studies have found more than 100 different definitions of Industry 4.0 (Moeuf et al. 2017). Thus, it is important to clarify the definition used to ensure construct validity. Similar to Liao et al. (2017), the relevant literature must be related to Internet of Things, smart factories, or digitalisation.

The fourth industrial revolution promises to change the manufacturing landscape, and those who are not able to reap the new technology-induced opportunities are destined to fall behind their competitors. An important area to investigate is the role lean manufacturing will play in this new industrial era. Buer et al. (2020) has surveyed the use of a number of emerging digital technologies as well as established lean manufacturing practices to investigate their relationship with operational performance in manufacturing. That study identified a strong correlation between users of digital technologies and lean manufacturing practices, suggesting compatibility between the two domains. Both factory digitalisation and lean manufacturing practices were significant positive predictors of the level of operational performance. Furthermore, it was shown that their concurrent use yields even larger performance benefits, suggesting a synergistic relationship between the two domains regarding their impact on operational performance.

Ohno (1988) describes the two pillars needed to support the Toyota Production System: just-in-time (JIT) and autonomation (jidoka). These pillars are also found in lean manufacturing (Bicheno and Holweg 2009). To successfully implement JIT, accurate and timely information sharing is a prerequisite (Haynes, Helms, and Boothe 1991; Zelbst et al. 2014). Accurate inventory data are especially important in lean supply chains because large buffers and safety stocks are eliminated. A digitalised supply chain will support this by providing timely and accurate data about inventory levels and location (Zelbst et al. 2014). Autonomation is about giving intelligence to the machines so that they autonomously can distinguish between normal and abnormal operations. Therefore, machines will stop if there is a problem, so no defective products are produced (Ohno 1988). The implementation of cyber-physical systems (CPS) in production gives machines intelligence and thereby facilitates autonomation. The machines will be able to report deviations faster, analyse the causes and initiate measures automatically (Thoben et al. 2014).

Roy, Mittag, and Baumeister (2015) argue that the introduction of Industry 4.0 does not eliminate lean manufacturing but rather helps to increase the maturity of the firm's lean programme. Rüttimann and Stöckli (2016) predict that Industry 4.0 will materialise in pieces that have to be integrated into existing lean frameworks and will eventually increase the flexibility of lean manufacturing. The term lean automation slowly gained popularity throughout the 1990s, and it concerns developing automation solutions with a low level of complexity that fits lean production environments (Jackson et al. 2011). The new possibilities enabled by Industry 4.0 have reignited some of the research within this field (Kolberg and Zühlke 2015; Kolberg, Knobloch, and Zühlke 2017).

Lean manufacturing focuses on eliminating all kinds of waste in the production process by identifying any unnecessary activities, streamlining the process, and creating standardised routines. Simple machines and workstations with low levels of complexity facilitate automation and digitalisation of the manufacturing process (Kolberg and Zühlke 2015). Lean manufacturing also emphasises visual control and transparency, which makes it easier to identify problems in the process. This has led to some researchers claiming that a lean implementation necessarily must be seen as a prerequisite for a successful Industry 4.0 transformation (Kaspar and Schneider 2015; Staufen AG 2016).

2.1 An innovative tool for mapping transactional processes: Makigami

Companies must continually redefine and redesign their processes to manage the competitiveness demanded by the challenges of current markets (European Commission 2004). As a result, it is necessary to have practical tools that support the redesigning process for manufacturing companies (Marchwinski 2004). Lean manufacturing and total quality management (TQM) have introduced several tools and principles that have rapidly spread to all types of industries. A variety of companies have experienced advantages from applying lean and TQM in their processes to reduce waste and increase customer satisfaction (Poppendieck 2002; Gaio et al. 2018; Hines et al. 2018). Many companies that have implemented lean and TQM belong to the manufacturing sector; however, lean and TQM principles are also applied in office-based functional areas, such as design, research and development, supply chain management, administration and customer service (Chen and Cox 2012; Lins et al. 2019).

Lean is a systematic approach for identifying and eliminating waste through continuous improvement. One of the key stages in lean implementation is the identification of non-value-added steps (Rother and Shook 1998). To achieve that aim, the lean manufacturing movement has developed the value stream mapping (VSM) tool specifically for analysing and measuring process performance with a lean vision (Womack and Jones 1996). To date, many cases have highlighted the success of the tool's application, rather than considering the practical difficulties the practitioners experienced or how to obtain maximum effectiveness from the VSM tool in different environments (Lasa et al. 2008). For instance, according to some authors (Chen and Cox 2012; Chiarini 2013), the tool can also be used in a transactional office environment, yet with some difficulties.

Office waste is difficult to define, with this study's literature review revealing poor results in terms of mapping the office environment, which causes practitioners and academics to struggle to achieve this mapping (Chiarini 2013). Although some office project case studies have been documented by practitioners and consultants, a systematic procedure to map the transactional office process has not been thoroughly analysed (Chen and Cox 2012). As such, the purpose of this paper is to demonstrate that a specific mapping tool—Makigami—is a helpful and meaningful mapping tool for transactional processes to evaluate non-value-added activities and other process performance. According to Chiarini and Gabberi (2020), the research explores the benefits and pitfalls of the tool and compares it with the well-known VSM. For the comparison, the research analyses a case study in the company in which both mapping tools have been implemented for the same process in the technical department.

In this section, the origins of the Makigami tool are traced back and the need for the process mapping proposed by TQM and lean are analysed.

TQM is essentially a method of planning, organising, and placing customers as the focal point of operations. Its aim is to continuously improve process performance to satisfy customer requirements (Bennis 1992; Sinha and Dhall 2018; Letti Souza et al. 2019). At the centre of TQM is the concept of process management (Zhang et al.

2018) and the existence of internal suppliers and customers within organisations (Oakland and Morris 2013). The functional areas of the company must be properly integrated with each other through understanding the importance of cross-functional processes (Oakland and Morris 2013).

Although the TQM movement has always recognised the importance of process management (Senge 1990; Ishiwata 1991; Deming 1993; Oakland and Morris 2013), there are no specific tools for mapping a process, and the majority of the tools employed have been borrowed from general business management. In this manner, tools such as data flow diagrams, activity diagrams, event-driven process chains, and swim-lane diagrams, to mention a few, can be found in TQM implementations (Rumbaugh et al. 1999; Van der Aalst, 1999; Zhu et al. 2002).

An interesting and structured tool used for process mapping in TQM is the cross-functional process map known as the swim-lane diagram (Ramias and Rummler 2009). Swim-lane diagrams differ from other diagrams in that they denote actor roles for the modelled workflow, assign tasks to specific actors, describe the order of tasks, and include conditions to determine which task comes next if multiple tasks are available. Rummler and Brache (1999) stated that the swim-lane diagram has become the primary modelling tool for planning business process reengineering (BPR) and company-wide software development (Hammer and Champy 1993; Davenport 1993). Rummler and Brache thoroughly studied this mapping tool, and swim-lane diagrams are also referred to as the Rummler and Brache diagram (Harmon 2009). According to Ramias and Rummler (2009) and Aldin and de Cesare (2011), the swim-lane diagram is a sequence of internal activities that may be performed by an organization to achieve an output of value. The swim-lane diagram also enables the visual depiction of activities and has been included in major business process modelling languages, such as Business Process Modelling and Notation (BPMN) (Bera 2012) and the Unified Modelling Language (Rumbaugh et al. 1999).

The defining characteristic of the swim-lane diagram is that each actor (sometimes identified with a single departmental/office) involved in a business process is shown in a separate swim-lane, and all activities belonging to the actors are positioned in the respective swim-lanes. The swim-lanes may be oriented vertically or horizontally, as necessary. The actors placed in each swim-lane may depend on the specific business process and the level at which the process needs to be defined. The sequencing of activities is conveyed using arrows, which typically connect the activities, so that the entire business process may be traced from a starting activity to an ending activity (Bera 2012), and the diagram may optionally depict time delays between activities. Given that business processes are generally cross-functional (Ould 1995), swim-lane diagrams typically contain actors from several departments (Rummler and Priest 2009)

The BPR movement particularly supported this tool, as it is based on the measurement and analysis of quantitative data (Hammer 1990) and various possible standardised languages that render the tool more practical and useful (Baudin 2002). Moreover, BPR introduced a new approach to the management of processes, producing radical improvements in performance (Hammer 1990; Davenport 1993), rather than a more gradual improvement approach, as with lean and TQM (Davenport 1993; Jaworski and Kohli 1993). Davenport (1993) suggested that, in

TQM, there is also a need to undertake process analysis via techniques of process visualisation and process mapping study to identify which process should be reengineered and which should be managed on the basis of continuous improvement. Davenport also suggested employing in TQM environments visual tools from BPR, while Harmon (2009) discussed introducing the swim-lane diagram to map transactional processes, which can be improved through lean solutions.

The lean movement created a particular approach to mapping processes called VSM, with the main aim of identifying waste in processes and designing an improved future state to be reached (Rother and Shook 1998). The use of waste removal and process improvement to drive competitive advantage inside organizations was pioneered by Toyota's manager, Taiichi Ohno (1988), and Shigeo Shingo (Japan Management Association 1985; Shingo 1989) and is oriented fundamentally toward achieving continuous improvement step-by-step via a systematic attack on waste.

According to Hines and Rich (1997), there are five stages involved in VSM adoption:

1. studying the flow of processes
2. identifying waste
3. considering whether the process can be rearranged in a more efficient sequence
4. considering a better flow pattern, involving a different flow layout or transport routing
5. considering whether everything being done at each stage is really necessary, and what would happen if superfluous tasks were removed.

In regard to VSM development, according to the well-known and quoted VSM book written by Rother and Shook (1998), the process is based on five stages that are implemented by a special team created for that purpose. The stages are:

1. selecting a product family
2. mapping the current state
3. mapping the future state
4. defining a working plan
5. achieving the working plan.

The VSM is based on peculiar symbols and uses a graphical interface in which it is easy to see the relationship between processes and information flows. Figure 5 presents an example from our case study dedicated to the technical department. The VSM is divided into three parts. The upper part is the information flow, where, for example, we can find information concerning how the company receives and plans orders. The middle part is the physical flow of the products or data, in the case of office departments. The lower part is the timeline for calculating cycle/process times and lead time.

According to Rother and Shook (1998), the steps for drawing a VSM usually are:

- a first view of the map showing the customer and its orders in terms of quantity per period
- a second view of the map with all processes, data boxes and inventory triangles amongst processes. In this step it is important to draw the processes

from left to right where on the left of the map we have the incoming products from suppliers and on the right the shipped final products to the customer. In the data set of each process data such as cycle time, change-over, number of people required to operate the process, uptime, working time, scrap rate, etc. can be inserted

- a third view showing the complete material flow
- a fourth view with information flow and push arrows. Specifically, the information flow represents the upper part of the map where we deal with how the shop floor and suppliers have been scheduled
- complete the map with the lead time and cycle time bars and overall data in the lower part.

Referring to more specialised papers (Rother and Shook 1998; Dinis-Carvalho et al. 2015), it is easy to understand that the VSM introduces a common language for the team and clearly indicates the organisational situation in terms of how processes link to each other, waste, lead time calculation, and production scheduling. For instance, in Figure 5, the current situation indicates a particularly long lead time because of several inventories or works-in-process (WIPs), identified by yellow triangles, and some not well-synchronized processes. The latter are identified through rectangles with a data-box for data such as cycle time or process time, quality, and setup time.

The VSM was invented mainly to map material flow on the shop floor, from incoming to shipping, where WIPs usually comprise physical products waiting for a specific production process. In the particular case study (Chiarini and Gabberi 2020) in Figure 5, WIPs are instead formed by a backlog of technical documents to be processed using computers and software. Some authors have considered the use of VSM in a typical transactional office environment. Keyte and Locher (2004), in a dedicated book, used VSM to improve administrative processes. This book for practitioners offers several case studies; however, the discussed office VSM seems to analyse processes from a bird's eye perspective, without going deeper into the process details and activities. Similar conclusions were reached when reviewing a paper in which VSM was used to improve the flow of supplier orders (Chen and Cox 2012) and another paper in which VSM was implemented into healthcare for the Brazilian army (da Silva et al. 2016).

VSM received also some criticisms, in particular when it comes to identify and measure waste inside the drawn map. As a consequence, some authors (Dinis-Carvalho et al., 2015; Dinis-Carvalho et al. 2019) proposed more customized and dedicated kinds of diagrams for waste identification.

Sabur and Simatupang, (2015) analysed a case study in a vaccine company that sought to reduce customer response time. The improvements were based on process mapping through the VSM. However, to more deeply analyse the process flow, the authors had to use different mapping tools similar to a swim-lane diagram. Chiarini and Gabberi (2020) found a similar approach in Tapping and Shuker (2018), who wrote a book proposing eight steps for implementing a lean office approach in administrative processes, using VSM as well. Other authors (Stadnicka and Ratnayake 2015) researched the VSM in business transactional processes such as the quotation preparation process concluding that the VSM could be used with no limitations even in a transactional environment.

Directly linked with the lean Japanese theory of waste removal and the transactional process mapping approach of the swim-lane, the literature presents another structured and interesting tool: Makigami. Makigami tends to be analysed and studied by practitioners and consultants, rather than academics. The first evidence of this particular mapping tool for transactional processes can be found in the healthcare system. Kuo et al. (2011) claimed that, although Makigami is very powerful for identifying waste in processes, it is not a traditional lean–TQM tool, and could be derived from the aforementioned BPR swim-lane. The authors claimed that Makigami can be viewed as a type of integration of lean VSM (to eliminate waste and introduce continuous improvement) with BPR metrics-based flow (to measure and reengineer processes).

According to Aij et al. (2014), Makigami is developed during a dedicated kaizen event, similar in its steps to VSM mapping, where a team deeply analyses activity after activity in the process flow, and eventually subdivides them further and highlights process metrics. Aij et al. (2014) demonstrated this particular use of the tool to map operating theatre processes, while Kuo et al. (2011) employed it in the same way to improve the post-anaesthesia care unit workflow.

Chiarini (2013) wrote a chapter that analysed the implementation of Makigami for the manufacturing sector. According to the author, the tool can be used as a magnifying glass for parts of manufacturing transactional processes, as well as for pure service processes. The author highlighted the possibility of using typical lean indicators, such as process time, lead time, and number of value-added activities, alongside more personalised indicators, such as the quality of the transaction and headcount–equivalent.

According to Kuo et al. (2011) and Chiarini (2013), Makigami can be implemented following defined steps which are:

- identifying the process and its boundaries
- breaking up the process into activities
- identifying the stakeholders or who is in charge of the activities
- measuring activity performance such as process time, lead time, headcount equivalent, etc.

Ultimately, the results from this literature review indicate how the lean and TQM movements have always coped with the need for process mapping. The lean movement has a specific process mapping process, named VSM, which is more related to the entire production flow, from incoming raw materials to the finished product shipping. However, the literature offers some case studies of VSM applications in office and service environments. In the 1990s, the BPR movement introduced a more detailed approach for analysing processes and activities, named swim-lane, which is also used in TQM implementation. The swim-lane approach seems in some ways connected with the more recent Makigami approach, which tends to be more focused and detailed in terms of activities inside processes and their connections. Makigami is transactional focused by nature and can use personalized metrics to measure the achieved improvements.

The literature review findings enabled Chiarini and Gabberi's (2020) study to establish research questions, which were analysed and discussed through the case study. These questions were as follows:

RQ1 – What are the main differences between the VSM and Makigami when both are used in a transactional office environment?
RQ2 – Are the VSM and Makigami useful in a transactional office environment or are they simply alternatives to each other?
RQ3 – Under what circumstances can the VSM and Makigami be combined for mapping processes?

To answer research questions, the adopted methodology was based on an exploratory case study (Eisenhardt 1989; Gammelgaard 2017). McCutcheon and Meredith (1993) emphasised that case research is particularly suitable for developing new theories and ideas and can be used for further theory testing. Many of the breakthrough concepts and theories in operations management, including TQM and lean, have been developed through field case research (Voss et al. 2002).

Chiarini and Gabberi's (2020) study gathered information through direct observation of the mapping tool implementation (specifically the Makigami) and through a semi-structured questionnaire concerning VSM and Makigami.
Table 1 displays the open questions from the semi-structured questionnaire.

The gathered information from the direct observation of the Makigami implementation and from the interviews was organised based on how it related to the central research questions (Bowen 2009). Content analysis was then used as a first review of the collected notes (Bowen 2009). In this manner, it was possible to identify thematic groups and similarities in the notes and answers and avoid suggestions and discussions not relevant to the central research questions. In this stage codes for the further thematic analysis emerged. According to Bowen (2009), thematic analysis can be considered a form of pattern recognition in the text. This analysis provides emerging themes and categorises them; it includes focused reading of information, as well as coding and category statements (Bowen 2009). For doing this, firstly Chiarini and Gabberi (2020) transcribed the interviews and the memoire of the direct observation into word files and then we used a visual basic macro which allows extracting from text sentences and themes connected with defined codes. For instance, the defined codes were: data, performance, indicator, measurement, improvement, difference, limitation, team, involvement, commitment, responsibility, training difficulty, pitfall, future state, etc.

Figure 4 recaps, from a graphical point of view the employed methods for the research.

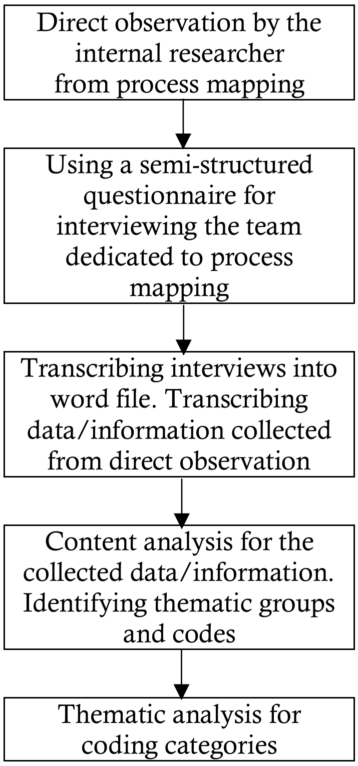


Figure 4: The employed methods and the research flow

Table 1: Open questions used for the interviews with the team members

Interview focus: VSM and Makigami implementation in a transactional office environment

Interviewer guide	*Open questions*	*Notes*
1	*When you map using the VSM, what types of data/information can you better collect and analyze?*	*Discuss what types of data and information—such as times, quality, and other performance—can be measured through the VSM.*
2	*When you map using the Makigami, what types of data/information can you better collect and analyze?*	*Discuss what types of data and information—such as times, quality, and other performance—can be measured through the Makigami.*
3	*What types of limitations have you encountered during the development of the VSM?*	*Discuss limitations in terms of waste identification and other technical aspects of the mapping tool.*

4	*What types of limitations have you encountered during the development of the Makigami?*	*Discuss limitations in terms of waste identification and other technical aspects of the mapping tool.*
5	*Have you obtained different improvements after implementing the two tools?*	*Investigate differences in terms of possible improvements identified and managed by the two tools.*
6	*Do you believe that the two mapping tools could be used together, or are they alternatives?*	*Investigate whether the two tools can be combined in some way.*
7	*Have you noticed any differences in terms of organizational implementation of the two tools?*	*Investigate difficulties and pitfalls in terms of people and manager involvement and commitment.*

The Makigami process was studied by the company and personalised to suit the main business processes linked to sales, design, procurement, testing, and commissioning. These processes are the most important for the organization in terms of value-added created. Similarly to the VSM, Makigami was adopted to examine the current state of the process and design the future state.

The employed Makigami is a sort of matrix, as presented in Figure 5, where the first column are the departments/offices, named "stakeholders" (Chiarini 2013), that take part to the process flow, while, in the following columns, the processes to be analysed are sectioned off into activities or transactions.

Each coloured cell in the centre represents the contribution of the related stakeholder to the particular activity described in the column. Some activities can be performed in parallel by different stakeholders. The development of the Makigami, column by column, starts from left to right. The company decided to use red arrows originating from a red KO symbol to identify loops where waste was hidden. For example, because of some mistakes, instead of going from Activity 4 to Activity 5, the stakeholder has to return to Activity 3 or even Activity 2 to do again something.

Once the Makigami as-is has been drawn, each activity/transaction is classified as:

- value-added
- non-value-added but necessary (e.g., mandatory by law or other regulation)
- non-value-added and not necessary: therefore, pure waste to be removed.

Japanese orientation to visual management in implementing TQM and lean (Schonberger 2014) suggests using visual tools, such as coloured cards, tags, and signals (Chiarini 2013). This study's company decided to use different coloured Post-It notes and develop the Makigami through large sheets of paper, as shown in Figure 6. To identify the non-value-added activities, the company decided to use a red emoticon icon.

Figure 5: Example of a typical Makigami

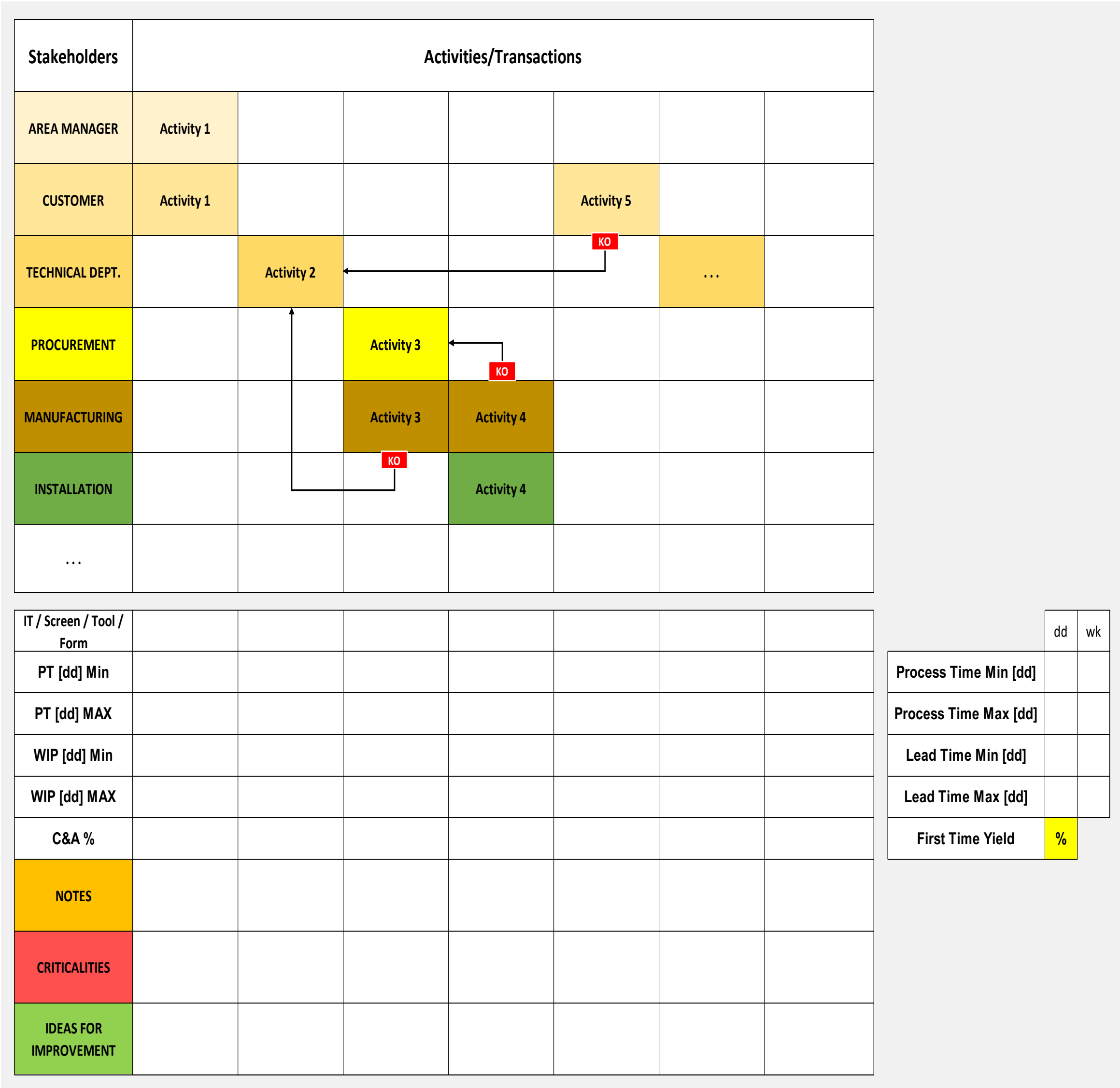


Figure 6: Visual management development of the Makigami

According to Chiarini and Gabberi (2020) the process flow between the truly value-added activities displays the critical path where optimizations and improvements can be made to reduce lead time and non-conformities/mistakes. In the lower part of the Makigami, metrics/indicators for monitoring improvement must be set depending on the goals the company wishes to meet. The company sought a time reduction in all operations processes to reduce the total lead time from the order to the installation of the automated machine at the customer plant, thereby simultaneously increasing quality and service level. Therefore, it was decided to introduce indicators, such as process time (PT), the real time spent on an activity, and lead time (LT), that sums to PT all the times plus backlogs, bottlenecks, non-conformities, duplications, and waste in general. Another important indicator is the WIP or backlog of documents, data, products to be processed, and completeness and accuracy percentage (C&A%), which contributes to calculating the first-time yield of the entire process. C&A% measures how many times activities encounter mistakes or receive incomplete information, data, files, or documentation, and how often non-conformities occur. Finally, in some Makigami processes, the headcount–equivalent indicator is introduced to evaluate how much time people dedicate to each activity. This is important to enable improved balancing of activities and tasks among staff.

Finally, the lower section of the Makigami refers to notes, criticalities, and ideas for improvement gathered from people, while the right side of the map presents overall indicators for the process, such as the total PT and LT, as well as the first-time yield. The latter takes into account the quality of each transaction/activity by multiplying all the C&A single indicators.

Makigami is developed through a specific kaizen event, where a team analyses a process stream's activity after activity in depth, and eventually divides them into sub-activities and highlights the necessary indicators and metrics. In this research's company, a team was created with specific figures to manage the Makigami process using a responsibility assignment matrix, also known as a Responsible-Accountable-Consulted-Informed (RACI) matrix or linear responsibility chart (Cabanillas et al. 2012). This type of matrix describes the participation of various roles in completing tasks or deliverables for a project or business process. The RACI matrix was also used in the past for other lean–TQM initiatives, such as VSM, problem solving, and ISO 9001 implementation. The RACI matrix is particularly useful for clarifying roles and responsibilities in cross-functional/departmental projects and processes, such as a Makigami mapping process. The key responsibility roles in the RACI model are as follows:

- responsible: those who do the work to complete the activity
- accountable: those who approve the activities to be undertaken and the work done
- consulted: those whose opinion is sought—typically subject matter experts
- informed: those who are kept up-to-date on progress.

The team selection was made by ensuring that every member had the required capabilities to analyse the investigated process and activities. The team selected for the scope followed some simple rules for correct execution of a Makigami process, such as:

- the initiatives should occur close to the process under investigation, similarly to VSM and other kaizen events
- data (such as times, non-conformities, and indicators) must be previously gathered
- a detailed scheduling of the event must be prepared.

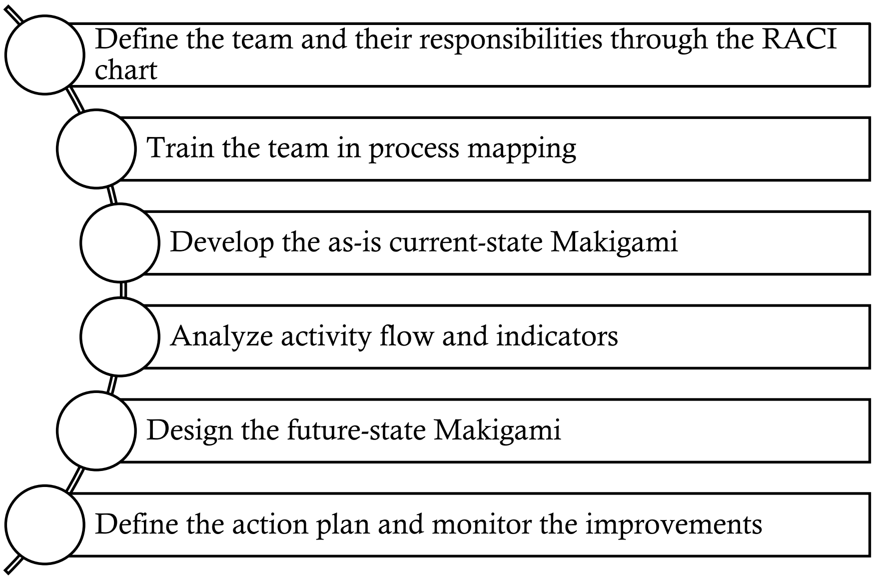
Basic training of the team members involved with the Makigami process was necessary to create a common language and to help draw the maps. As a second step, a current-state Makigami was drawn. As with VSM, the current-state Makigami map helps the team see and understand the present flow of material and information, and particularly how their activities influence the quality of the activities that are in succession. In particular, through highlighting potential loops between some activities, the Makigami can indicate where the office waste is hidden.

By interviewing process owners and other managers, the team members obtained and gathered most of the necessary information for the Makigami process, such as PT and WIP or pending work for each activity. After the first walkthrough, team members became familiar with the complete current flow and sequence of creating the output. In a second walkthrough, the owners of the activities described the sequence of their jobs, thereby completing other indicators of the Makigami, such as LT and C&A%. Finally, to complete the current-state evaluation, the team members verified and corrected uncertain information collected in the previous stages and recorded notes, critical issues, and ideas for improvement.

The following phase of the mapping process involved a deep analysis of the results obtained. The Makigami structure immediately draws attention to process loops and non-value-added activities. For instance, the team focused on time wasted because of lack of information or incomplete deliverables from the upstream process. The team also highlighted a variety of transactional waste, such as internal errors, unbalanced resources, duplications, and over-processing. Finally, the team designed the future-state Makigami, which was approved by the senior manager sponsor of the project. Gathering information from different points of view enabled the team to draw a future-state Makigami that highlighted all the necessary improvements. The team usually creates a dedicated action plan that lists all the improvements required and prioritizes the actions in terms of savings.

The Makigami implementation, including the future-state map and action plan, should be managed as quickly as possible, and improvements must be implemented with no temporal discontinuity. Further, we noted that improving a process without ascertaining a global view of its effect on other processes could penalize the flow as a whole. Figure 7 recaps the main stages of the observed Makigami implementation, while Figure 8 presents an example of a complete current-state Makigami for a process in the technical department.

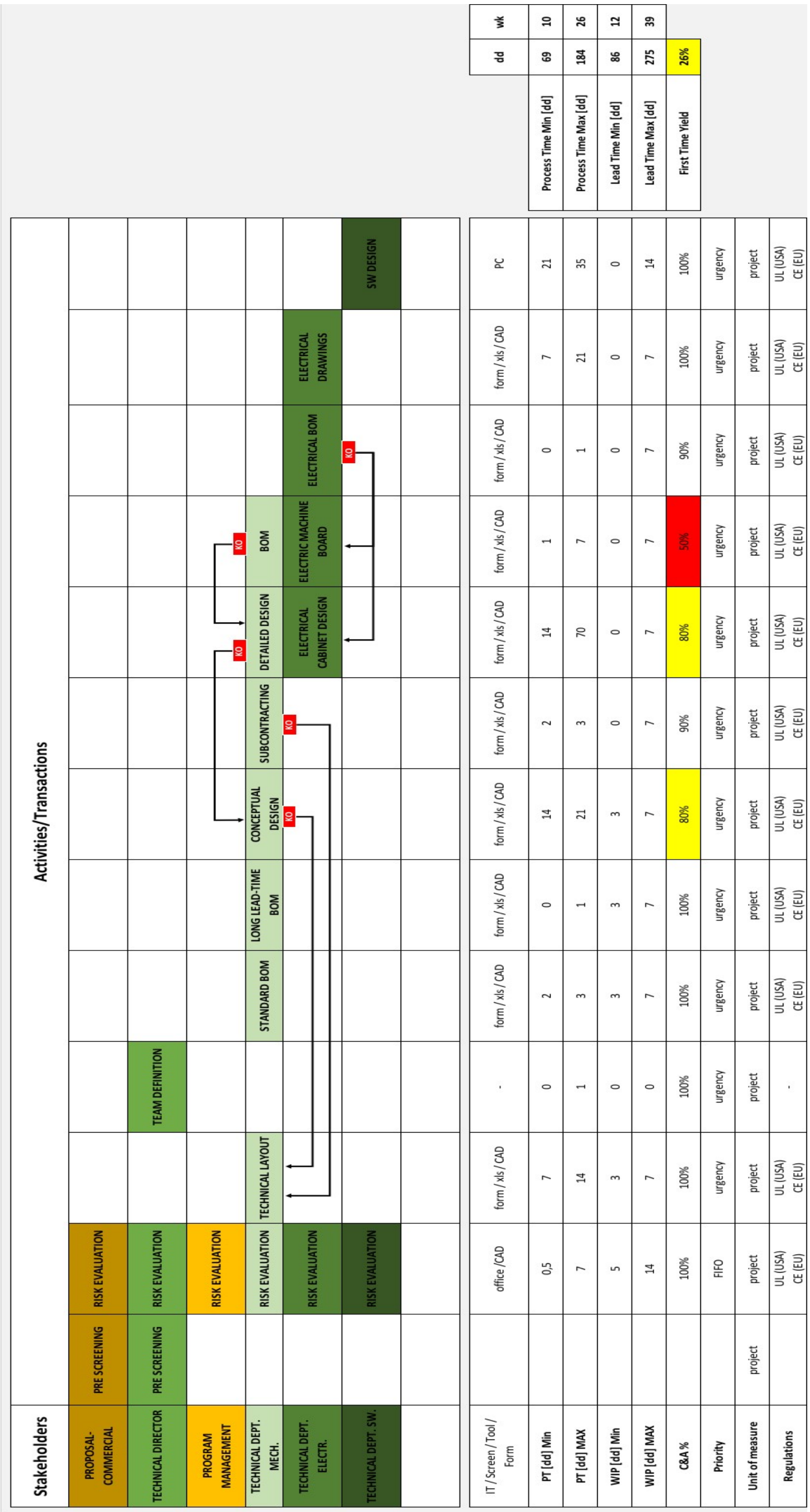
Figure 7: Observed main stages of Makigami implementation



Chiarini and Gabberi (2020) analysed and compared the two different mapping tools, especially through discussing the information gathered and categorised from the semi-structured questionnaire. They also discussed and observed how the company developed the VSM in Figure 9, which was a map of the same technical department process mapped using the Makigami in Figure 8. From Figure 9 we can see how in this map the team identified and drew the same processes of the VSM and used the same values for the lead time and cycle time. For instance, in the final right lower data box we have an overall lead time which can vary from 86 to 275 days, while the total cycle time ranges from 69 to 184 days. All the cycle times and lead times in the VSM are expressed in days and the C&A measurements were expressed in percentage like in the previous Makigami in Figure 8.

Starting from the first and second open questions in the questionnaire, the interviewed members of the team highlighted how they had been trained in the VSM approach through using the original manufacturing version proposed by Rother and Shook (1998). According to the interviewees, the original VSM was created to collect data from the production, such as the cycle time, LT, setup time, overall equipment effectiveness (OEE), and quality ratio, and was not used for transactional data and information. Therefore, in the VSM, they needed to collect further data, such as the C&A% and first-time yield. However, the interviewees stated that the real difference between the two tools is that, in the Makigami, they could also collect information such as the type of software used to manage an activity, the priority assigned to the backlog or WIP, and other more personalised and qualitative metrics.
Further, in the Makigami, for each map, there is a table on the right that summarises the metrics for the process as a whole.

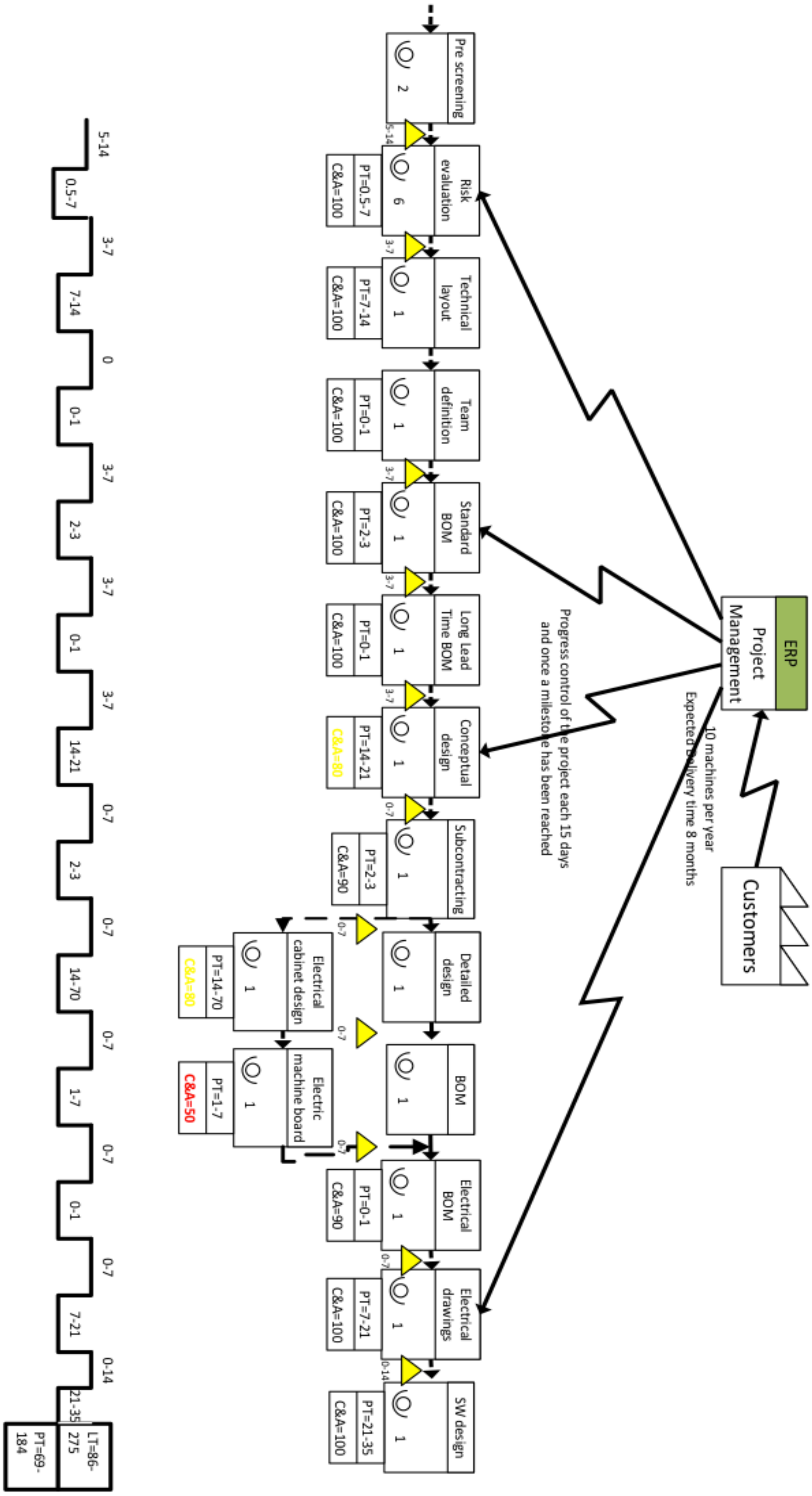
Figure 8: Example of a current-state Makigami for the technical department



Notes/Criticalities/Ideas for improvement

1. The head of the technical department is often abroad. His participation in the risk evaluation activity delays the flow; thus, we suggest avoiding his participation. There are three other engineers who could evaluate possible risks.
2. During the conceptual design activity, 20% of the time, the BOM is incomplete and/or has mistakes. Thus, we suggest introducing a new design review.
3. The electrical BOM is slowed down 50% of the time by previous mistakes in terms of incorrect components and integration. Thus, we suggest a more efficient design review.

Figure 9: Example of current-state VSM for the technical department



Through discussing the limitations of the tools, as stated by other authors (Chiarini 2013), the interviewees believed that the Makigami allowed them to map processes with a much greater level of detail. They stated that it allowed them to divide an activity into the numbers of sub-activities or elementary tasks required. In fact, the Makigami was created as a pure transactional mapping tool (Kuo et al. 2011) to such an extent that it has this particular granularity-level advantage. Further, according to the interviewees, the Makigami, through using arrows, loops, and swim-lanes dedicated to each stakeholder, better displays the flow and sequence of all activities within a process.

The biggest limitation of the VSM in transactional office environments is that it does not indicate who is in charge of an activity and the headcount–equivalent measurement. For instance, in the process icon of the VSM, there is only the number of operators involved, yet no indication of whether they are dedicated to the activity full time or to which department or office they belong. In the Makigami, one can even include the name of the operator or manager in the stakeholder column.

However, the interviewees also discussed some limitations of the Makigami. They stated that the Makigami tends to ignore data and information such as setup times or failures when there are machines/technologies in the transactional flow. Moreover, the backlog or WIP is not as viewable as in the VSM, where one can immediately see the yellow triangle. Synchronisations between activities are also more visible in the VSM. Finally, the Makigami does not allow users to analyse how the process flow is scheduled, planned, or controlled during its progress. The VSM offers a dedicated upper part to this aspect. For instance, in Figure 9, the flow is scheduled and controlled each 15 days by specific project management software integrated in the ERP which deals with 10 machines per year and has a certain expected delivery time.

In terms of obtained improvement in the future state of the maps, the interviewees believed that the VSM used in a transactional office environment was poor in displaying organizational action plans. The VSM functions well in highlighting waste in terms of WIPs, long times, poor quality, and non-synchronisation; however, it is difficult to understand, for example, whether these factors can be linked with overloaded people who could be helped by people from other departments. In any case, in both VSM and Makigami, in the current state it is important to compare cycle times with takt time for flow balancing and waste identification.

Ultimately, when Chiarini and Gabberi (2020) reached the question of whether the two different mapping tools could be used together or whether they were alternatives, the interviewees agreed that, for mapping a transactional office process, it is preferable to use the Makigami, particularly for a single process. However, the VSM, apart from the production processes, could be used to determine an overview of the process or to combine different processes mapped through the Makigami.

As a final and interesting note, the interviewees highlighted how the Makigami, as a more detailed process that involves more metrics, generally took more time to develop than the VSM. Moreover, depending on the level of detail, more people must be involved in collecting data and information outside the team.

Table 2 (Chiarini and Gabberi, 2020) summarises the differences between the two different process mapping tools.

Table 2: Main differences between the Makigami and VSM in transactional environments

Characteristic	**Makigami**	**VSM**
Metrics	Strongly customizable times, quality, headcounts, etc., and even qualitative information, such as the type of software, priorities, workload, etc. A final table calculates metrics for the process as a whole	More focused on traditional manufacturing metrics, such as cycle times, LTs, quality ratio, OEE, failures, etc. A so-called timeline shows the total LT and cycle time
Level of detail	Can map activities and sub-activities	More for process level
Visual information	Immediately displays the activity flow and waste in terms of loops Immediately shows all the involved stakeholders and their responsibilities for the activities and their workload	Immediately shows waste in terms of backlog or WIP and non-synchronizations Indicates how to plan, schedule, and control the progress of the flow
Highlighted improvements	All kinds of improvements	All kind of improvements, apart from organizational improvements
Integration	Difficult to integrate with other mapped processes	Can be used for integrating different processes and different Makigamis
Resources involved	On average involves more resources in terms of time and people	On average uses fewer resources

The final open question of the semi-structured questionnaire (Chiarini and Gabberi, 2020) led to a discussion concerning organisational difficulties and pitfalls from using the two mapping tools. The direct observation and interviewees' suggestions confirmed that the two tools are similar in their implementation and have similar organisational obstacles. Using thematic analysis and codes such as involvement, commitment, responsibility, training, improvement, etc. five specific categories of obstacles for both tools were identified:

- limited management commitment and involvement
- poorly defined roles and responsibilities
- team members not well-trained regarding lean–TQM principles and mapping tools
- people from departments/offices not involved
- improvements in the future state not well monitored.

The first obstacle is typical of the implementation of many tools and principles related to lean and TQM approaches. In their book dedicated to VSM implementation, Rother and Shook (1998) highlighted how VSM can fail in many areas if there is not direct involvement and commitment from senior managers. The same was observed for the Makigami. Senior management must appoint a manager who must act as team manager during the as-is and future-state processes. Moreover, a sponsor among senior managers must periodically review the indicators and the achieved results by communicating with people at all levels.

Senior management commitment and involvement is also important when the company comes to appoint the appropriate members of the mapping team and process owners. As discussed before, in this research, the company used a RACI matrix to establish rules and responsibilities. Without this matrix, it was unclear who should perform which activity and to what extent. The RACI matrix issued and approved by the sponsor provided clarity and removed these types of obstacles.

Senior managers must also provide resources to train people on the general concepts and principals of lean and TQM and to train the team members specifically in the VSM and Makigami steps. To achieve this aim, this study's company employed an external senior consultant who acted for a period as a coach for the team.

To succeed in mapping processes, it is essential to raise the awareness of all involved personnel at all levels. When the team must map a process, many individuals and managers outside the team can be involved in providing data and information. The same people can then be involved in implementing action plans for improvement. Without specific training on lean and TQM principles and without communication from the sponsor, people tend to not give the appropriate priority and attention to the mapping process.

Connected with the above discussed issue, we also noted difficulties among the individuals and manager of the company in performing and accomplishing the assigned action plans for organisational improvements. In this case, training and communication are very important, as are strong commitment and control from the sponsor and senior managers.

Through a case study performed at an Italian manufacturing company, the exploratory research of Chiarini and Gabberi (2020) sought to answer research questions connected with the use of VSM and Makigami in transactional office environments. The research questions were:

RQ1 – What are the main differences between the VSM and Makigami when both are used in a transactional office environment?
RQ2 – Are the VSM and Makigami useful in a transactional office environment or are they simply alternatives to each other?
RQ3 – Under what circumstances can the VSM and Makigami be combined for mapping processes?

The findings have developed a new theory concerning mapping tools for lean–TQM implementation, which will be helpful for managers and consultants who are dealing with this form of implementation and represents the main contribution of this paper.

Specifically, concerning the RQ1:
What are the main differences between the VSM and Makigami when both are used in a transactional office environment?
Chiarini and Gabberi (2020) found that, in general, the Makigami is a more powerful magnifier for mapping activities, sub-activities, and even tasks within a process. According to the literature review results, this is the main characteristic of the swim-lane approach, a tool that shares similarities with the Makigami.

The results from this research clearly indicated the Makigami tendency to strongly customise metrics and indicators, even in terms of qualitative information linked with the activities. In contrast, the VSM tends to be more focused on typical manufacturing indicators, such as cycle time, LT, OEE, quality, and failures. The Makigami provides clear visual information in terms of activities sequence and waste linked to loops among activities, as well as the possibility of identifying all the stakeholders for each activity, the time stakeholders devote to certain activities, and stakeholders' workloads. In contrast, the VSM lacks all these characteristics. The Makigami, in its future-state version, can easily highlight all types of improvements to be managed, including more organisational improvements connected with job descriptions, skills, and organisation chart positions. In contrast, the VSM cannot lead to such types of improvements.

However, the Makigami is also affected by some negative characteristics, such as the difficulty in immediately visualising backlogs and WIPs, as well as non-synchronised activities. In contrast, the VSM was made to highlight these types of waste. Moreover, the Makigami does not indicate how the process is planned, scheduled, and controlled in its progress, while the VSM has an entire part of the map dedicated to these factors.

Apart from the above limited issues, the Makigami seems to be a better vehicle for mapping a transactional office process characteristic of the digital transformation, in contrast to the VSM, which must be changed in many ways from the original version proposed by Rother and Shook (1998). Other differences can be found in Table 2.

Concerning the RQ2:
Are the VSM and Makigami useful in a transactional office environment or are they simply alternatives to each other?
Chiarini and Gabberi (2020) found that both can be of some help in transactional office environments, even if some authors tend to consider the two maps alternative to each other. In any case, answering the third research question, findings highlighted important overlaps.

Regarding the RQ3:
Under what circumstances can the VSM and Makigami be combined for mapping processes?
Authors can say that the VSM could be used to integrate different Makigamis to compose a bigger picture of all organisational processes linked together.

Finally, authors also investigated the organisational obstacles that can jeopardise the VSM and Makigami implementation. They found five specific categories of obstacles: lack of management commitment and involvement, poorly defined roles and responsibilities, lack of training, relevant people not properly involved, and improvements not well monitored. Some of these issues have also been discussed in the literature.

The literature review findings enabled this study to establish research questions, which are analysed and discussed through the case study. These questions are as follows:

RQa – Is Makigami an effective tool to map business processes, and can its features be a plus for transactional processes, streamlining the work of practitioners?

RQb – Can the integration between Lean Manufacturing and Digitalisation synergistically create tangible value for a company? In other words, are waste reduction, process improvement and digitalisation key impacting factors on business results nowadays?

3. Methodology

To develop this research work, the adopted methodology was based on an exploratory case study (Eisenhardt 1989; Gammelgaard 2017). McCutcheon and Meredith (1993) emphasised that case research is particularly suitable for developing new theories and ideas and can be used for further theory testing. Many of the breakthrough concepts and theories in operations management, including Total Quality Management and Lean Manufacturing, have been developed through field case research (Voss et al. 2002).

This research's case study, as mentioned in the introduction, involved a company, CT Pack, that designs and manufactures integrated packaging systems and automation for food and other industries, with a focus on bakery goods, chocolate, ice cream, and frozen food. The company is located in the north of Italy, has about 120 employees, and was established more than 60 years ago. It now belongs to an international group that operates in 60 countries. The main departments are sales, technical, production, supply chain management, testing and commissioning, and after-sale service. During the last 20 years, the company has reached ISO 9001 certification, and launched TQM projects to improve its processes and customer satisfaction. Its products are usually complex and customised automation machines, and the customers demand a high level of quality and service. Thus, in recent years, the company has launched a lean manufacturing approach and appointed a dedicated continuous improvement engineer. An internal team continually maps all the processes and launches kaizen events to reduce waste, lead time, and the costs of poor-quality products. Initially, the company used VSM to map processes to identify waste; now, the company adopts Makigami and VSM.
The company resulted to be the ideal candidate for the aim of the research since it had knowledge of Lean Six Sigma, it is an Italian SME, and it had necessity to embrace digital transformation to be competitive in the world market.

Follows Figure 10, that summarise the path followed in this research's development. Looking at Figure 10 in depth, the classic frame of Lean Six Sigma approach can be easily recognised. Indeed, the project in all its details has been developed following the Lean Six Sigma DMAIC methodology, summarised and streamlined as follow:

1 Define: target, resources and timing definition, represented in Figure 10 with Target and Research of the tools;
2 Measure: gather information and measurable data, represented in Figure 10 with Processes' current state maps;
3 Analyse: study causes that originated problems, and possible solutions, represented in Figure 10 with Criticalities and Processes' future state maps;
4 Improve: identify and implement solutions, represented in Figure 10 with Processes digitalisation, Products standardisation and Products digitalisation;
5 Control: control improvements to make them permanent, represented in Figure 10 with Results on business.

Clearly, as a peculiarity of lean thinking, these methodologies, like DMAIC or Deming's cycle, are iterative, in order to pursue continuous improvement: results gained are not the final point, but a new starting point for further improvements.

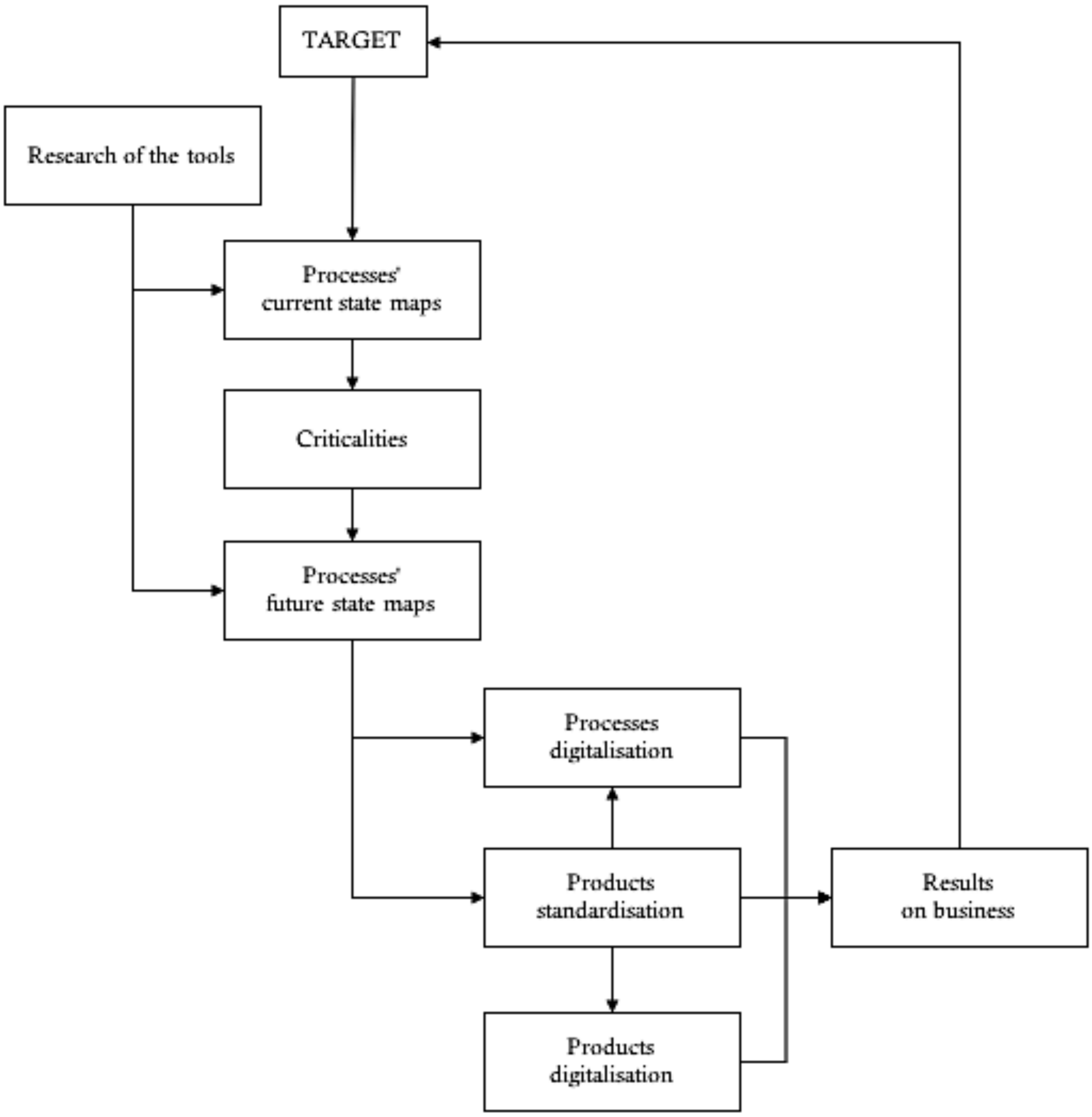


Figure 10: diagram that summarise the development of the research.

Resuming, having clear in mind the targets to be achieved, first of all adequate tools have been researched in order to map company's processes and obtain a global perspective of the organisation.

Then, data have been analysed to identify weaknesses and to re-engineering and streamlining all company's processes.

Furthermore, in order to create value as the main aim of author's contribution to the company, digitalisation has been introduced in processes and in products in different ways based on mapping results.

Finally, results on business have been measured and compared to the previous ones, then new targets were set, creating company's continuous improvement mindset.

In general, the whole researched has been developed considering Lean Manufacturing, Total Quality Management and Six Sigma approaches.

4. Business Processes Digitalisation

4.1 Business process mapping "as-is" state

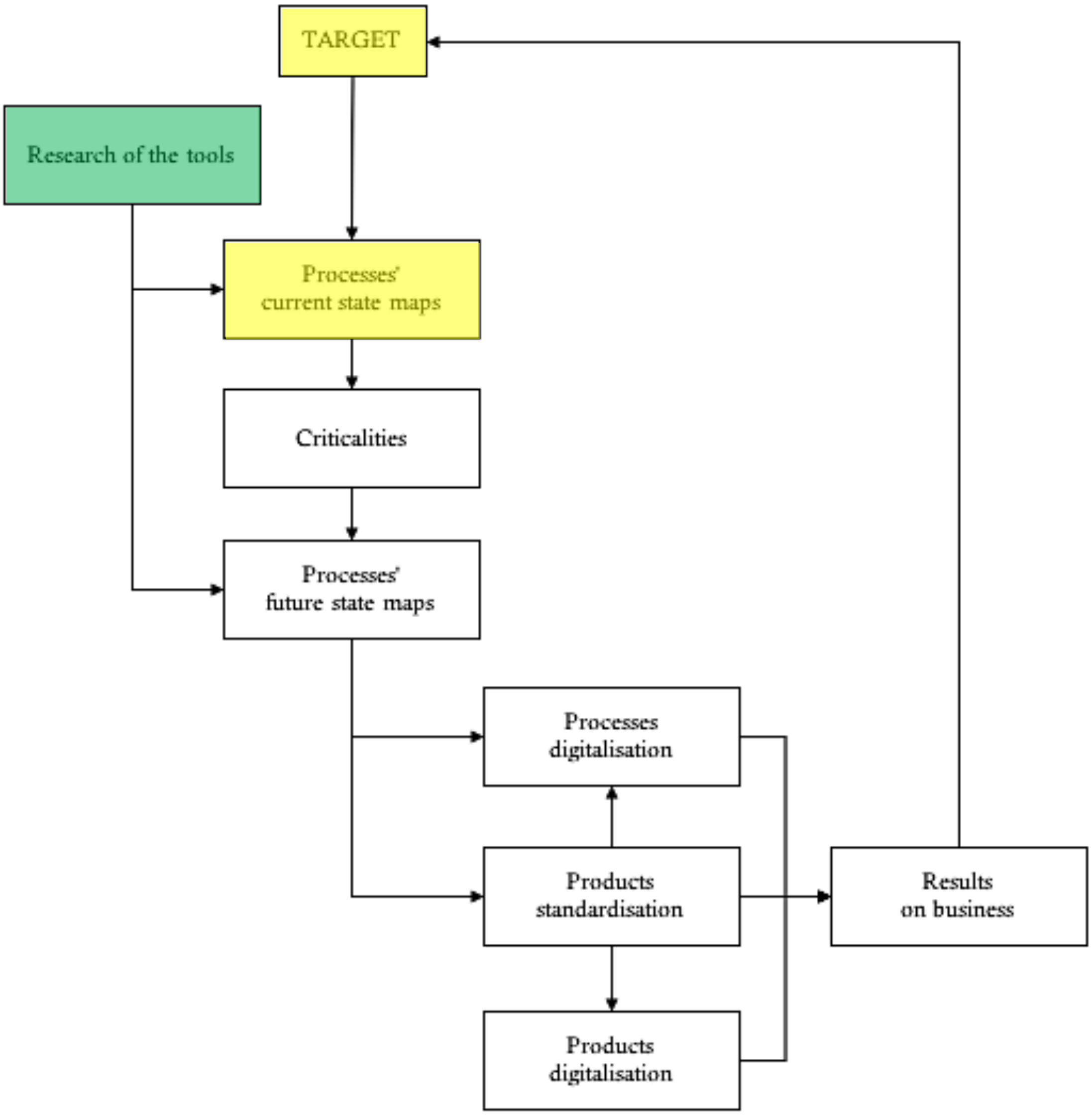


Figure 10.1: diagram that summarise the development of the research.
In this chapter the focus is processes' current state maps, the overall picture that the author found at the beginning of the research.
In particular, the colour code introduced simplifies the reading, since it highlights the status of research development according with methodology premises: green indicates steps developed and concluded, yellow indicates the step under discussion in the chapter, always watching toward the target and, finally, white steps still to be faced.

The exploratory research of Chiarini and Gabberi (2020) defined the main mapping tool used in this thesis work, the Makigami, since the most of company's processes are transactional and the tool seems to be effective and multipurpose.
In this section all the main process as-is state maps are shown and commented, in order to have a clear vision of the starting point of this thesis work.

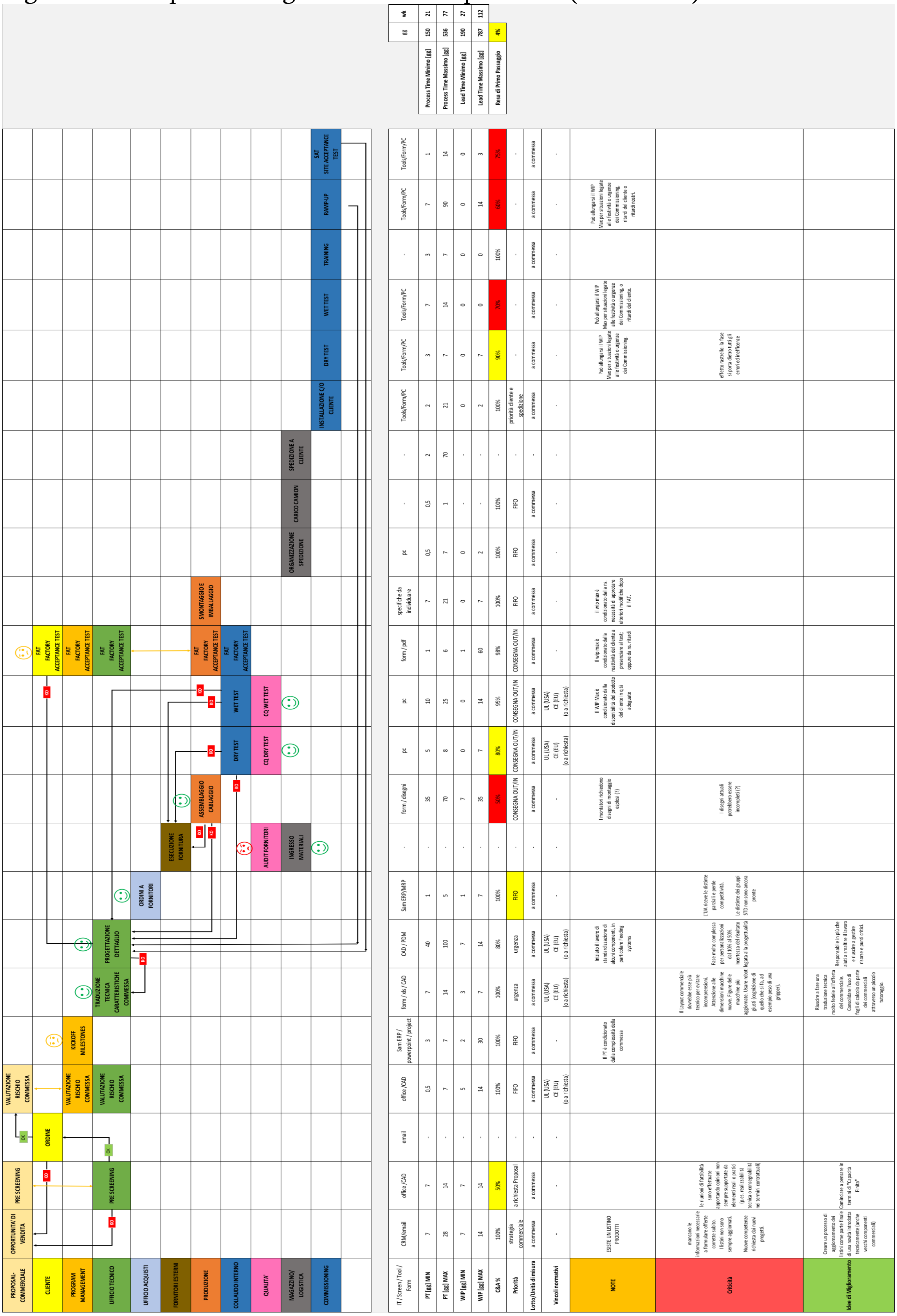
As it is structured, CT Pack is a company that works for projects, since it business as highlighted in the introduction is the design, manufacturing and implementation of complete turnkey and fully-customised systems for packaging sector.
The main departments, or processes, that contributes to projects development are:

- Sales;
- Engineering;
- Procurement;
- Production;
- Commissioning.

Figure 11 is a clear and simple map of these processes, developed by using Makigami with a low level of detail. Despite the fact that this map, built just to have a vision of the big picture, is low-detailed, the main interaction between transactions and between different processes are anyway visible.
In particular, Makigami allows practitioners, thanks to its visual effectiveness, to focus on process loops, so all the activities of re-processing due to mistakes, incomplete information, delays, lack of something to step forward to the next transaction.
Not rarely a loop lead to transactions that are not the one immediately before, but a bit early in the process instead: the power of Makigami is to clearly show where to act to reduce waste and to improve effectiveness and efficiency of processes.

In the low-detailed global Makigami map (Figure 11) is simple to see at least one important loop for each department process, an indication that reinforced the idea to map in detail each one of the processes.
As reported in the literature review, in the section related to Chiarini and Gabberi (2020) study on Makigami tool, in the mid-lower part of each map some indicators are reported, to help the understanding of main data necessaire for a mapping tool: process time, lead time and Completion&Accuracy percentage are the most interesting ones.
Finally, at the bottom of the map useful notes, criticalities and improvement ideas are reported for each transaction.

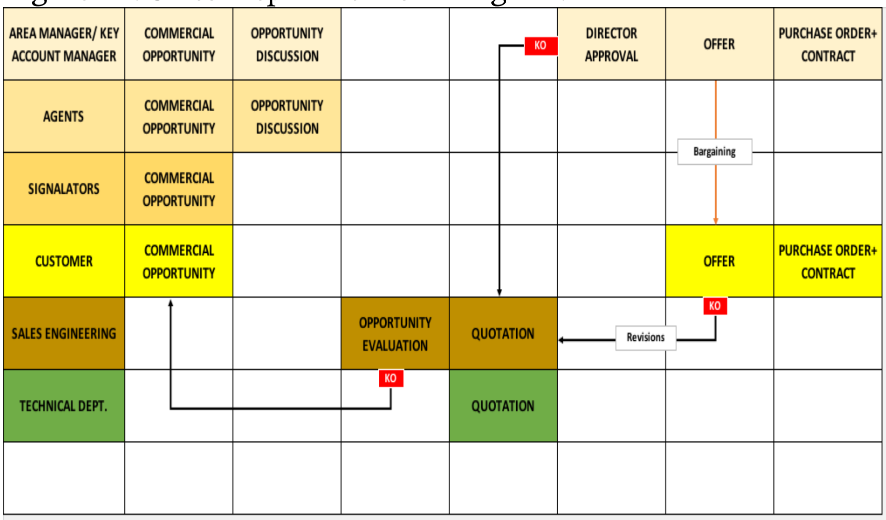
Figure 11: Complete Makigami of business processes (low details).



All the Makigami maps reported in this section were developed following Chiarini and Gabberi (2020) methodology, so departments managers were involved to understand transactions, the flow, indicators. Furthermore, their opinion was precious to take useful notes and to identify criticalities and improvements ideas. Detailed as-is Makigami maps were developed as follows:

- Figure 12: Sales Department's Makigami;
- Figure 13: Technical Department's Makigami;
- Figure 14: Procurement Department's Makigami;
- Figure 15: Production Department's Makigami;
- Figure 16: Commissioning Department's Makigami.

Figure 12: Sales Department's Makigami.



IT / Screen / Tool / Form	email/phone/audit	CRM	form/CAD	office/CAD	-	email	form/email/office
PT [dd] min	1	1	7	7	0,1	7	7
PT [dd] MAX	1	1	14	28	1	-	-
WIP [dd] min	0	0	7	7	0	-	-
WIP [dd] MAX	0	7	14	14	5	-	-
C&A %	-	-	50%	100%	-	5%	100%
Priority	commercial strategy	FIFO	commercial strategy	commercial strategy	FIFO	commercial strategy	commercial strategy
Unit of measure	-	project	project	project	project	project	project
Regulations	-	-	-	-	-	-	-
Notes						PT e LT dipend on customer and are not deductible	PT e LT dipend on customer and are not deductible
Criticalities		Lack of information and data		Price-list not reliable			
Improvement Ideas		Obtaining all starting information needed by area managers using existing form about Quality Funcion Deployment		Definition of reliable price-list and periodic updating procedure			

	dd	wk
Process Time Min [dd]	30	4
Process Time Max [dd]	45	6
Lead Time Min [dd]	44	6
Lead Time Max [dd]	85	12
First Time Yield	3%	

Figure 13: Technical Department's Makigami.

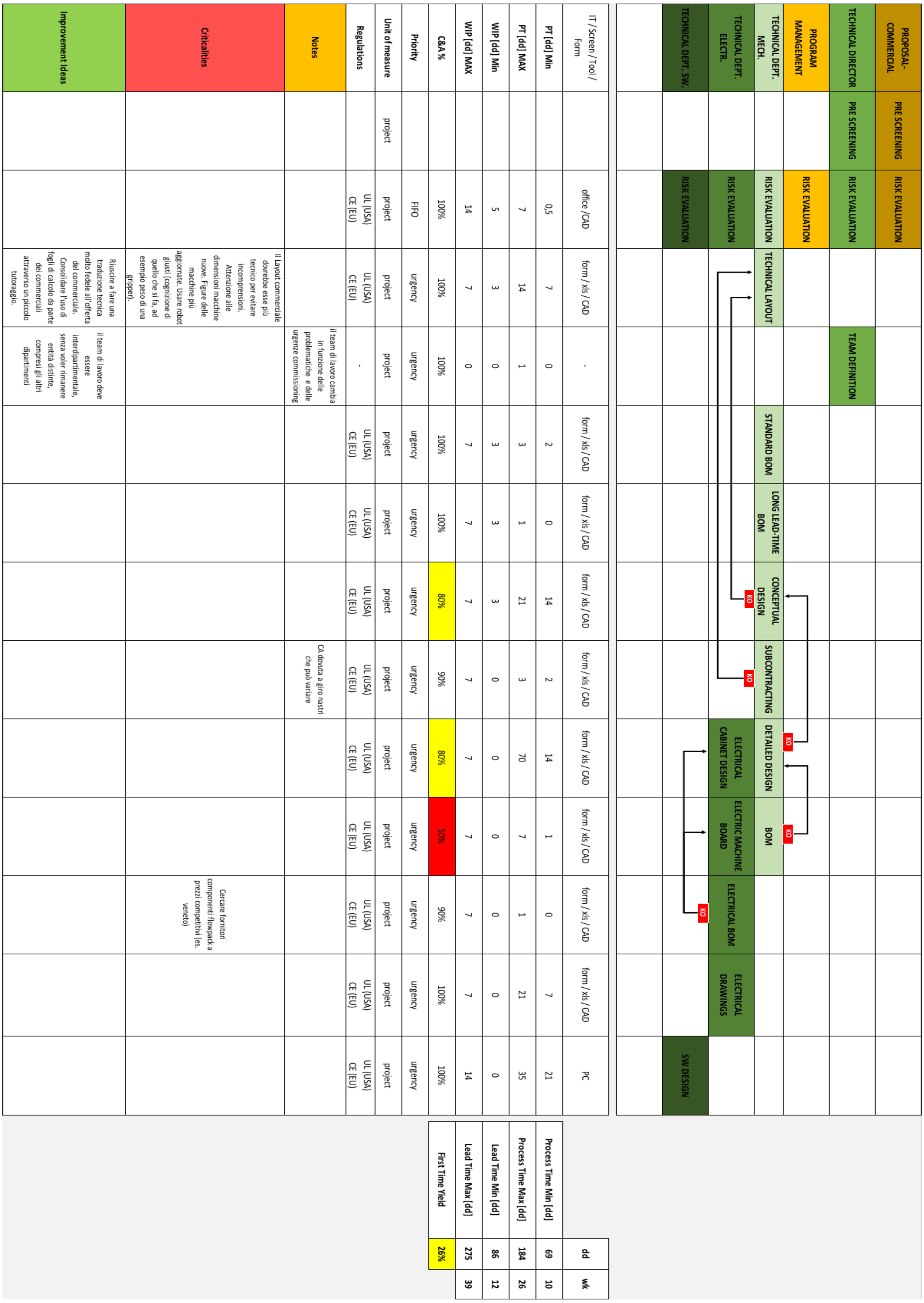
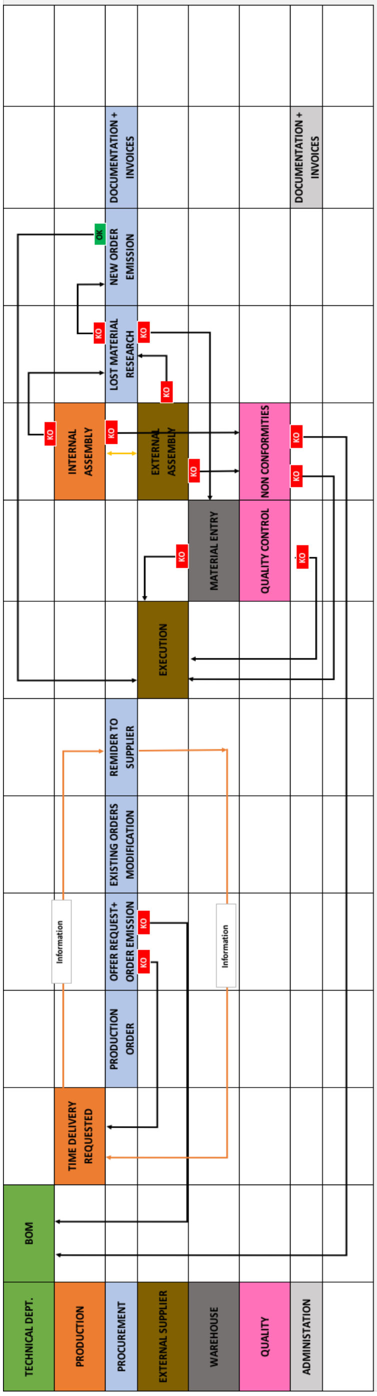


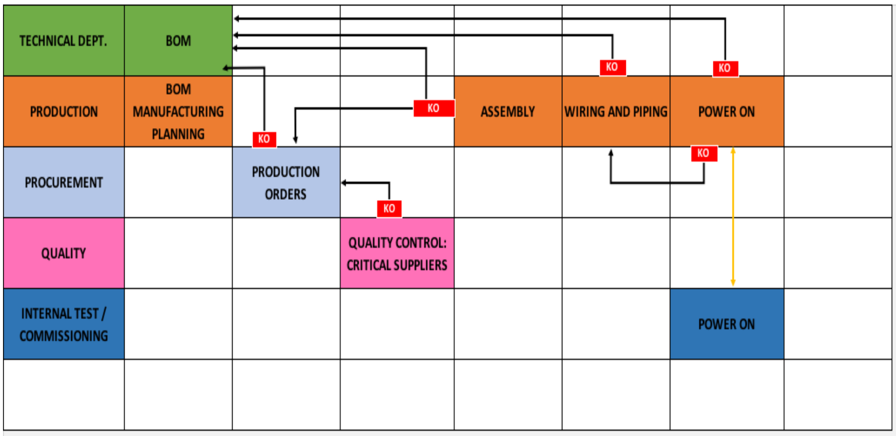
Figure 14: Procurement Department’s Makigami.



IT / Screen / Tool / Form	PDM/form	PC	SAM	email/phone/SAM	SAM	SAM/email/phone	-	-	-	SAM	SAM	form/phone/email	
PT [dd] Min	-	0,1	0,1	0,1	0,1	0,1	-	0,1	0,5	0,1	0,1	3	
PT [dd] MAX	-	0,5	0,2	0,5	0,2	0,2	-	2	3	1	0,5	5	
WIP [dd] Min	-	0	0	0	0	0	5	0,5	0	0	0	0	
WIP [dd] MAX	-	2	2	5	3	1	200	3	3	0	1	0	
C&A %	-	100%	100%	80%	90%	100%	-	99%	-	100%	100%	100%	
Priority	-	FIFO	Machine assembly	Machine assembly	Machine assembly	Manufacturing demand	-	FIFO,Manufacturing demand	-	Manufacturing demand	FIFO	Administation demand	
Unit of measure	-	project	project	project	project	project	project	project	project	project	project	-	
Regulations	-	-	-	-	-	-	-	-	-	-	-	-	
Notes		Il lavoro di pulizia DB e creazione OP dovrà essere svolto da PRD (pianificatore di produzione)	Attraverso l'introduzione del PLM il problema duplicazione codici viene eliminato, quando tutto sarà a regime	Visti i tempi ristretti di consegna non vengono richieste più offerte. Si cerca di impegnare il fornitore designato attraverso un ordine di produzione in stato proposto, da confermare e contrattare successivamente. In	Aggiunta di particolari, loro annullamento, revisione. Prima era tutto tracciato, ora no, perché non tutte le modifiche creano problemi	Non c'è monitoraggio standard, si inviano solleciti dopo feedback produzione/UT		KO per incongruenza documenti/materiali consegnati	C&A% è riferita a gestione NC, perché implica anche UA				
Criticalities			Sistemazione distinta base perché i codici UT non sono quelli utilizzati da UA. Attività manuali	I KO sono dovuti a commerciali obsoleti o a progettazioni non DFMA, o incongruenze/errori effettivi di progettazione.	Attività manuali		Talvolta il fornitore chiede spiegazioni sui disegni, per scarsa precisione di informazioni o delucidazioni tecniche. UA è un tramite con l'UT						**Le criticità UA dipendono dalle richieste degli altri dipartimenti, in particolare da errori UT, mole enorme di modifiche**
Improvement Ideas			In divenire, utilizzo più appropriato dei campi del MRP permetterà una migliore gestione degli ordini		Eliminare attività modifica ordini esistenti	Questa fase sarà più contenuta e automatizzata con il progetto IUNGO				Maggiore tracciabilità particolari in uscita (bolle quando si spostano merci)			

	dd	wk
Process Time Min [dd]	4	1
Process Time Max [dd]	13	2
Lead Time Min [dd]	10	1
Lead Time Max [dd]	233	33
First Time Yield	71%	

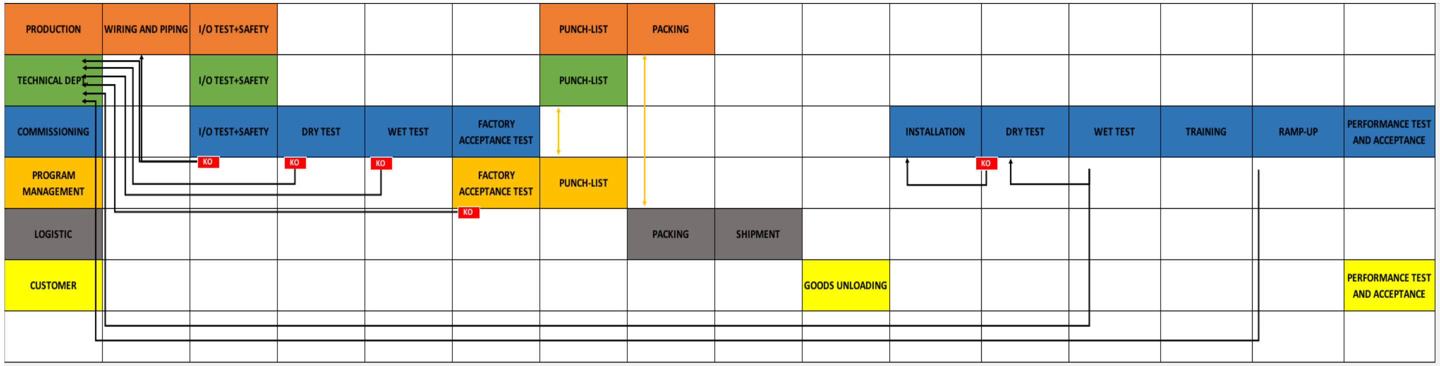
Figure 15: Production Department's Makigami.



IT / Screen / Tool / Form	PC		Form	Tools/Form	Tools/Form	Tools/Form/PC	
PT [dd] Min	0	0,1	-	21	21	1	
PT [dd] MAX	7	0,5	-	50	40	7	
WIP [dd] Min	0	0	-	0	0	0	
WIP [dd] MAX	2	5	-	20	20	7	
C&A %	100%	80%	99%	60%	80%	90%	
Priority	FIFO	FIFO/Machine assembly	-	FIFO/INPUT	FIFO/INPUT	FIFO/technicians availability	
Unit of measure	project	project	project	project	project	project	
Regulations	-	-	-	-	-	-	
NOTE				Spesso si verificano problemi dovuti a disegni sbagliati		LT dipende dalla disponibilità dei softwaristi	
Criticità	Spesso i disegni sono sbagliati o richiedono modifiche	Spesso i fornitori non rispettano le date di consegna richieste					
Idee di Miglioramento		Spesso si verificano non conformità per disegni costruttivi mal realizzati, a libera interpretazione		Utile avere disegni esplosi, e disegni costitutivi ben realizzati	Utile avere disegni esplosi, e disegni costitutivi ben realizzati		

	dd	wk
Process Time Min [dd]	43	6
Process Time Max [dd]	105	15
Lead Time Min [dd]	43	6
Lead Time Max [dd]	159	23
First Time Yield	34%	

Figure 16: Commissioning Department’s Makigami.



IT / Screen / Tool / Form	Tools/Form	Tools/Form/PC	Tools/Form/PC	Tools/Form/PC	Tools/Form/PC	Tools/Form/PC	Tools/Form	-	-	Tools/Form/PC	Tools/Form/PC	Tools/Form/PC	-	Tools/Form/PC	Tools/Form/PC
PT [dd] Min	35	0,5	3	7	1	1	1	1	1	2	3	7	3	7	1
PT [dd] MAX	70	7	21	35	5	28	14	60	5	21	7	14	7	90	14
WIP [dd] Min	7	0	0	0	0	0	0	-	1	0	0	0	0	0	0
WIP [dd] MAX	35	0	14	7	5	3	5	-	3	2	7	0	0	14	3
C&A %	60%	90%	50%	60%	80%	100%	100%	-	-	100%	90%	70%	100%	60%	75%
Priority	FIFO/INPUT	FIFO/technician availability	FIFO/technician availability	FIFO	FIFO/customer availability	FIFO	FIFO	-	-	FIFO	FIFO	FIFO	-	FIFO	FIFO
Unit of measure	project	project	project	project	project	project	project	-	-	project	project	project	project	project	project
Regulations	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NOTE	Le macchine sono considerate pronte per l'accensione anche se sono incomplete. Risulta estremamente difficile riuscire a collaudare una macchina completa. Rischio sicurezza.		Spesso effettuato a spezzoni perché l'impianto non è completo. Non tutte le macchine possono essere testate singolarmente perché il software non è modulare.		LT dipende anche dal cliente.	Talvolta non si riescono ad implementare tutti i punti prima della spedizione perché le lavorazioni richiedo tempo.			Lo scarico merce è sempre effettuato dal cliente.		LT dipende da fattori esterni, chi deve collaborare con i tecnici a monte e a valle.			LT dipende dal cliente o da macchine di fornitura esterna	Non c'è una fase schedulata vera e propria. Non viene fatto per tutti gli impianti, il cliente può accettare la macchina anche dopo il ramp-up
Criticità	I collaudi interni non sono gestiti, le risorse sono assegnate in maniera non ragionata. Manca la figura del responsabile di collaudo di determinate macchine.	Al momento c'è pochissimo preavviso per la pianificazione		Talvolta mancano i prodotti e le scatole per i test			Non c'è uno standard di smontaggio, perciò in alcuni casi l'assenza di linee guida porta ad avere problemi nel riassemblaggio								
Idee di Miglioramento			Possibilità di miglioramento scorporando le singole macchine a livello meccanico e software, per procedere in parallelo.												

	dd	wk
Process Time Min [dd]	74	11
Process Time Max [dd]	398	57
Lead Time Min [dd]	82	12
Lead Time Max [dd]	496	71
First Time Yield	4%	

4.2 Criticalities

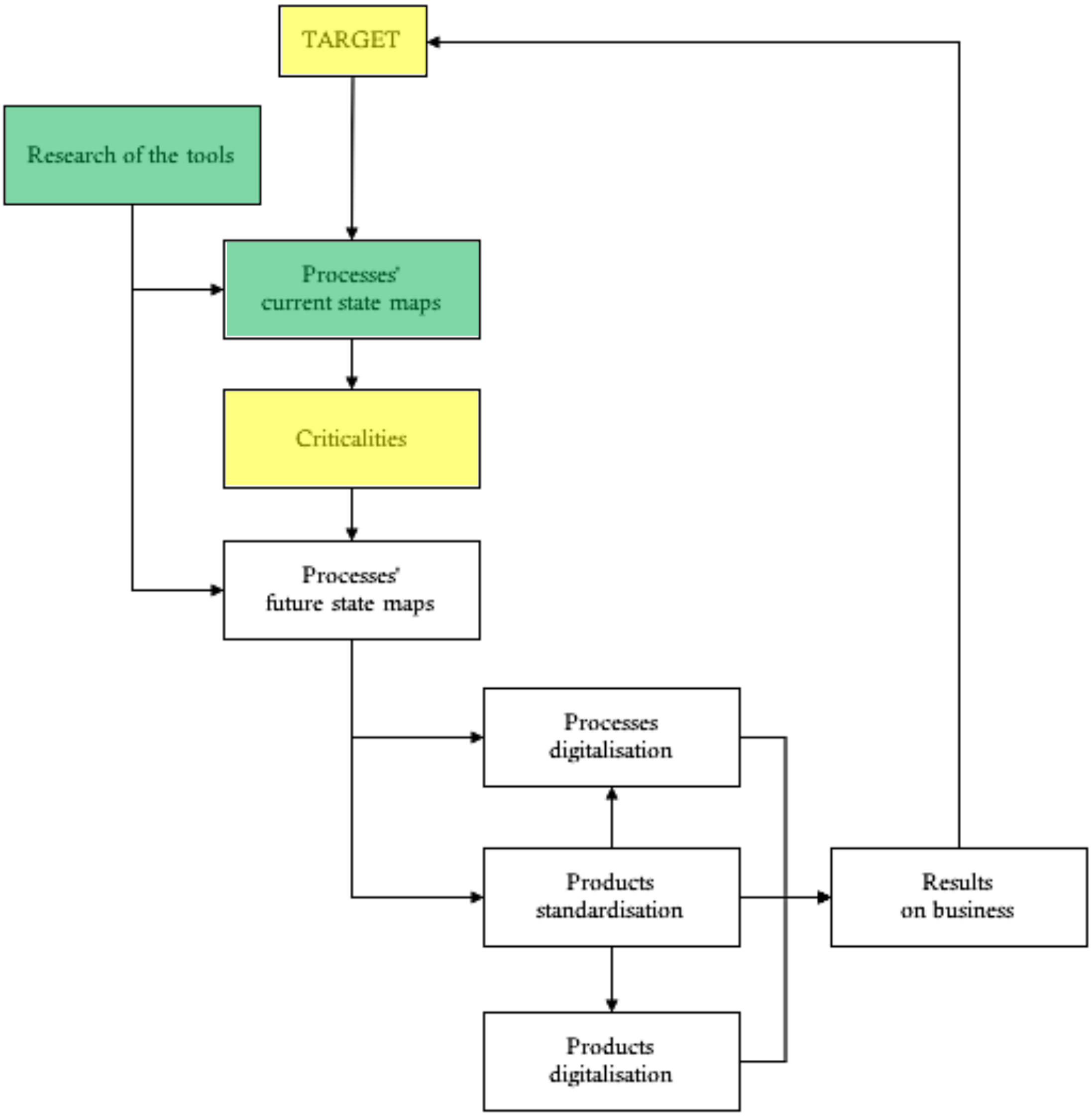


Figure 10.2: diagram that summarise the development of the research.
In this chapter the focus are criticalities found in current state processes.

In this section all the criticalities divided for each department are identified and analysed: this job drew the attention to possible improvements and digitalisation ideas.

Sales department (ref. Figure 12):

Since the company works to deliver complete customised turnkey packaging systems to customers, is clear that the most time-consuming activity in Sales department is related to quotations' preparation. In particular, this activity consists in gathering all customer's needs, find the most suitable solution and quote it considering all the customisations, in a very short time slot and with huge numbers of requests.
It was reckoned that the lack of a simple but accurate supporting tool in quoting activity was causing damages to the company, in particular:

- Quality function deployment sometimes misrepresented real customer needs, with tendency to over-processing or re-working (internal cost increase);
- Wrong quotation of hours of labour or customisation materials (internal cost not aligned to what sold);

The direct consequence is that inaccurate features and costs of goods sold led to an immediate project's gross margin loss.

Technical department (ref. Figure 13):

Customisation of machines at the state of art, one of the strength of the company praised by all the customers, was creating difficulties in internal organisation together with challenging growth targets of the company, to expand its business.
The main findings in Technical department were:

- Agreed quotation for cost of technical department labour were usually underestimated, leading to a cost increase;
- Projects' plans were suffering delays due to the challenging and increasing number of projects and their customisation requirements.

Two were the main direct consequences that created negative synergies: internal cost increase and threatening accumulation of work in process.

Procurement department (ref. Figure 14):

Difficulties faced by Technical department were having an impact on the whole organisation. The infernal pace created by over-processing, re-working, delays and inaccurate costs led the entire organisation to work with urgency for any matter, jumping off the program plan.

- Codes ordered were exponentially multiplying due to oversights, and the amount of work in process in Procurement department reached an intolerable standard;
- Suppliers were delaying any code and were asking for prices simply out of the business. No certain delivery date in order to be able to review programs plans.

– Non-quality costs skyrocket due to all-urgent requests.

Over and above of the consequences in common with all the departments at that time, the most dangerous one was a kind of bad influence that was twisting between colleagues of diverse departments due to the intolerable pace.

Production department (ref. Figure 15):

The main criticality faced by Production department was related to non-conformities in the materials (internal or depending on suppliers), delays and re-work.

Any non-conformity set the loop technical department – procurement department – supplier – production department from the beginning aggravating delays and urgency feeling.

Commissioning department (ref. Figure 16):

The Commissioning department is the one deputed to the internal test of the automated lines and their installation and commissioning to customers' sites all over the world.

Over ad above delays issues due to the flow of processes belonging to all the other departments, that induce cost increase, such as assembly issues, missing codes, functional design issues, etc., the main criticality detected was the quotation of internal test costs and installation costs, that usually were overestimated (to dampen the effects of accumulated delays). This situation created selling prices widely above targets, with negative consequences on sales. Despite this fact, projects' budget was exceeded anyway, and projects' lead time started to be unacceptable: the situation had to be fixed.

Criticalities of all the departments were in a certain way each other related and after an analysis that involved all the processes, three main process loops were highlighted due to the same number of root-causes:

1. Loop between Technical department and Sales department;
2. Internal loop in Technical department;
3. Loop between Production/Test department and Technical department.

According to the analysis and feedbacks gathered for people involved, loops are due to three main root-causes that created the vicious circle previously explained:

a. Lack of accurate and detailed products' pricelist;
b. Lack of comprehensive and timely information between departments and inside each department;
c. Poor standardisation and modularisation of products and procedures.

Makigami led the team to be aware of process loops, and clearly show where are they located; this tool suggests gathering notes, criticalities and improvement ideas, showing the main indicators chase for each process, thus identifying the main improvement target was a direct consequence.

Figure 17 shows in a basic way the synergies of the action thought to stop the unacceptable vicious circle and change organisation's results. All the improvement targets seemed to be related each other and to contribute to support company transition from a small artisanal company into an industrial one with strategic targets of a completely different extent.

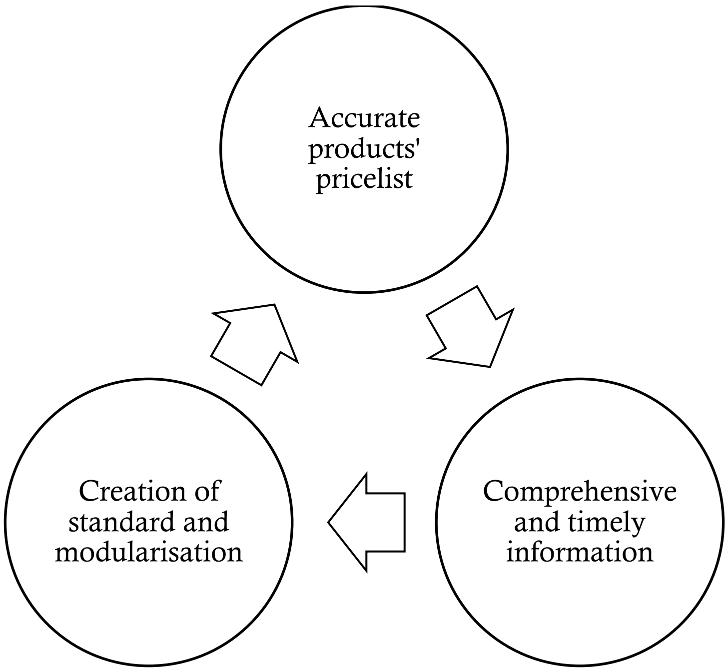


Figure 17: representation of improvement circle.

All the strategic initiatives, processes streamlining, and projects introduced in the company with this thesis job, that are explained in the next chapters, are based on the three fundamentals reported above.

In conclusion, Table 3, Table 4 and Table 5 summarise the main points constituting each one of the fundamentals reported in Figure 17, developed in the next chapters.

Table 3: Summary of main points developed for an accurate products' pricelist.

Accurate products' pricelist		
Activity	**Benefits**	**Resources involved**
Analysis and partition of products' portfolio	Census of sold products types depending on number of selling, useful to focus standardisation and modularisation efforts	Sales Department Technical Department Leader
Functional groups analysis	Being able to address standardisation, revision, and improvement of groups for each product's category	Technical Department Leader
Functional groups costing	Accurate and under control budget, useful info for Design For Manufacturing and cost management	Procurement Department Technical Department
Groups' assembly costing	Accurate and under control budget, useful info for Design For Assembly and cost management	Production Department
Accurate pricelist creation	Creation of accurate and reliable tool for Sales Dept. to reduce quotation lead time	Sales Engineering
Periodic pricelist update procedure	Keep information accurate and reliable	Sales Engineering Leader

Table 4: Summary of main points developed for information improvement.

Comprehensive and timely information		
Activity	**Benefits**	**Resources involved**
Accuracy in Request For Quotation Standard Form to address customer to the best solution	Gathering necessaire information for the quotation	Sales Department
Updated ready-to-use products template layout to prepare quotation layout	Decrease internal revision to fix quotation layout and technical solution needed	Technical Department Sales Engineering
Definition of the complete conceptual solution for each project before starting the design	Project awareness, reduction of re-working and non-quality cost	Sales Engineering Technical Department Program Management Production Department
Improvement of drawing skills and principles	Decrease non-conformities (internal and external) and manufacturing costs	Technical Department
Checklists used daily	Streamline information, give visibility on the status of projects, faster feedback	All

Table 5: Summary of main points developed for standardisation and modularisation.

Creation of standard and modularisation		
Activity	**Benefits**	**Resources involved**
Functional groups' standardisation and modularisation	Decrease internal costs of design, decrease non-conformities, lead time cut	Technical Department Leader
Software modules' standardisation	Decrease internal costs of programming and tests	Technical Department Leader (Automation)
Design process standardisation	Improvement of activities master plan, non-conformities reduction	Technical Department Leader
Assembly, wiring and piping standardisation	Decrease non-conformities and manufacturing costs	Production Department
Creation of testing standard procedures	Decrease non-conformities and labour costs	Production Department

4.3 Business process mapping “to-be” state

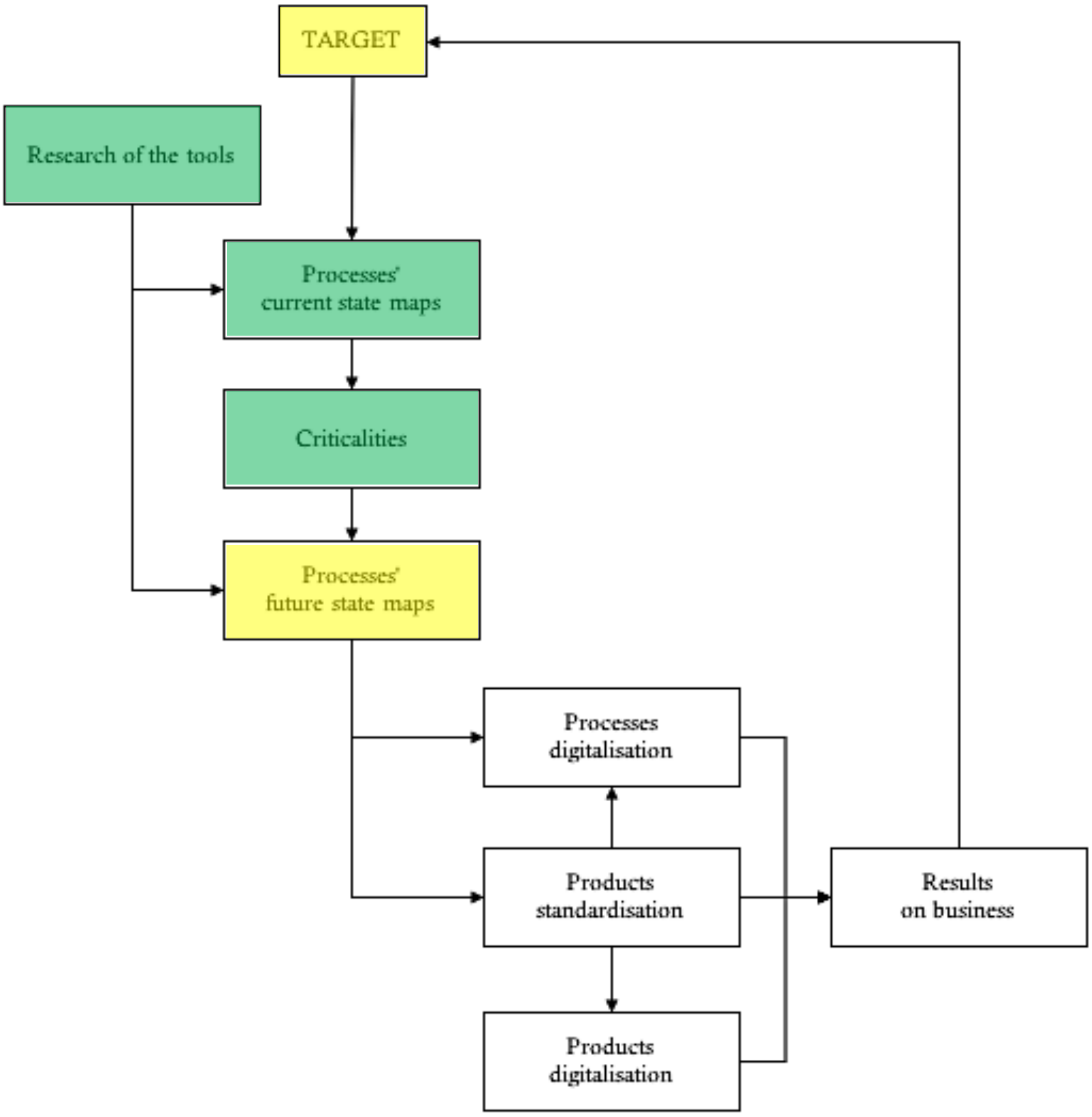


Figure 10.3: diagram that summarise the development of the research.
In this chapter the focus is processes’ future state maps, the overall picture re-engineered and developed according with board management strategy.

In the present section are reported all the "to-be" state Makigami maps, the re-engineered processes consequence of information gathered by "as-is" state mapping processes.
Differently from the "as-is" state section, it was decided to design processes with the maximum level of detail, so each, even minimal, transaction is reported in the maps. Furthermore, some processes have been divided in sub-processes, mapped and shown as well. In order to visual-manage all the details of new transactions, the structure of Makigami changed: one of the plus of this tool is flexibility, so in addition to maximum level of detail, diagrams are developed in vertical (stakeholders are in the first row instead of the first column), not horizontal as the "as-is" state, because this helped a lot in visual management of relations between transactions and owners due to the extent and the detail level of processes chosen.

Symbols were used to better identify transactions, questions, documentation and other processes as follows in Table 6:

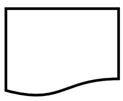
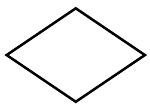
Symbol	**Description**
	Transaction/Activity
	Process
	Documentation
	Questions (Y/N)

Table 6: symbols used in the Makigami to-be state maps.

Then, as reported above, sub-processes have been identified and mapped as well, according to the following global punch list:

- Sales Department (Figures 18.a, 18.b, 18.c);
- Program Management: new process not present in the "as-is" state mapping (Figures 19.a, 19.b);
- Technical Department (Figures 20.a, 20.b);
- Purchasing Department: divided in Purchasing (Figures 21.a, 21.b), Goods receipt (Figure 22), Goods sorting (Figure 23);
- Production: divided in Production planning, Production (Figure 24 and 25);
- Commissioning Department: divided in Internal test (Figure 26), Installation planning (Figure 27), Installation & Commissioning (Figures 28.a, 28.b).

Figure 18.a: part 1 of 3 of Sales Department to-be state Makigami.

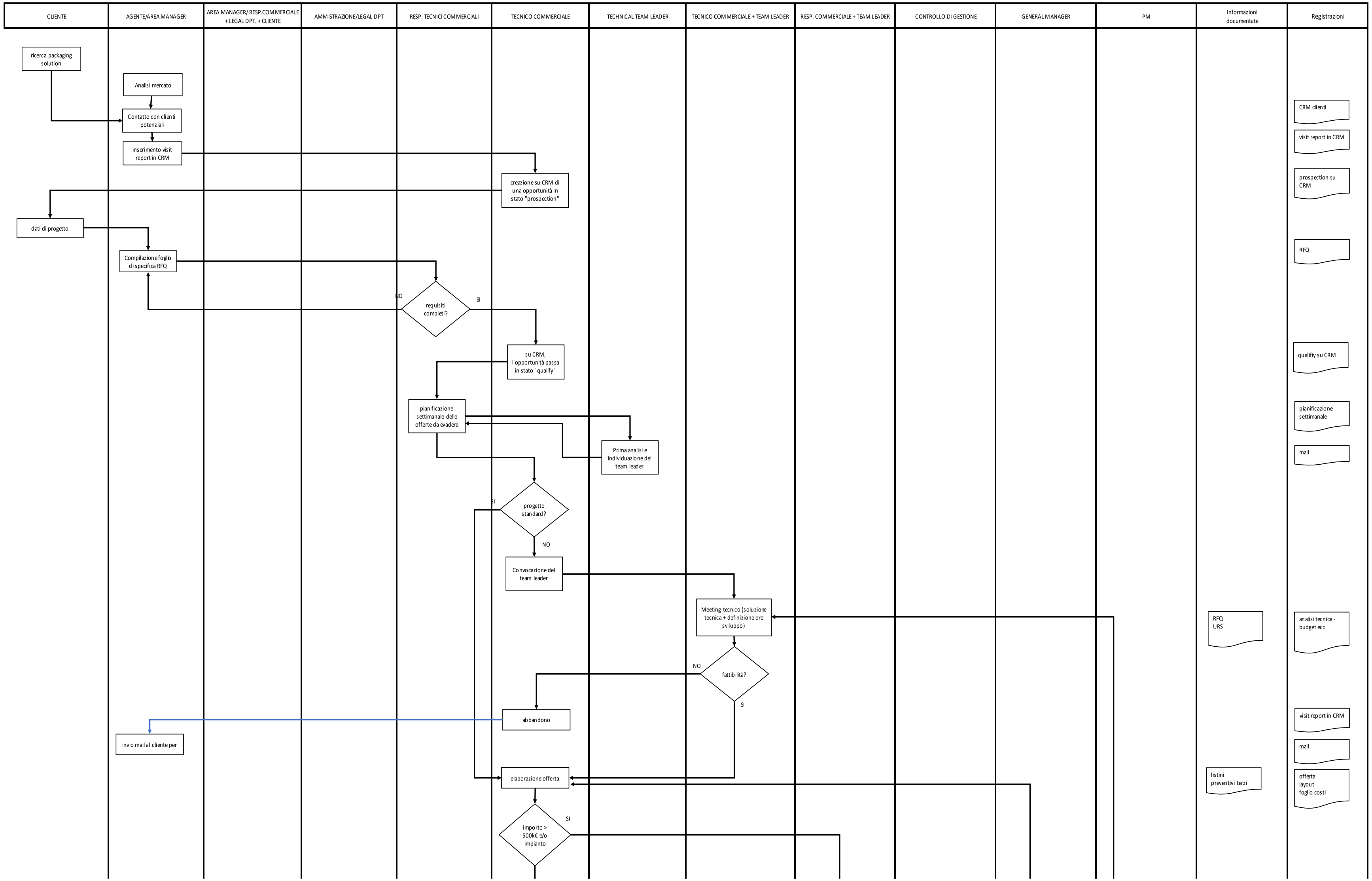
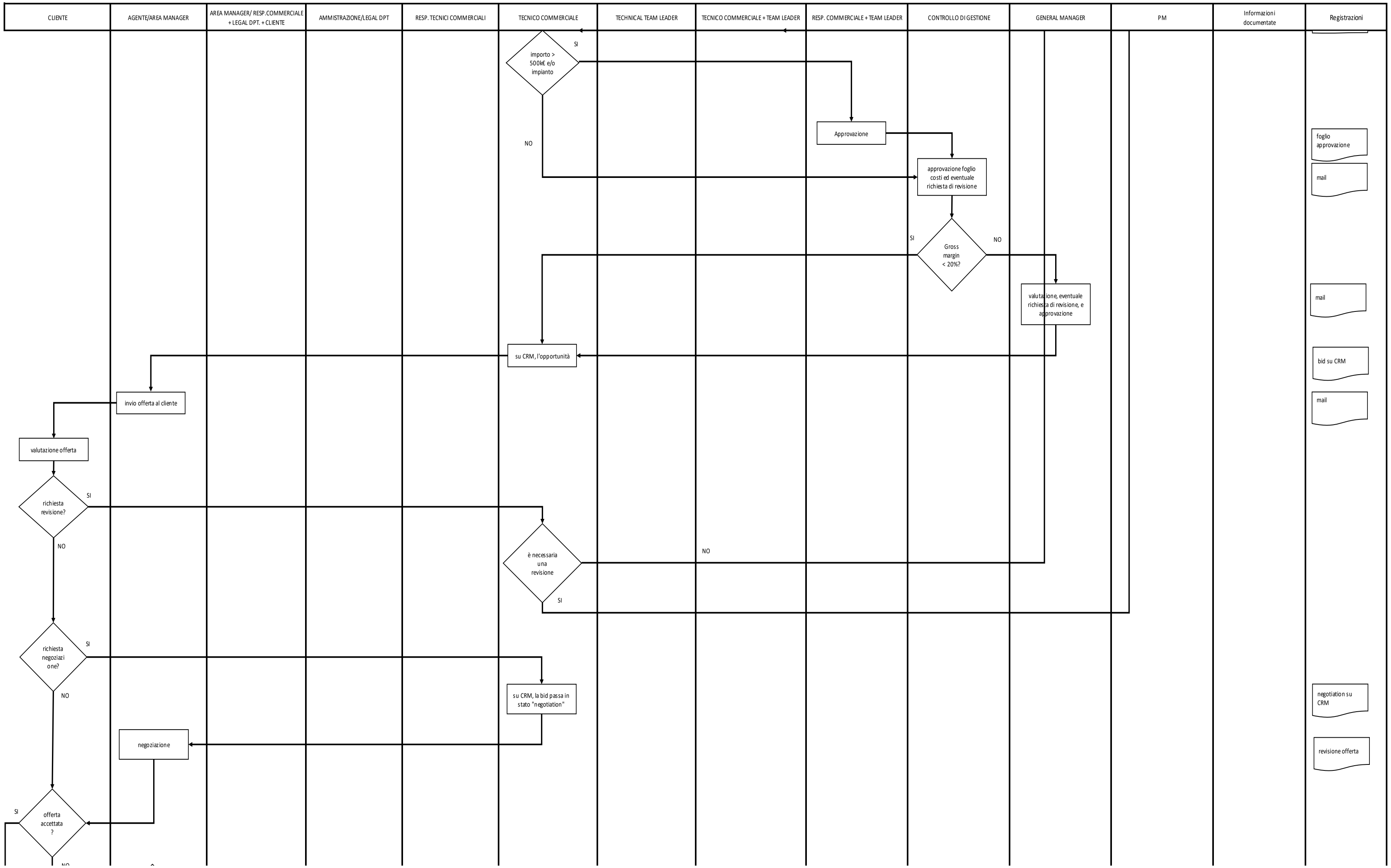


Figure 18.b: part 2 of 3 of Sales Department to-be state Makigami.



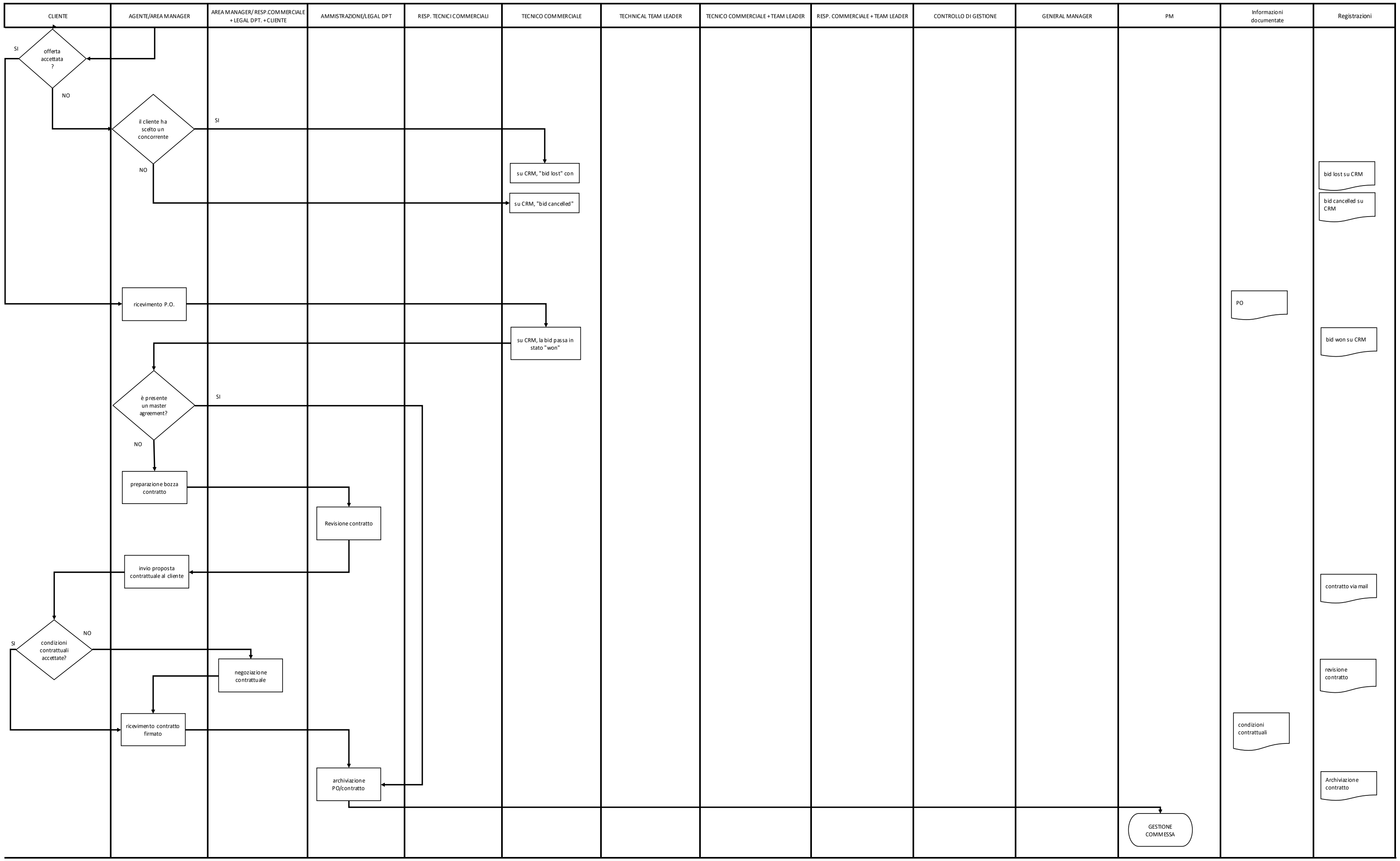
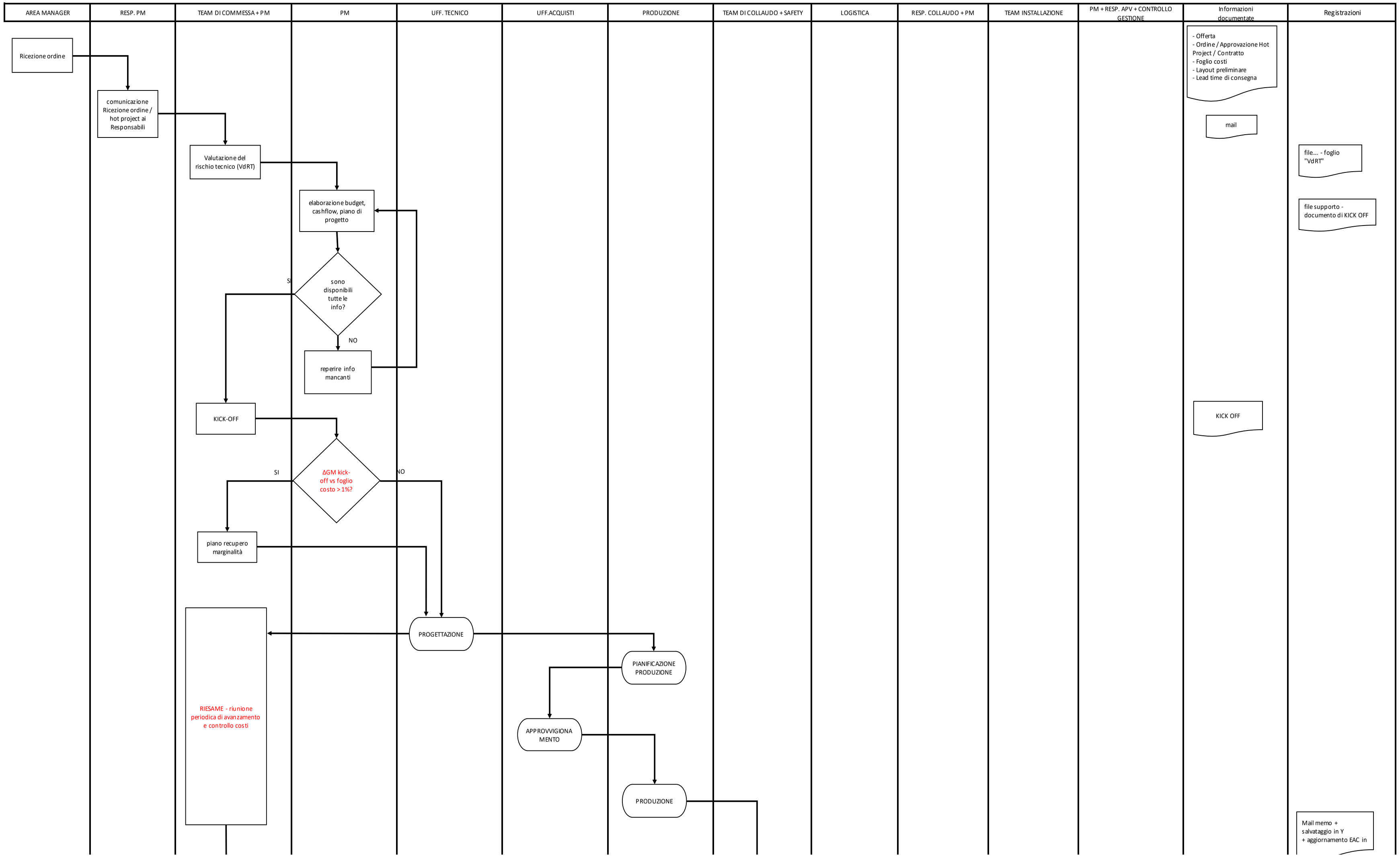


Figure 18.c: part 3 of 3 of Sales Department to-be state Makigami.

Figure 19.a: part 1 of 2 of Program Management to-be state Makigami.



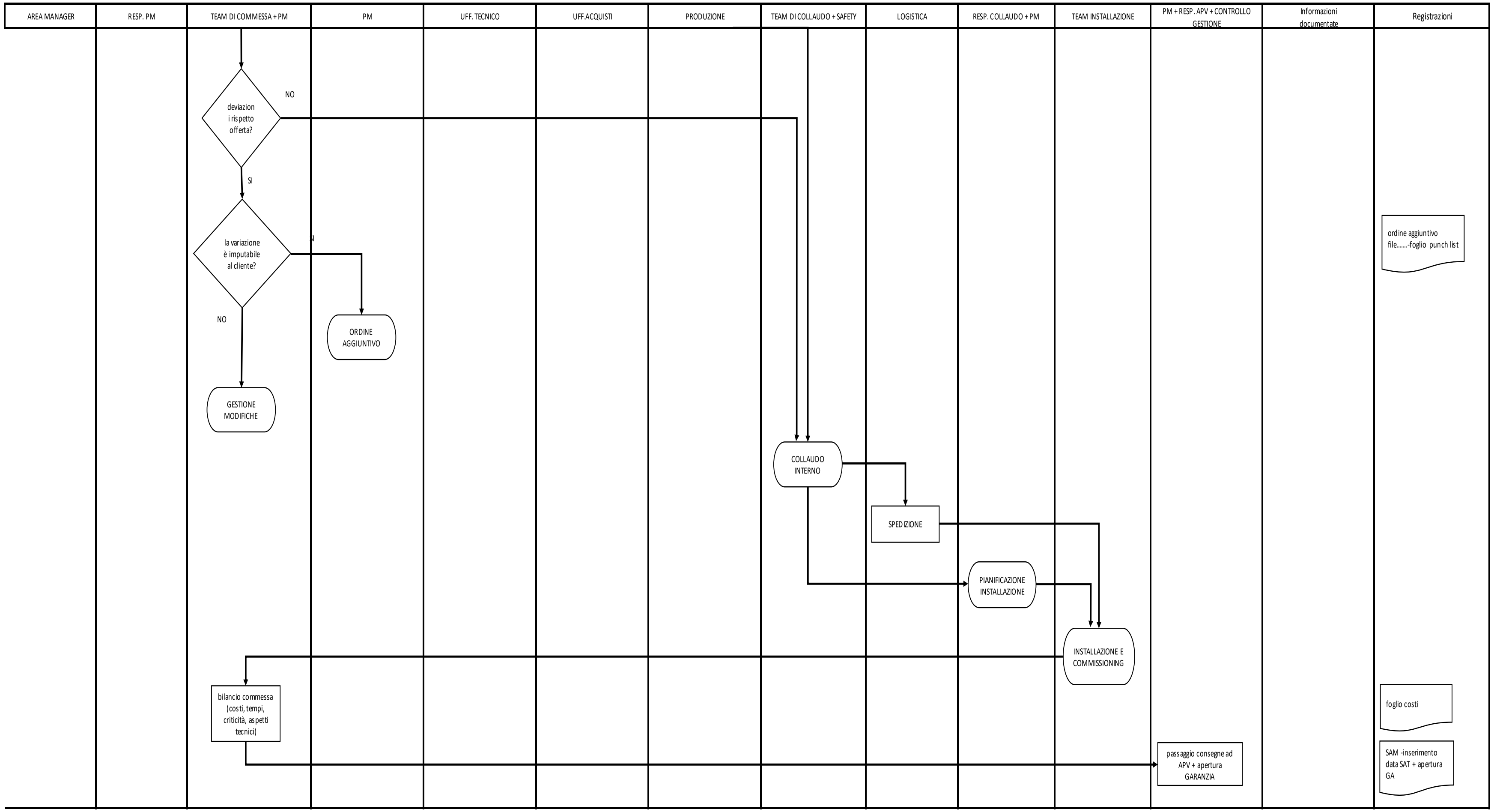
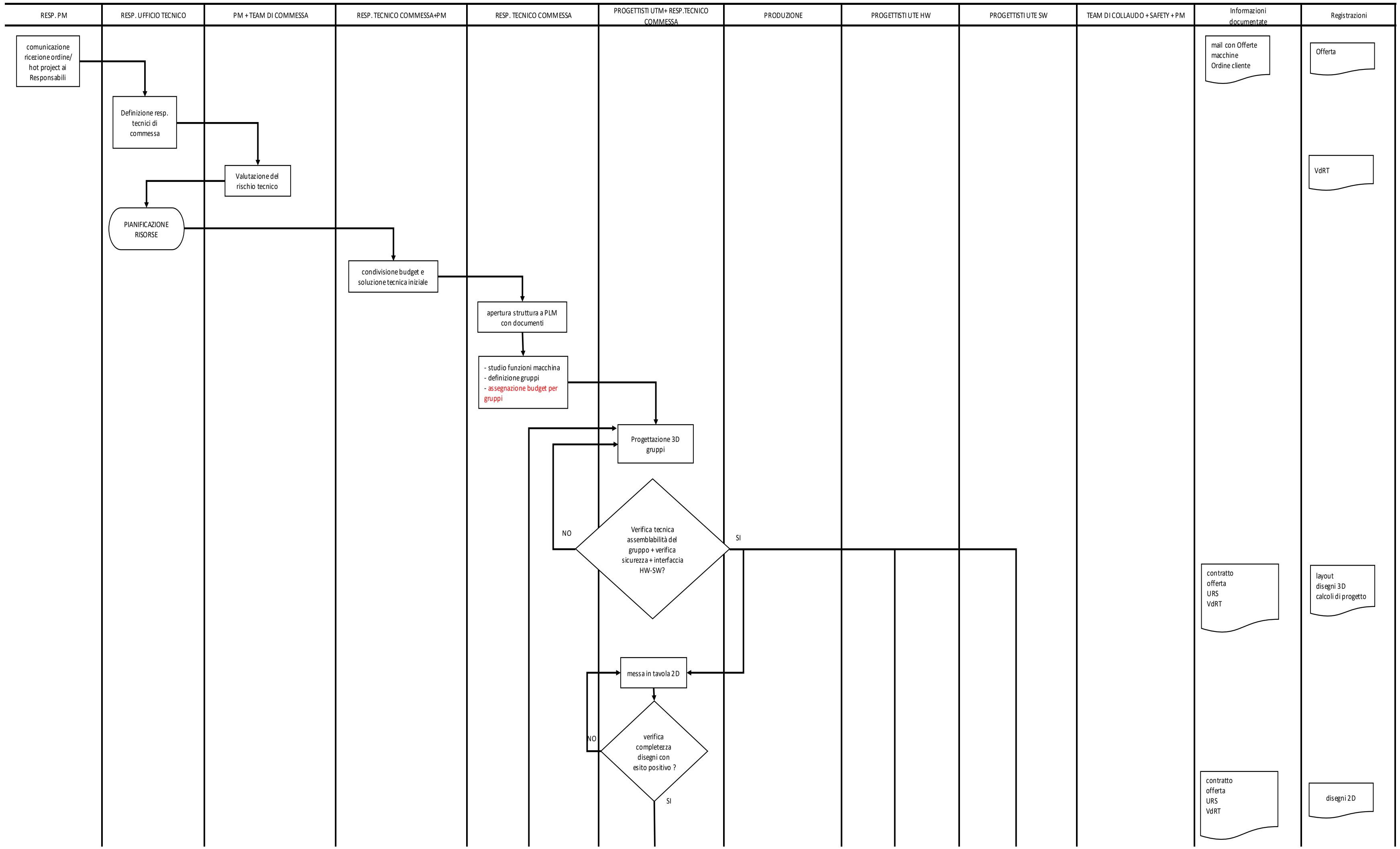


Figure 19.b: part 2 of 2 of Program Management to-be state Makigami.

Figure 20.a: part 1 of 2 of Technical Department to-be state Makigami.



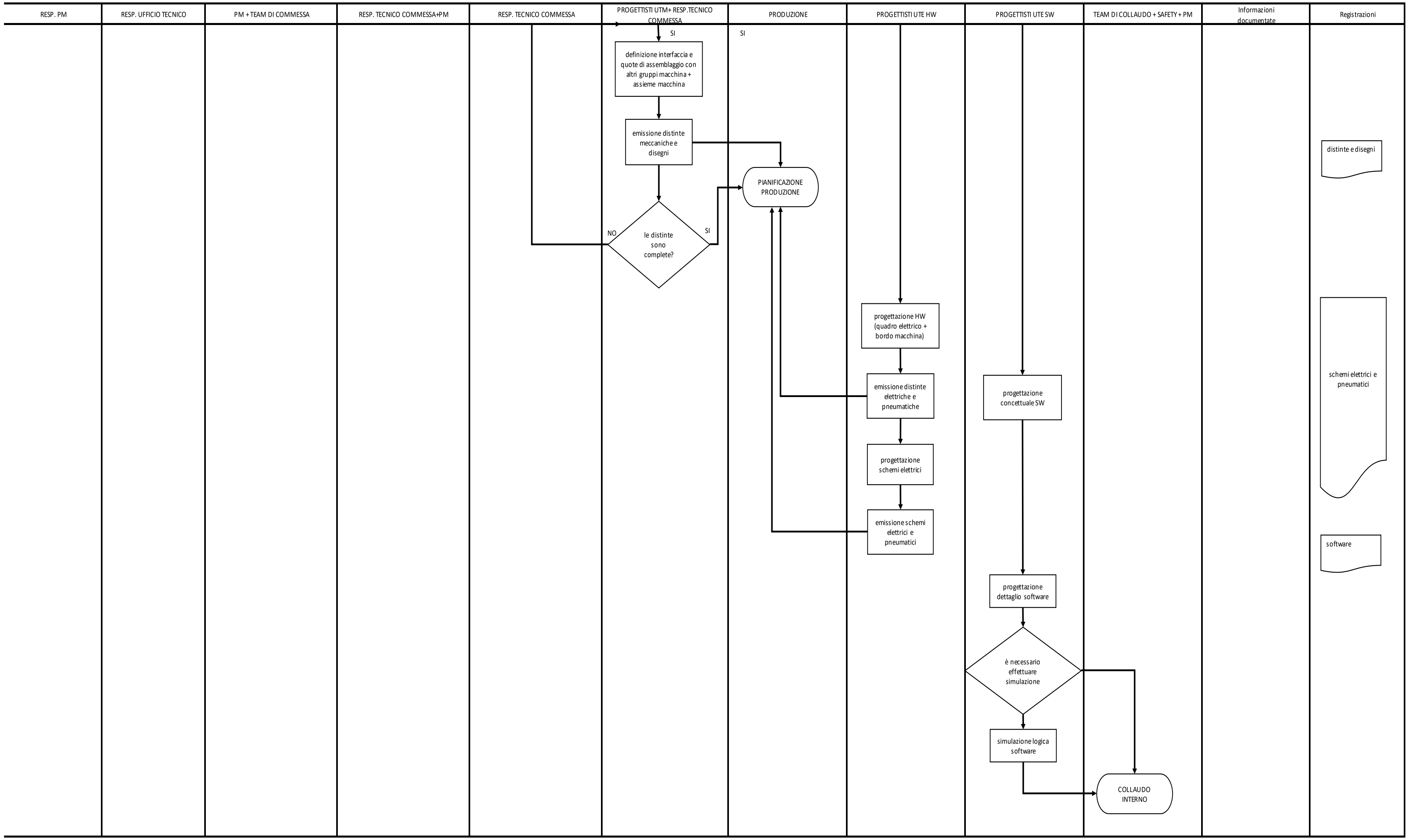
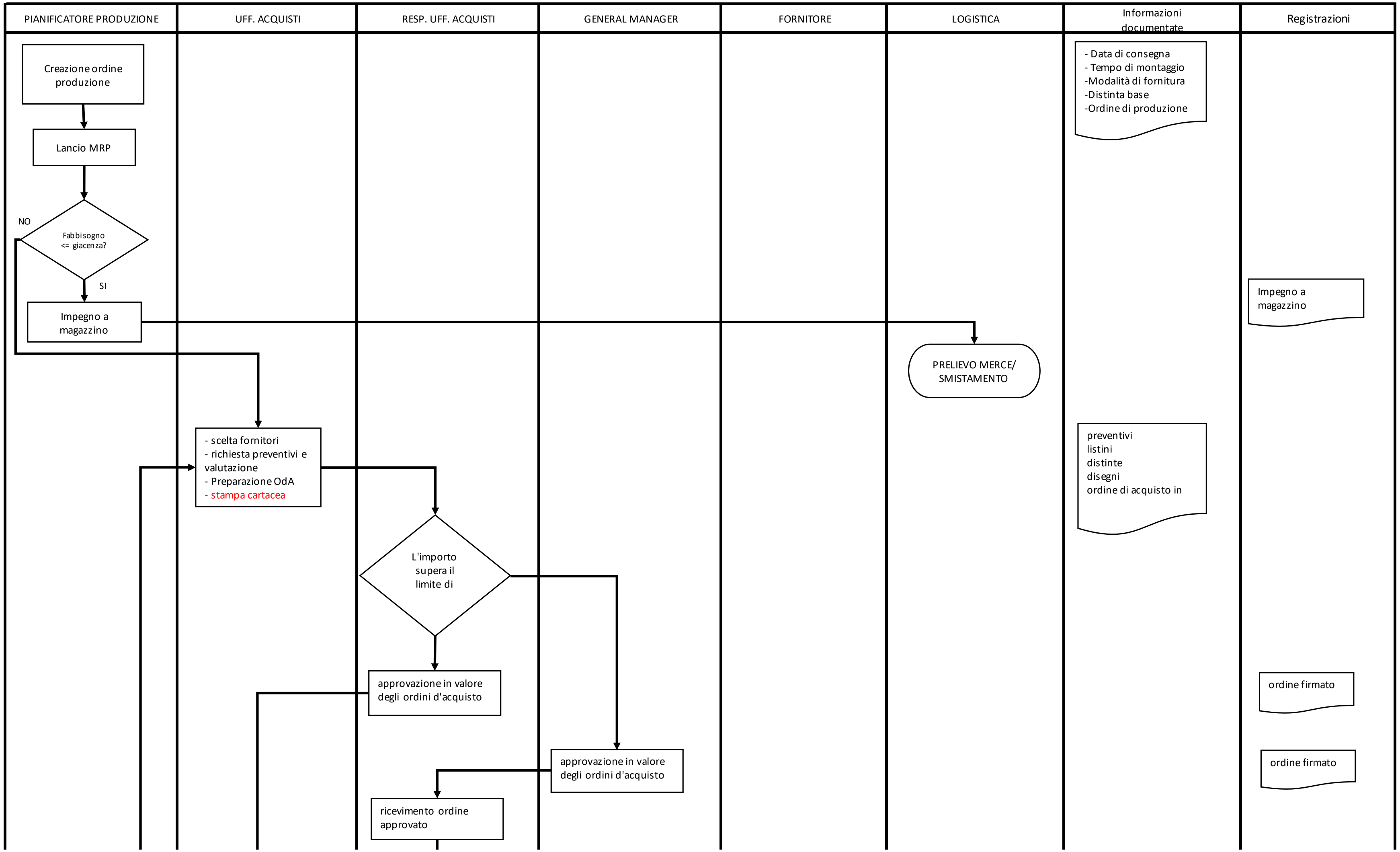


Figure 20.b: part 2 of 2 of Technical Department to-be state Makigami.

Figure 21.a: part 1 of 2 of Purchasing to-be state Makigami.



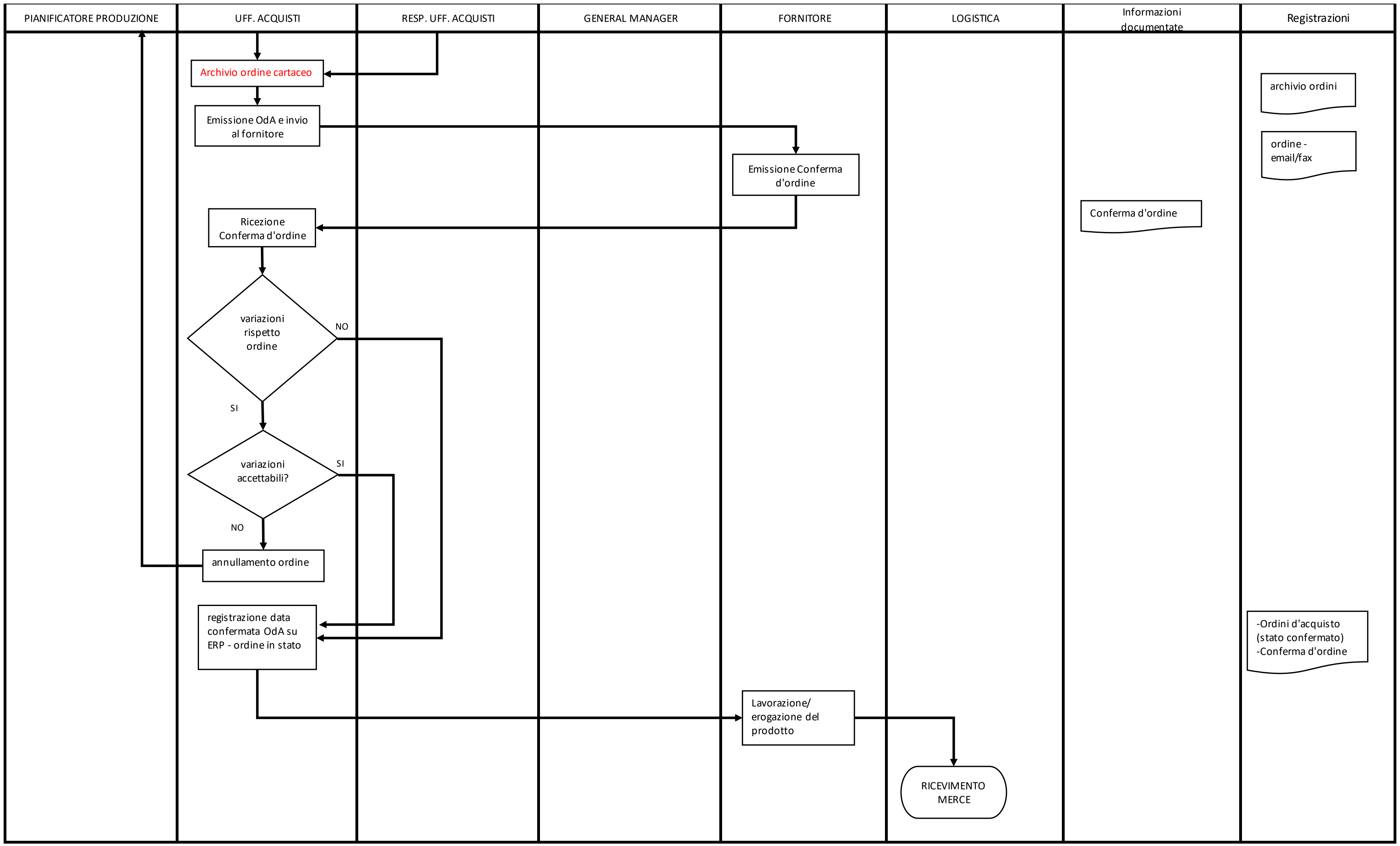
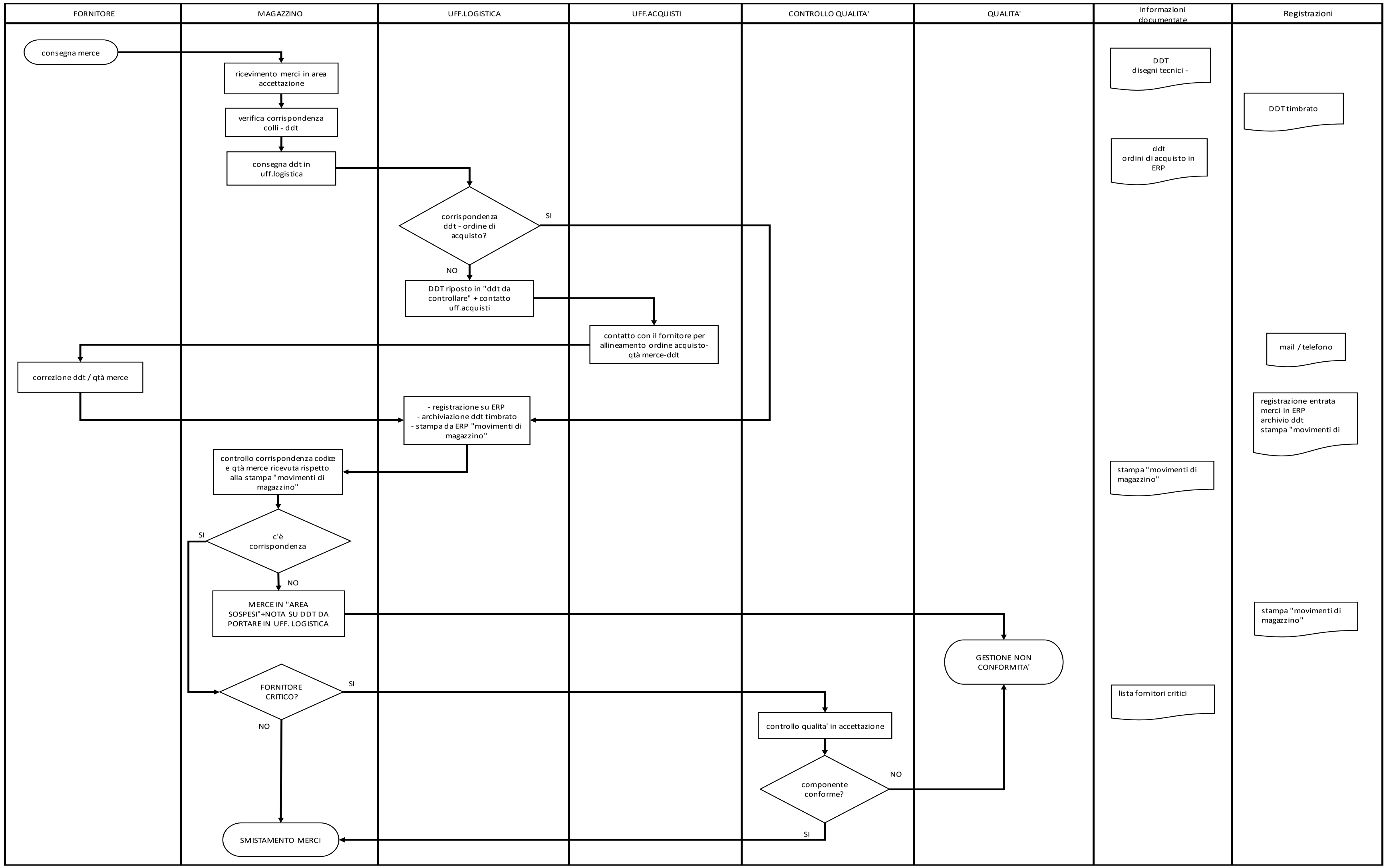


Figure 21.b: part 2 of 2 of Purchasing to-be state Makigami.

Figure 22: Goods Receipt to-be state Makigami.



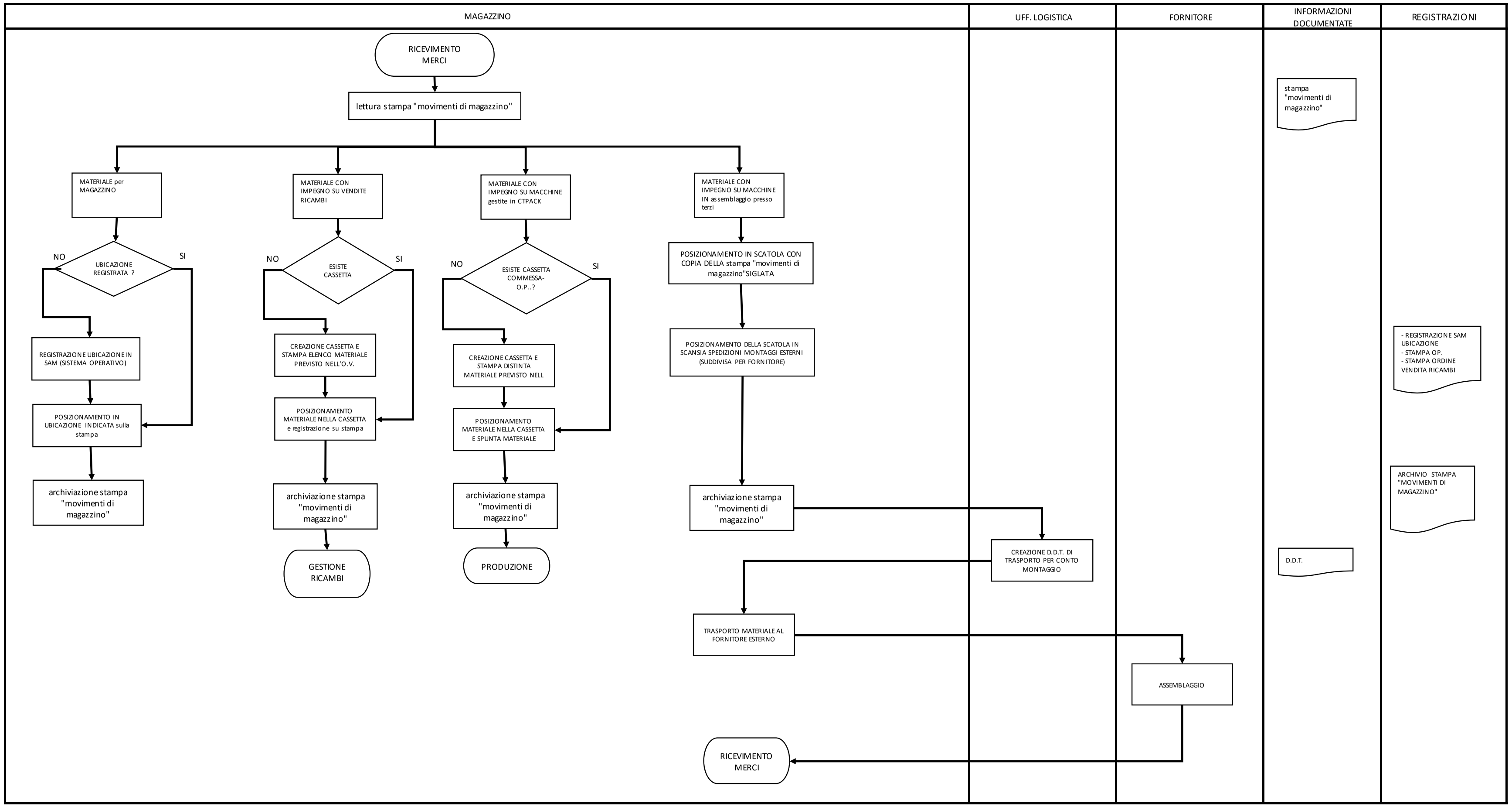


Figure 23: Goods Sorting to-be state Makigami.

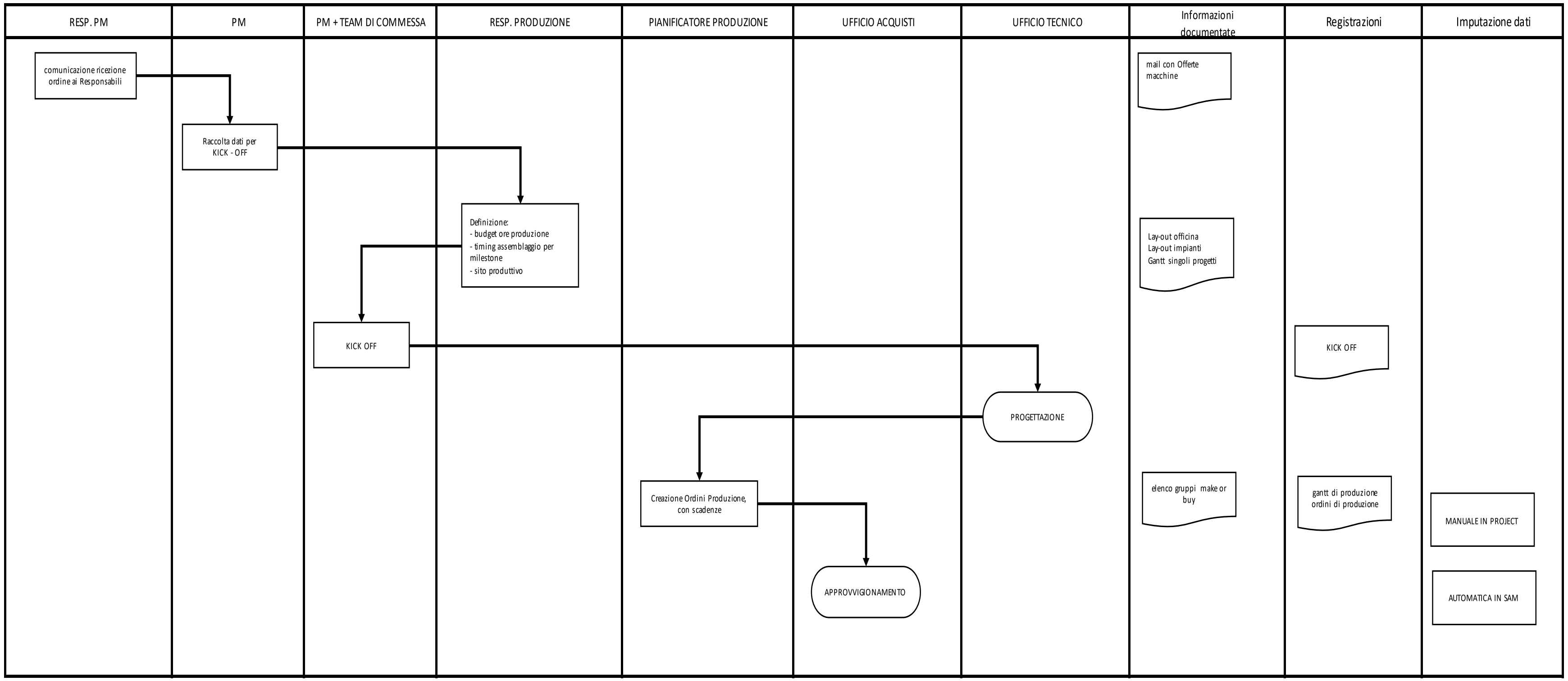


Figure 24: Production Planning to-be state Makigami.

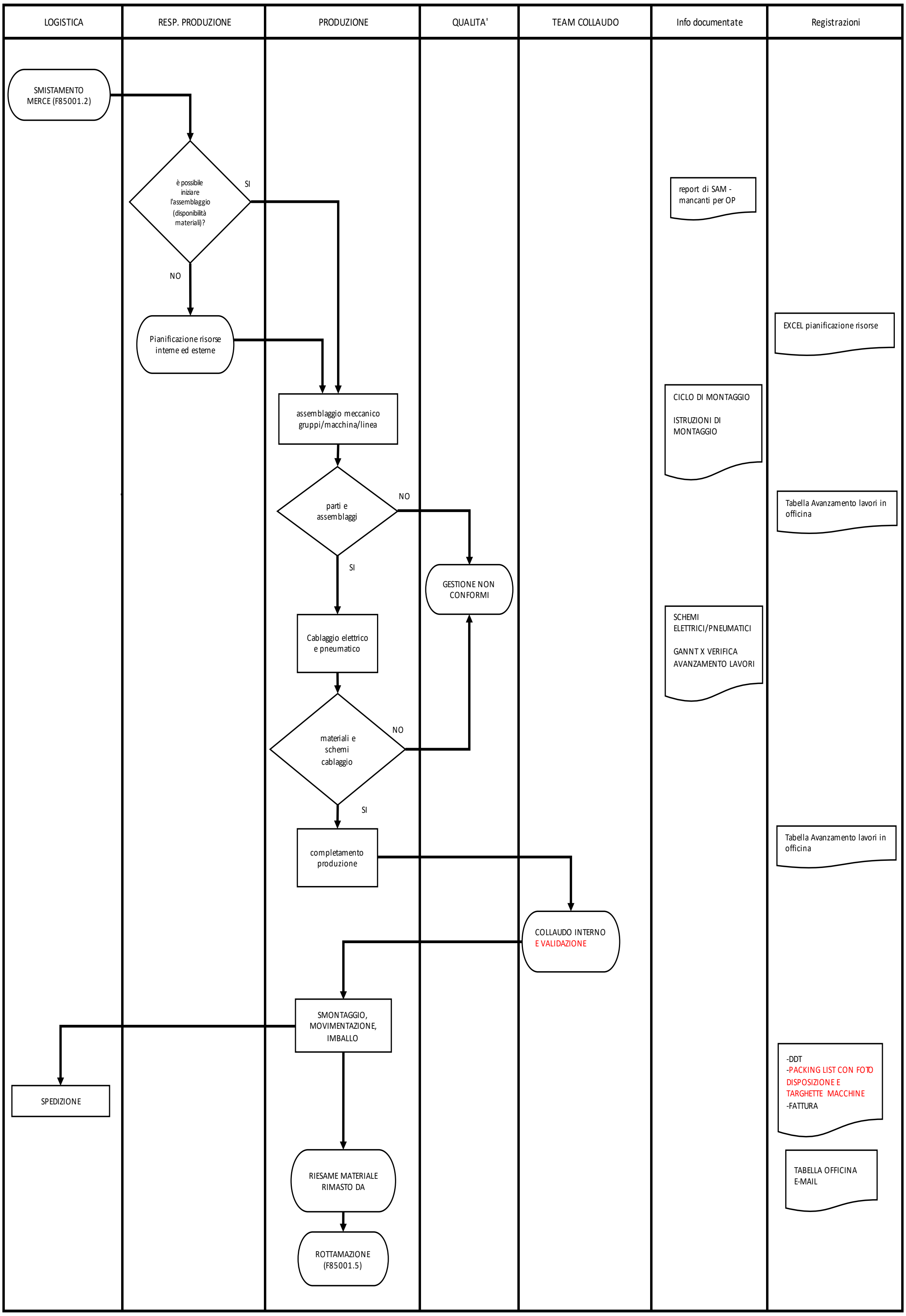
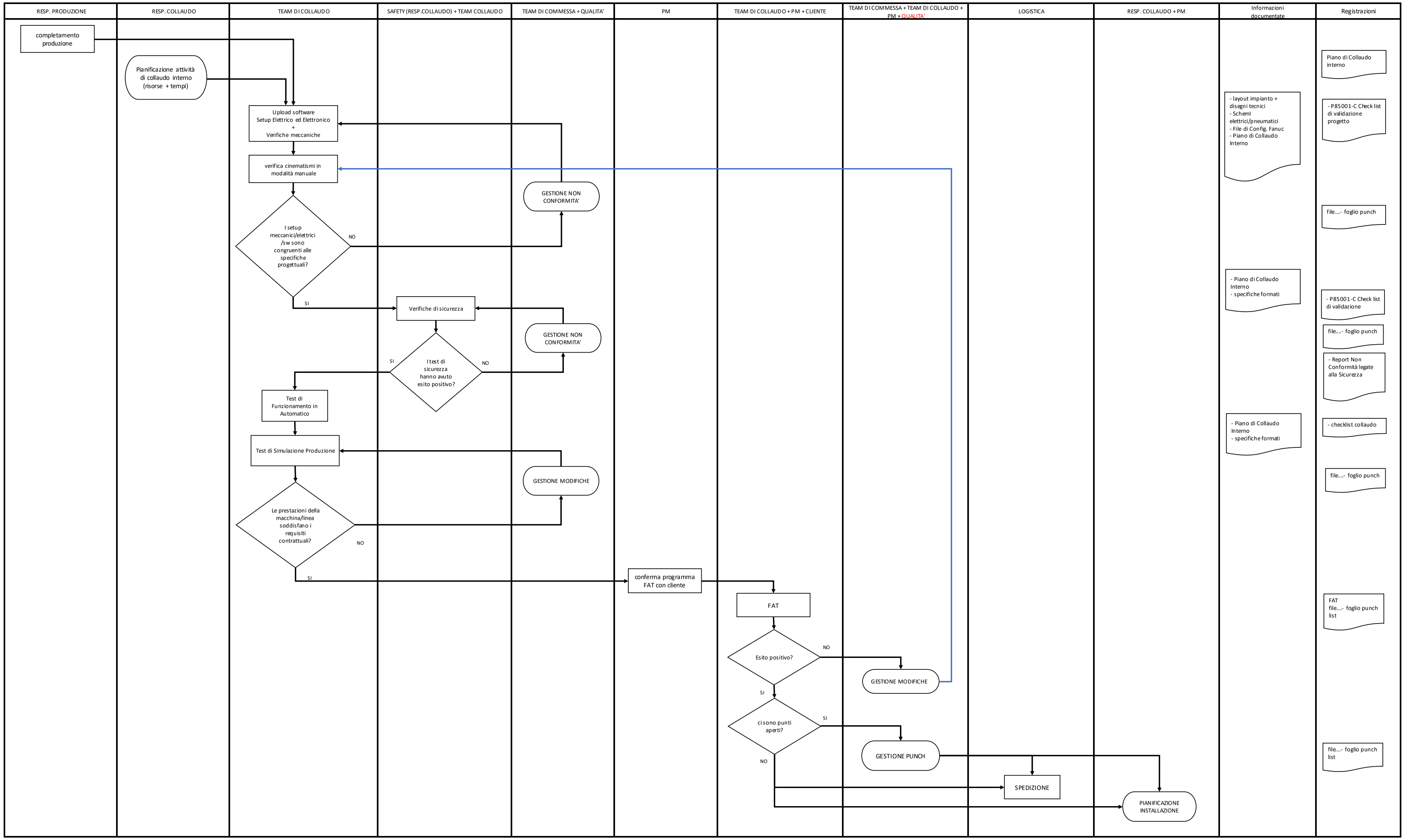


Figure 25: Production to-be state Makigami.

Figure 26: Internal Test to-be state Makigami.



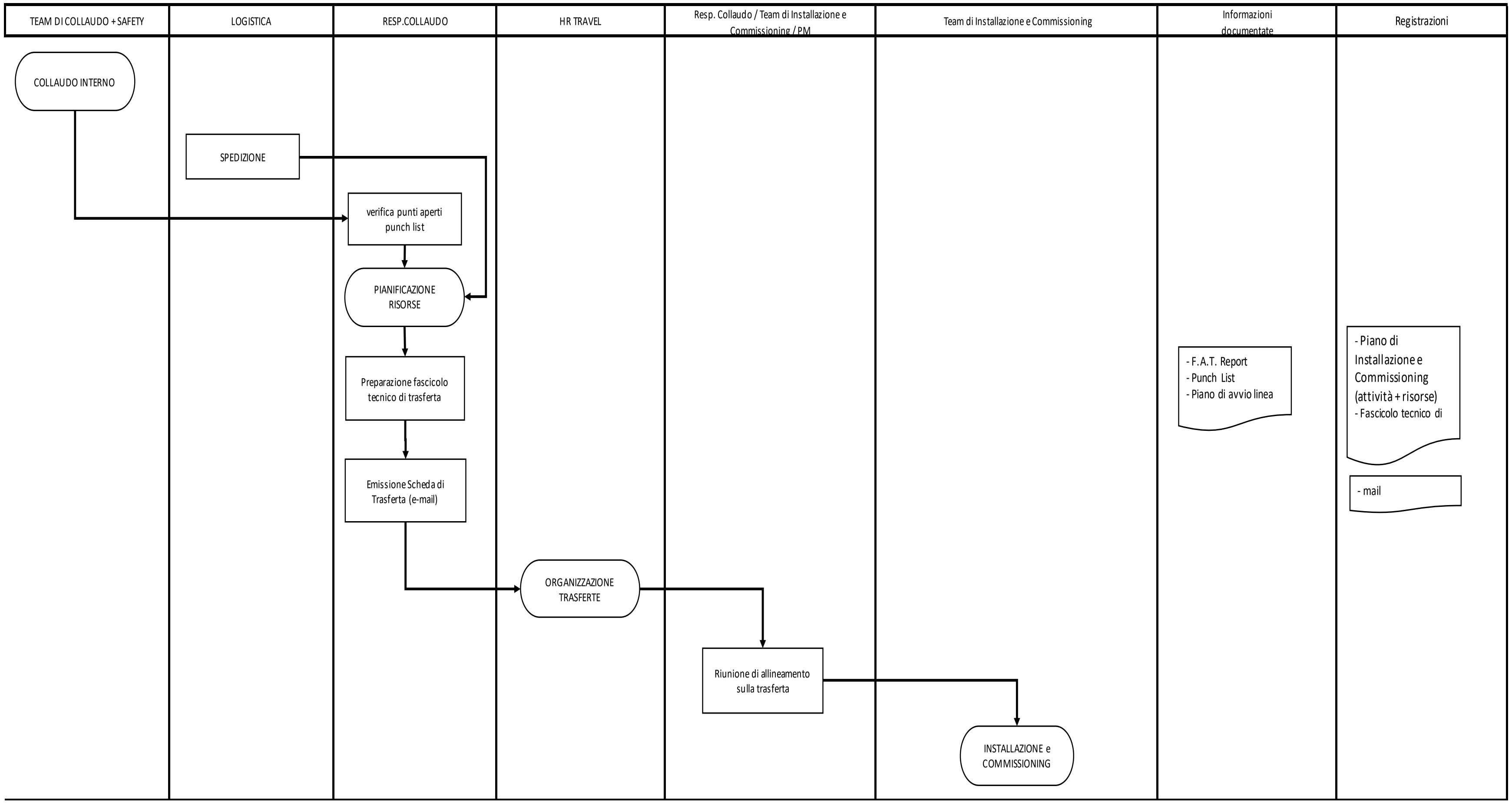
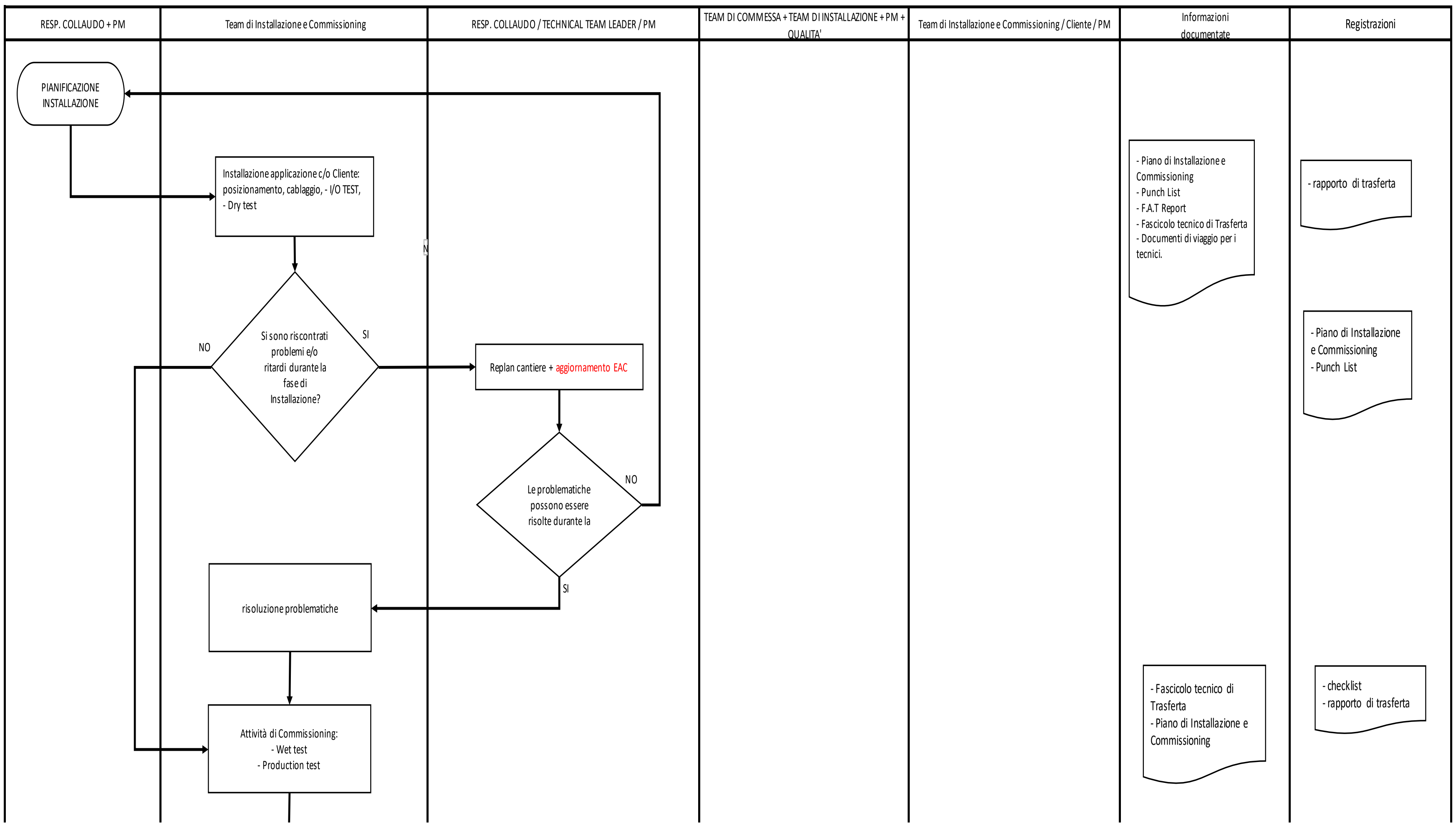


Figure 27: Installation planning to-be state Makigami.

Figure 28.a: part 1 of 2 of Installation&Commissioning to-be state Makigami.



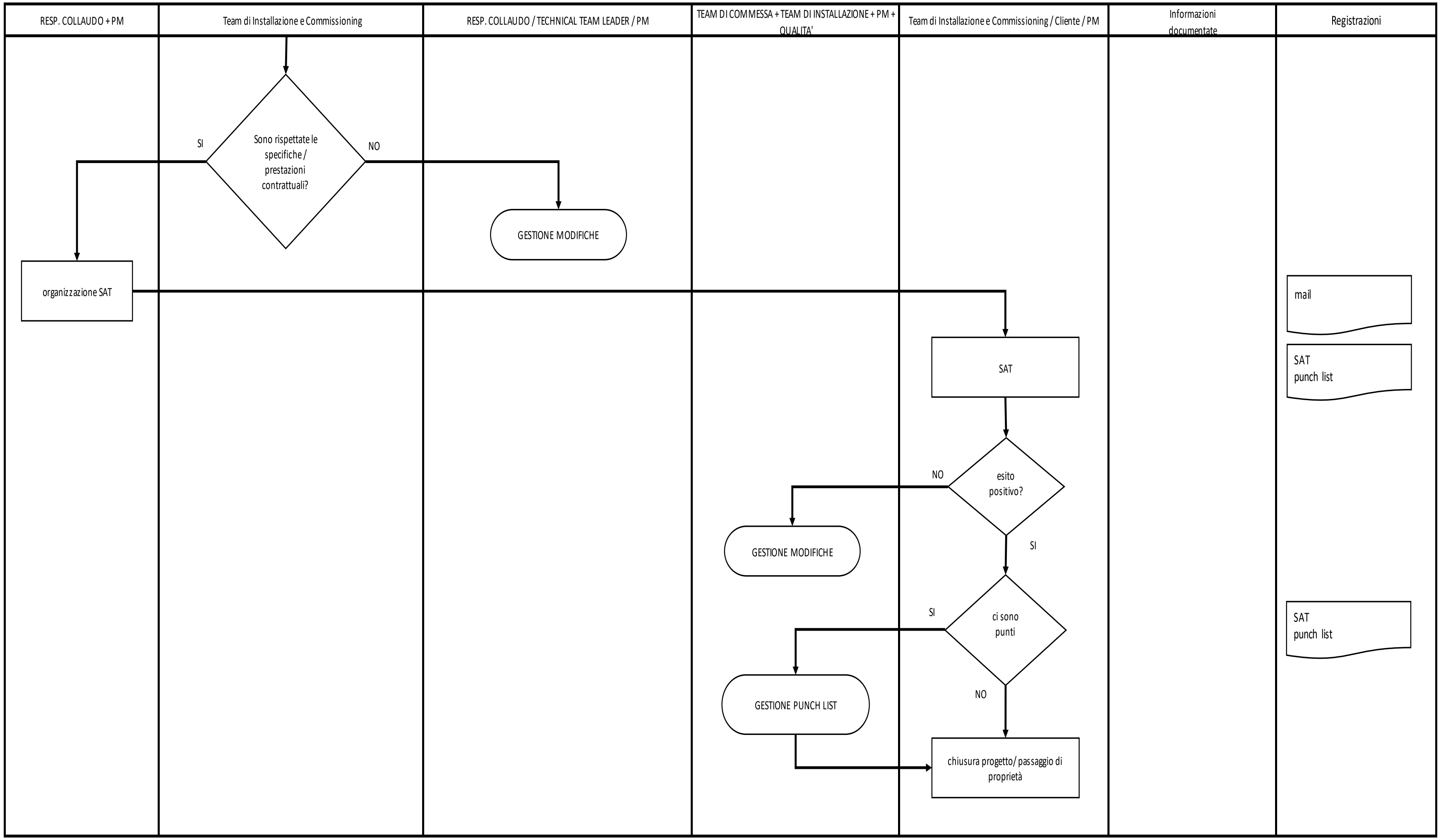


Figure 28.b: part 2 of 2 of Installation&Commissioning to-be state Makigami.

The re-engineering of business processes involved some ancillary processes as well, but these ones are not reported in this work, which aims to highlight improvement on core business processes. However, the methodology used for core processes can be easily adopted for any other process: the scope of this work as reported at the beginning, according to author's intents, is to provide with clear and real examples of the jobs done to create value by waste reduction and digitalisation on the present case study, and inductively generalise the methodology that led to outstanding results on CT Pack business for any company.

Finally, the last part of this chapter contains a brief recap of main improvements developed on "future-state" processes compared to the "as-is" maps, and the introduction of digital tools and standardisation that allowed improvements and supported them into being effective, as explained in detail in the next chapter.

Sales department:

The main criticalities highlighted by the "as-is" state map of Sales Department, that generated loops were related to commercial opportunity evaluation and offers elaboration/revision.

1. Commercial opportunity evaluation: in order to have reliable information about commercial opportunities, understand where the company could be strong in terms of solutions proposed and to execute fast and precisely, it was decided to implement in the "to-be" state process two digital tools, elaborated in depth in the next chapter:

   electronic Request-For-Quotation module, basically a form to be fulfilled by area managers with detailed information about potential customer, products, CT Pack possible solutions, risks, etc.;

   customised CRM (Customer Relationship Management Software) containing information about customers' projects of particular interest for CT Pack strategy. This digital tool has been developed and customised in order to be able to study data, statistics and master-planning forecast.

   These two digital tools implemented and empowered allowed the company to cut timing and mitigate risks on commercial opportunity evaluation.

2. Offers elaboration/revision: the "as-is" state Makigami highlighted a loop in offers elaboration/revision activities. Studying in depth that phenomenon, time-consuming activities, waste and risk catalyst were discovered. The main activities carried on are related to machines standardisation and creation of a new pricelist electronic sheets that led to solution-cost binomial certainty.
   New pricelist electronic sheets, strictly related to standardisation of machines that will be discussed in the next section, allowed to drastically reduce offer elaboration-revision timing and decision-making activities.

Technical department:

The main criticalities highlighted by the "as-is" state map of Technical Department, that generated loops were related to technical layout modifications due to conceptual design of customised solution and onerous and time-consuming detailed design phase of completely customised solutions.

The main activities introduced in Technical Department "to-be" state process are the following:

1. Technical study of the opportunity and RFQ data (together with sales engineers) for highly customised projects: this transaction reduces the risk of layout macro-changes during the conceptual design phase. This activity is no longer necessary for the majority of projects, thanks to the extensive standardisation of components and machines.

2. Standardisation: discussed in depth in the next section, standardisation of products, machines and components bring incredible improvements on all the business. Effects on technical department are related to significant cost and time reduction and components cost-awareness. Non-conformities KPIs have benefited of standardisation as well.

3. New PLM (Product Lifecycle Management Software) and related procedures: PLM Software, as explained in detail in the next chapter, if compared to the previous tool used, a Product Data Management Software, allows to better keep track on conceptual design, detailed design, drawings revisions, solutions adopted, reducing timing and risk of duplication of codes and mistakes.

   Furthermore, in order to have structured assignments for Purchasing Department, it was decided to gather bills of material (BoM) following the tree-organisation of machines in the PLM: starting from the smallest set, sub-components, through components, parts and finally the biggest set of components that can be found in a project: machines.

   Albeit this organisation could seem difficult to understand, gathering the bills of material following the structure of PLM allows Technical Department to have three milestones in the process for each project: standard and commercial components BoM, detailed design drawing BoM, completion BoM. According to these packages of materials, Purchasing Department reduced consistently the operations to be done by buyers and synergistically create values with improvements acted in the Purchasing Department.

   Finally, PLM allows to have a variety of data related to codes, revisions and so on, that create cost-awareness of design on the whole technical team.

Purchasing department:

The main benefits experienced by Purchasing Department are related to standardisation, that allowed to enhance its structure and responsibilities.
Indeed, standardisation streamlined the following activities of the department: suppliers scouting, definition of preferred suppliers for certain elements through yearly supply master agreement, quality control of goods delivered.
Main results, but not limited to these, are: economic advantages on supplies, reduced lead-time, reduced non-conformities since the main goods from each supplier are identical or similar.
To be mentioned that the whole supply chain involves local suppliers, national suppliers and multinational suppliers (e.g. Rockwell Automation, Siemens, Fanuc, Keyence, etc.).

Furthermore, customised CRM helps in master-planning forecast, since its output are data to study suppliers chain work load for future projects, addressing of new orders to suppliers not saturated in that period or, eventually, projects standard selling lead-time modification after detailed markets analysis about overall supply chain lead time.

Then, standardisation allowed Technical Department to automatically gather assignments for Purchasing Department following a tree-organisation of projects bills of material: in this way operations to be done by buyers are significantly reduced (buyer, if applicable, can set the order for a group of components or an entire part of machine instead of hundreds of single codes).

Finally, Purchasing Department introduced a supply chain collaboration software that is able to automatically check orders status.
Buyers with this tool have not to spend a good amount of time checking manufacturing status and delivery status of orders, since it is done for most by the software, so they can focus on urgency, purchasing or other added-value activities.
This supply chain collaboration software, is discussed in the next section.

Production department:

As far as Production Department is concerned, the main issue highlighted by "as-is" state mapping was related to non-conformities: internal non-conformities belonging to design phase, or external non-conformities due to suppliers manufacturing mistakes.
The re-engineering of processes, digital tools introduced and standardisation itself reduced the problem in both the directions: standard components verified already by technical team and already manufactured in the past by selected suppliers, historical data on PLM software about previous revisions of a specific component, etc. contributed to dull the issue.

Whereas non-conformities would arise, a dedicated procedure was created and implemented to manage non-conformities. This procedure enable definition, tracking, root cause search, data to avoid the same non-conformity in future works.

Finally, assembly procedures have been studied and introduced for standard machines to ensure replicability, top quality standards, minimum assembly time.

Commissioning department:

Commissioning Department benefited of the improvements done in all the upstream processes: non-conformities decreased, standard assembly procedure to increase quality and reduce timing of assembly, purchasing lead time under control to avoid as much as possible supply chain delays, etc.

Furthermore, depending on the type of machine to be delivered, internal test procedures have been studied and implemented as well.
The aim of internal test procedures is indeed to guarantee maximum quality standards and replicability of internal test and commissioning tests, over and above the consequent timing and cost reduction for these two processes.

Commissioning process speeds up because there is now an engineered procedure to be followed, depending on the technical nature of each machine belonging to a project.
The use of an electronic checklist completes the standardisation of this important activity, helping step by step technicians who perform tests, training to customers' operators and customers' technicians and avoiding general oversights.

Program Management department:

Program Management Department is a collector of information for each project.
Its target is to keep aligned projects' teams, anticipate action needed, reduce costs, timing and risks, correct eventual deviations pursuing the needed actions to be taken, create an environment where projects can be completed successfully according to the schedules and plenty of customer satisfaction.
Program Management Department is a facilitator and its process has been engineered in order to enhance improvements done in all the other processes and on the business in general.
Proactivity is the main feature of the department and all the transactions contained in Program Management process are focused on that.
The program management is a tactical simultaneous sight of all the projects in progress, and proactivity allows to design scenarios to optimise resources, decrease risks and reach projects targets according with board management strategy.

In order to briefly recap all the steps taken until now, after the choice of the right tool to map processes, a baseline was created and analysed: the "as-is" maps. Then, main improvement areas have been identified from analysis and new processes have been re-engineered as shown in detail in the present chapter: note that indicators of each one of the "to-be" processes (core and ancillary) are not reported in detail in this work because currently under monitoring to build statistics, however Figure 29 shows the expected impact on business lead time:

Actual	Forecast after improvements
Lead Time (min) ~ 220 gg	Lead Time (min) ~ 180 gg
Lead Time (max) ~ 1000 gg	Lead Time (max) ~ 700 gg
Weighted Lead Time ~ 330 gg	Weighted Lead Time ~ 230 gg

Figure 29: comparison between actual lead time and the forecast after improvements. Weighted Lead Time is the result from statistics depending on projects' complexity and extent (from historical data of projects between minimum and maximum lead time).
To be underlined a weighted reduction of lead time of 100 days (around 30%), that set to 230 day the time from Purchase Order receipt and Site Acceptance Test completed (final acceptance of the project by customer, after final commissioning in customers' plants). Forecast Weighted Lead Time of 230 days is currently being confirmed by the first measurements done in recent "average" projects, however still not numerical enough to confirm a strong statistic.

In the next chapter the focus is on the introduction of digital tools and standardisation that allowed improvements reported and supported them into being effective.

4.4 Digital tools to improve business processes

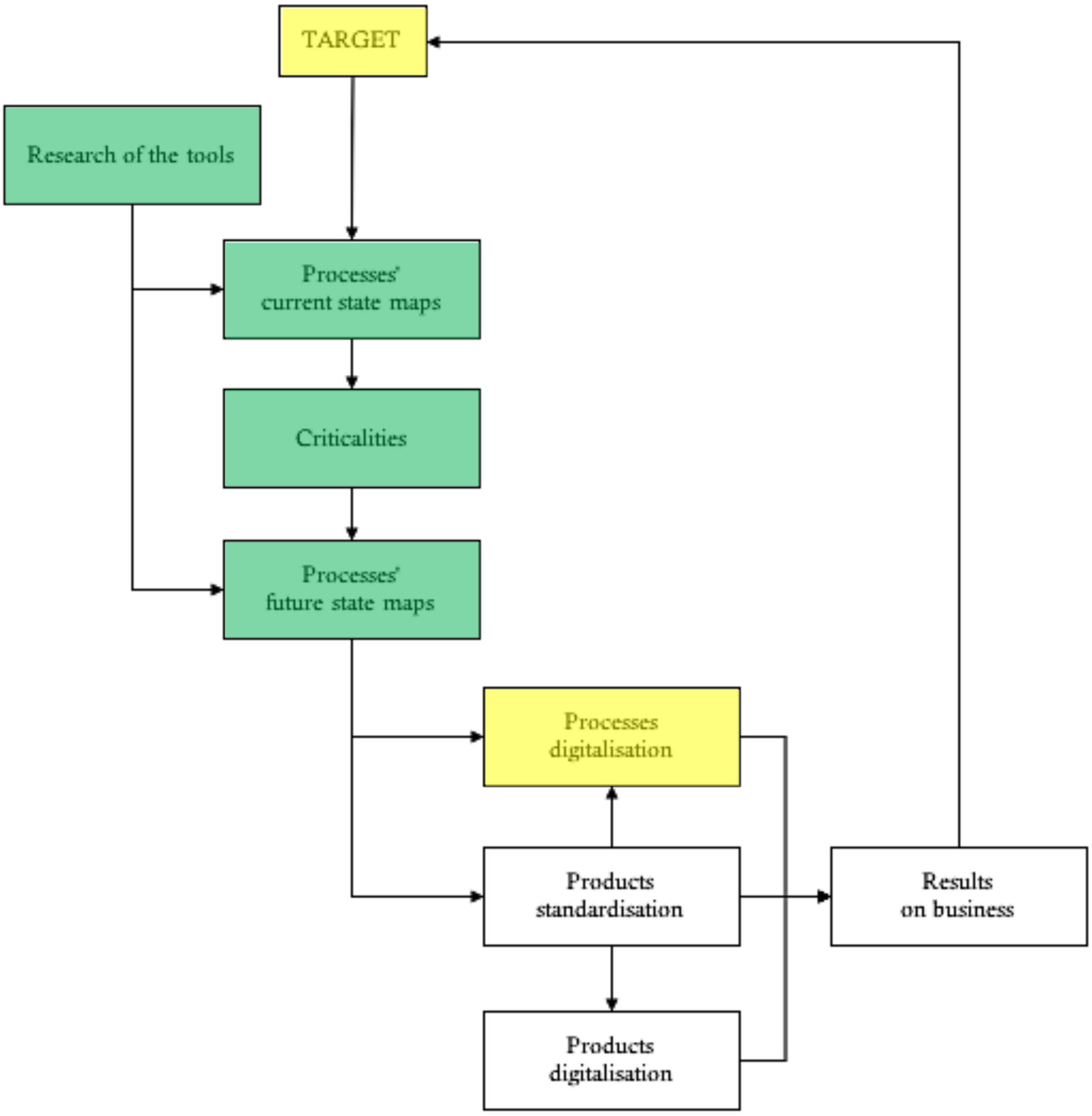


Figure 10.4: diagram that summarise the development of the research.
In this chapter the focus is on digital tools to enhance re-engineered processes.

In the present chapter all the digital tools introduced in business processes "to-be" state are briefly shown, with some general explanations about their nature and a discussion regarding qualitative improvements produced on processes.
Data regarding new processes performance, as reported at the end of the previous chapter, are still under monitoring to build strong statistics, however synergic benefits on business due to Business Process Digitalisation and Business Products Digitalisation are already significant, as shown in Results and Conclusion chapter.

Following the logical flow of processes, below the overall view of binomial department-digital tool is reported:

- Sales Department: customisation of CRM software, new digital pricelist;
- Technical Department: new PLM software;
- Procurement Department: new IUNGO supply chain collaboration software;
- Production and Commissioning Departments: new digital procedures for assembly and test.

Sales department:

Digital tools introduced in Sales Department are CRM customisation and a new digital pricelist.

Firstly, CRM (Customer Relationship Management) is a term related to the concept of customer management and customer loyalty. CRM target is to enable companies into stay continuously in touch with their customers, by means of marketing strategy.
In these paragraphs we are not going to see CRM as a vehicle for marketing management and customer management, but its role as a digital tool to make previsions on sales, extending its potentialities towards the inner frame of the company rather than the outer one.
Indeed, the "as-is" state of this software, in order to give continuity to the Makigami terminology, was the classical frame of a CRM software targeted towards customers, quotations database, relationship database and so on.
Since CRM is the first touch with customers and the space where the main information about new potential projects are reported, we figured out that, with some customisation, data gathered could have been strategically useful for company's internal processes master-planning.
A master plan is a dynamic long-term planning document that provides a conceptual layout to guide future growth and development. We declined this definition in CT Pack's overall organisation.
Thus, customisation consisted in create new fields to be completed by area managers, where there are data related to types of machines offered, info about products to be packaged over and above information about customer, site, etc.
All these data gathered together in a structured report allows managers to foresee work load and supply chain load depending on specificity of each machine included

in the offers, in order to manage and eventually balance resources on their skills and preferred suppliers on their actual load and future previsions.
In this way the organisation, depending on the success rate of each quotation, knows in advance the main features of future projects incoming and can be more effective and quick at purchase order released since the organisation and suppliers are already balanced.
This simple customisation of the CRM software together with a great job of Purchasing Department on suppliers' agreements, as reported later in this chapter, brought excellent results on operations that contributed to overall performance.

On the other hand, the improvement that mostly benefited on business results is the creation of a new digital pricelist.
Sales Department, indeed, work with this tool every day to bring business to the company, preparing quotation for a variety of customised technical solutions, and its reliability in terms of information and costs is crucial.

The methodology used to carry on this job is the same used for the whole research, so it is based on Lean Six Sigma DMAIC, in particular:

1. Define: definition of the problem (gross margin loss and previous pricelist inconsistency), definition of the target (decrease the quotation's gross margin loss to an overall maximum of 0,5% throughout all business processes).

2. Measure: measurements done on gross margin loss and buyers statistic on codes purchasing.

3. Analyse: analysis of core business products (best sellers) to set priorities on machine types to be completed firstly, breakdown of the technical structure of each type of machine and new quotations for each part of it from selected suppliers depending on manufacturing specific skills.

4. Improve: design and implementation of a new digital pricelist, that reflects the technical structure of each type of machine (as it is shown in the new PLM software) with consistent and reliable costs for each part, main customisations included. Implementation of automation in the pricelist to be able to quote many different configurations just with a few clicks, reducing quotation cycle-time.
   Furthermore, decades of experience in full customisation of automatic lines drew the attention to families of customisation that could have been simplified and standardised to be directly considered in the new pricelist as optionals.

5. Control: monitoring of new pricelist for each type of machine quoted in new projects and define a brand-new procedure for pricelist update.

Measurements done to validate the new pricelist report an astonishing 0% deviation on actual cost versus new projects' budgets costs (Sales department quotations), spotting on the target of the improvement.
In order to carry out this job thousands of codes have been studied, analysed, quoted and updated. The standardisation work done for all the machines, discussed in the next chapter, is the core activity that permitted the incredible success of new pricelist consistency and reliability.

Technical department:

Technical department digitalisation mainly consists into a migration from a PDM (Products Data Management) software to a PLM (Products Lifecycle Management) software.
In a nutshell, PDM is a folder of engineering data about products, such as computer-aided drawings, bills of materials, codes, brands, etc.
According to company growth strategy, needs changed and PDM did not provide with compliant features. The main needs were:

- Exclusive login on 3D drawings one person at time following a booking procedure (to avoid different modifications on the same source at the same time from different people).

- Be able to do research targeted on different keys such as description, emission date, designer (instead of just codes).

- Be able to classify elements depending on commercial category of use (for instance shafts, flange, brackets, etc.).

- Be able to manage the whole lifecycle of a component, monitoring every step.

- Be able to manage revisions and obsolescence of components, highlighting the reasons that led to revisions and the historical of components.

- Be able to use the same environment and interface with the ERP software to launch purchasing orders with a standard simple codification.

PLM permits to fulfil all the reported needs, albeit migration had been difficult: decades of years of codes had to be revised and uploaded with the new codification and the needed data attached.
Migration from PDM to PLM required a couple of years of back-office work and about 6 months from the go-live to reach again the previous productivity of all the technical team, however the interaction between processes of different departments is now smooth and simplified.

The introduction of PLM software allowed to decrease significantly the number of codes of similar goods: previously similar elements were named with different codes

and researching them were difficult, whereas with PLM classification depending on commercial category of use Technical department was able to identify standardisation areas between similar components, decreasing as a matter of fact the number of codes that represent a commercial category of use.
This job together with heavy standardisation on machines parts benefited on the overall business and on Procurement department operations in particular.

Procurement department:

The introduction of PLM software together with the standardisation of machines and components (discussed in detail in the next chapter) allowed Procurement department to take some actions that improved the business, streamlined Procurement process (as explained in chapter 4.3) and decreased components lead-time and cost by means of yearly supply agreement with selected suppliers.

Moreover, in terms of Procurement process's digitalisation, the company adopted a supply chain collaboration software. Supply chain collaboration is defined as two or more autonomous firms working jointly to plan and execute supply chain operations, delivering substantial benefits and advantages to collaborators.

CT Pack interpreted this style of management in a vertical collaboration, that means with supplier in an earlier stage in the supply chain, where suppliers work with CT Pack buyers to ensure the right quantity of materials is delivered in the right time. As the purchase order goes through its life cycle of order to delivery, at each stage there needs to be a tight collaboration between the partners for correct and efficient execution.
Furthermore, supply agreements have been made with selected suppliers for selected items, in order to have fixed prices and delivery time throughout a year of time: this leads to reduce significantly prices for each code (economies of scale) and delivery times since suppliers can buy raw material in advance.

As far as supply chain collaboration software is concerned, it streamlined buyers' transactions allowing them to focus on more value-added activities. In particular, by means of this software:

- Importing a new purchase order from the ERP, the software calculates the amount and evaluate whether higher-level approval is necessaire or not; if yes send automatically an email report with all the details that can be approved or refused with a click.

- All the approved purchased orders are automatically sent to the selected supplier, who will confirm or modify, quantities, prices and delivery dates.

- Until these key indicators are confirmed from both the parts, the software sends automatic reports highlighting what is necessaire to be evaluated and confirmed, otherwise it sends the overall confirmation report and save data in the correct position inside the ERP system.

- In case reminders are needed (to verify the actual delivery of codes), buyer can select from the ERP all the codes needed independently from suppliers (for a single machine a variety of suppliers could be involved), and the software automatically builds and sends a report to all the suppliers that have to deliver some of the previous mentioned codes, just with the codes that each supplier is manufacturing and have not been delivered yet. Each supplier can finally confirm previous delivery date or modify it (in this last case approval from CT Pack is requested).

- Have the possibility to extract automatic KPI reports of suppliers to periodically evaluate their performances.

In general, this new Procurement department digital tool relieved buyers from different time-consuming activities/transactions, increasing productivity of the office and permits to have more control on supply chain stages, reflected into a better control of projects.

Production & Commissioning departments:

Production and Commissioning departments' processes have been empowered and improved by means of the design and adoption of electronic assembly and testing procedures sheets, studied and introduced for standard machines to ensure replicability, top quality standards and minimum cycle time for each activity/transaction.
These electronic procedures-checklists are structured considering the nature and the operation logic of each family of machines:

First of all, each type of machine is breakdown in functional groups, so the frame of assembly procedures is similar to the one of test procedures.
Then, assembly procedures are determined by the design of each functional group, putting in sequence all the necessaire steps to assembly, wire and pipe it.
Each step contains detailed instructions, descriptions, tools requested, inspection to be done and standard time to complete the activity (see Table 7 as an example).
In case of issues/non-conformities, a procedure to manage them was created and the problem is registered in a continuous improvement vision to avoid it in the future.

ID	Picture	Description	Tools	Inspections	Time	Notes
Code 1	Img 1	Activity 1 Activity …		Check 1 Check 2	00:00 min	
Code …	Img …	Activity 1 Activity …		Check 1 Check 2	00:00 min	

Table 7: example of the assembly procedure structure for a general functional group.

As far as test procedures are concerned, each functional group has to pass mechanical tests, electrical/pneumatical tests. After that, power-on, I/O tests, safety tests and kinematic dry test (test without products) are carried on in order to verify that each movement spots on.
Once all these activities are successfully finalised, machines are tested with products: firstly, manual feeding test, then small batch of product and finally continuity test according to CT Pack infeed capacity.

Figure 30 shows the logical flow of internal test procedure.

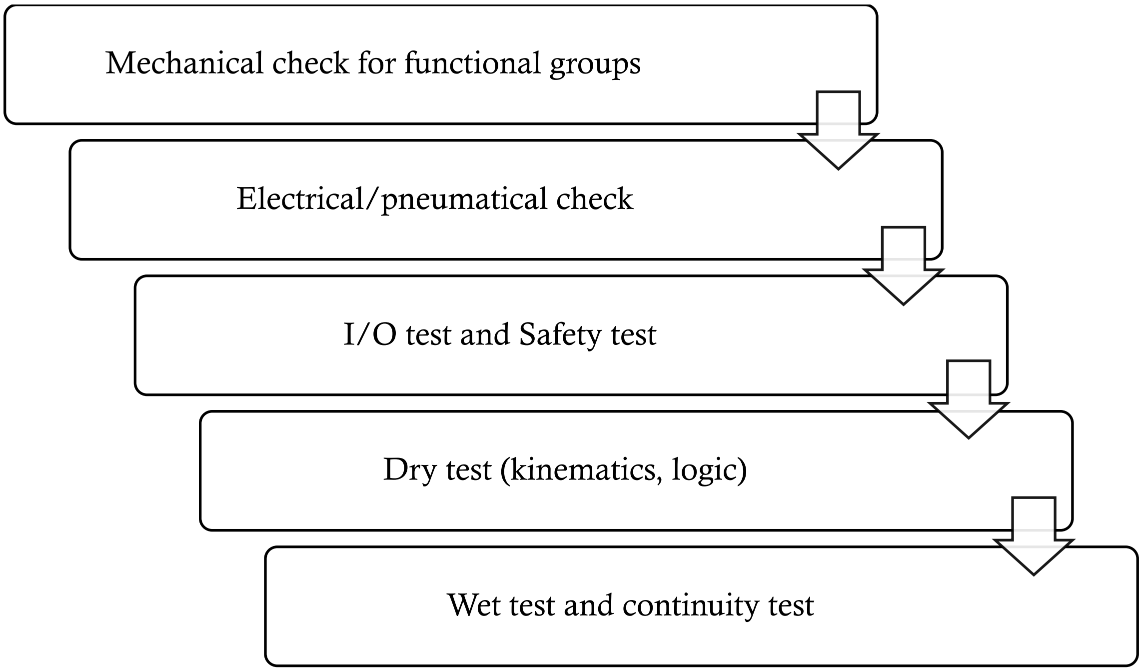


Figure 30: logical flow of internal test procedures. Each one of these stages has it particular and detailed activities to be completed and registered, customised depending on the type of machine.

In conclusion, during commissioning phase, after the installation at customer's site, all the tests are repeated (even if the time required is a lot less than for internal tests) and ramp-up of production (jointly with customer's production process) to reach contractual performances are carried out until Site Acceptance Test of the project by the customer.

In the present chapter a complete overview of the main digital tools introduced in the company has been discussed. Each one of these tools contributed to streamline processes, improving performances of departments and positively impacting on overall business: a confirmation that digitalisation jointly with waste reduction and a lean approach produce outstanding results on business.

It is author belief that it would not been possible to improve performances and streamlining processes with the power of digitalisation without a previous waste reduction and lean thinking approach, since entropy would have grown uncontrollably causing a highly-probable collapse of processes.

Now that business processes have been studied in depth, re-engineered and digitalised, in the next section another key factor for business results is analysed: products digitalisation. The next two chapters describe how standardisation of products and functional groups built foundations to take another important step for a modern company that aims to excellence in its business: products digitalisation toward Industry 4.0, taking one step at time to be able in a near future to complete the transition to become an effective 4.0 company.

5. Business Products Digitalisation

5.1 Standardisation and new designs

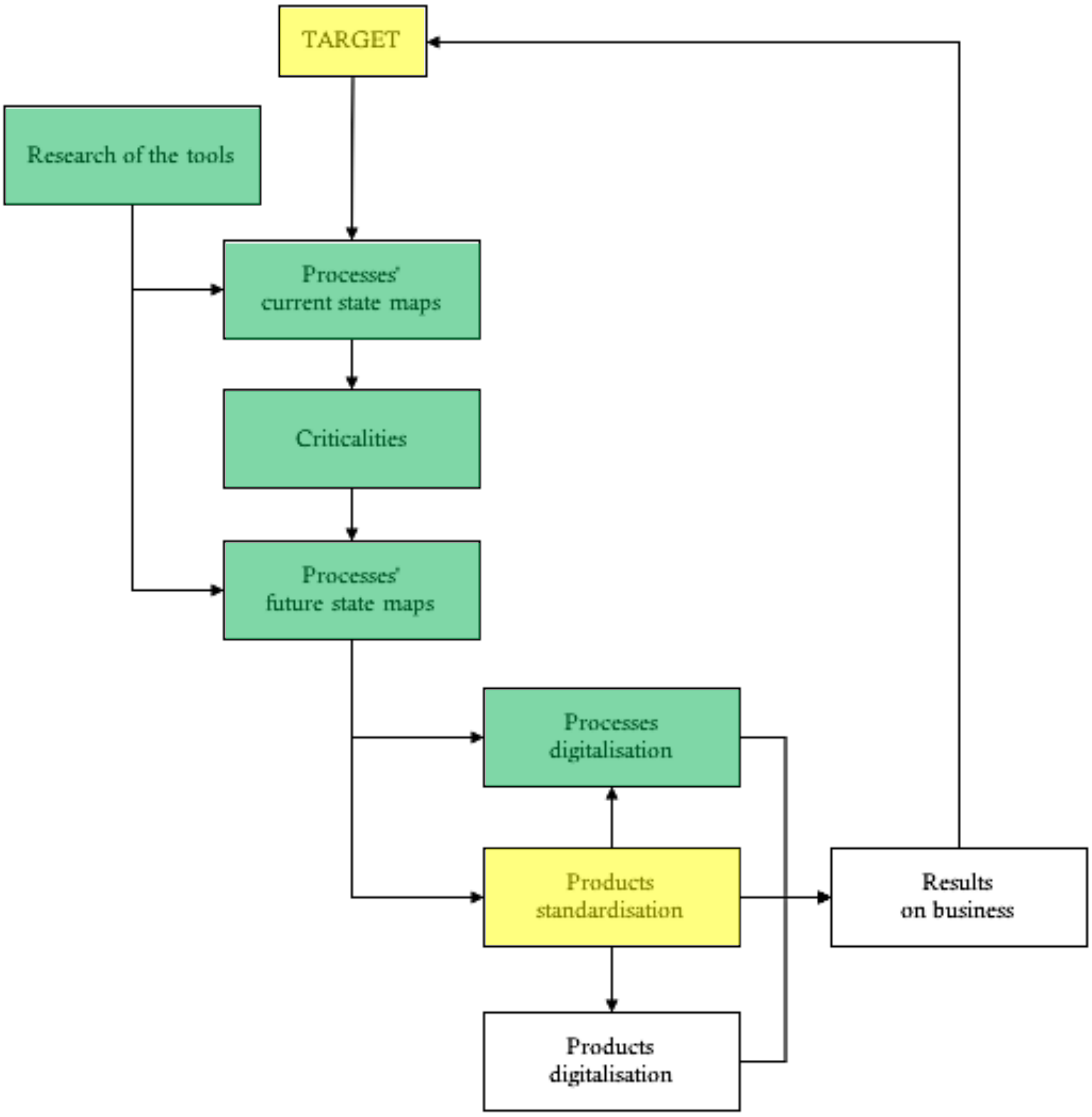


Figure 10.5: diagram that summarise the development of the research.
In this chapter the focus is standardisation of products, one of the main factors that contributed into processes streamlining and waste reduction.

Standardisation has perhaps been the most time-consuming and all-encompassing activity carried out during this thesis work.
This activity involved the mechanics, the electronics/pneumatics and the software of each family of machines belonging to company's core business.
Results obtained by this activity impacted in a positive way also other aspects of the company, such as performance improvement of Technical, Procurement and Production departments, over and above the fact that allowed business to be more effective (improving margins) and contributed to fight wastes inside processes.

In general, the methodology adopted to develop this standardisation activity, or, in other words, the standardisation strategic project, is based on the main methodology adopted for the overall thesis work: Lean Six Sigma, DMAIC.

Standardisation strategic project was defined starting from an analysis of the business: families of products were created in order to be able to tailor dedicated activities to each category, starting from the ones which presented high volumes of sales, to maximise results from the beginning.
Findings are the following:

1. Delta robots pick-and-place lines;
2. Other secondary and tertiary packaging robotic solutions;
3. Horizontal flowpack machines.

Then, historical data for each family of products were gathered to understand weaknesses and wastes.
The analysis revealed that the main waste was related to the poor standardisation of groups and codes that actually could have been common for the family of products.

In general, the improvement related to each one of the families of products started from the analysis of each code of each group of machines discussing the technical scope and considering manufacturing and assembly.
Codes were simplified, reduced in number and redesigned smarter, following Design For Manufacturing and Design For Assembly guidelines. This led to the possibility to make important supply agreements with reduced costs, reduced lead-time and reduced errors.

Finally, a new modular software was developed according to the new mechatronic design, considering each part of the machine as a standard functional part, for which its strings of software can be downloaded ready-to-use from product-family standard library.

In particular, the main achievements are related to delta robots pick-and-place lines: at the beginning of the project the standardisation of groups was around 30%, however, diving deep, a lot more could have been done.

This ambitious sub-project involved the redesign of most of the groups of this type of lines, in order to level up standardisation to an incredibly 90% but also to improve modularisation of this solution.

In order to better understand the job done on this family of products Figure 31 shows the subject of the study: this kind of solution can have a variable number of delta robot cells depending on the productivity; products are carried by a shaped conveyor that goes through the area under the pick and place robots; near products conveyor can be present a boxes conveyor (to carry boxes where products are placed in) or a pocket conveyor to work different formats in a different secondary packaging machine (such as an horizontal cartoner machine for instance).

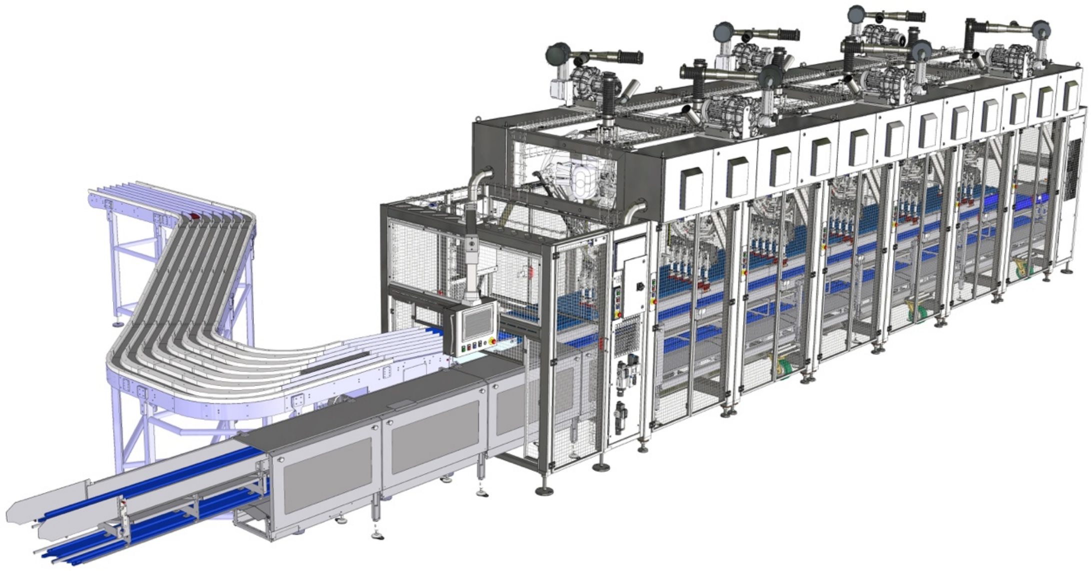


Figure 31: delta robot pick-and-place 6-cells line.

Delta robots pick-and-place lines were redesigned in order to be completely modular: the line of cells has its minimum piece that is represented by the single cell, that can be replicated identically n-times. Each cell has its stable frame with guarding, its electrical cabinet with robot automation electronics, its vacuum pump, its gripper head to pick products, etc.
Before the improvement, project frame and guarding were designed ad-hoc for each project, making impossible any strategy for Procurement Department and wasting a lot of working hours in Technical Department.
Gripper heads were standardised as well, reducing the variability at two models with a number of picking heads that is configurable (Figure 31.1), instead of a complete new design for each new project as did before the improvement project.
Both product shaped conveyor and boxes conveyor were modularised according to the new minimum unit, in order to have a scalable design.

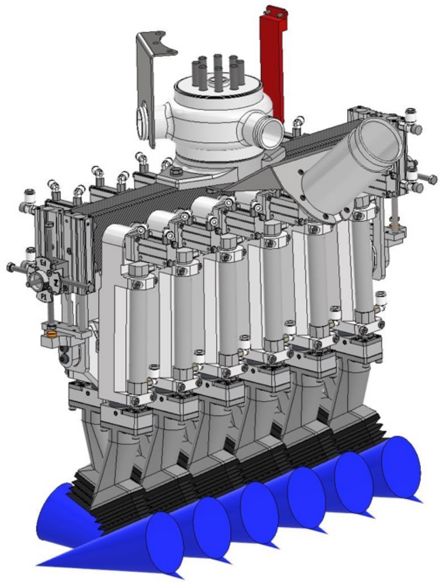


Figure 31.1: Gripper head for the single robotic cell particularly for ice-cream cones. Number of cans is configurable according to formats required by customers. To be noted that terminals and other elements are 3-D printed in order to guarantee light weight, improving robotic cycle, and to be cheap and quick to be changed in case of damages.

It is clear that this sub-project brought a lot of improvements such as: increased reliability related to the new design of each code, decreased costs of 28% (both working hours, basically cut in half, and cost of manufacturing), decreased lead time of 20% and net-zero errors from selected suppliers on the new standard items.

Another important family of products worthy to be discussed is the horizontal flowpack machine (see Figure 32 as reference).
As far as flowpack machines are concerned, two main activities characterised this particular improvement project:

1. New design of a standard "entry-level" solution, called M60 (single lane flowpack machine with film speed up to 60 m/s);
2. Re-design of the more performant solutions, called M120 (single lane high-speed flowpack machine) and M240 (compact double lane high-speed flowpack machine) according to the standardisation and cost reduction of M60.

The main challenge of this improvement project was related to cost reduction of component, however, standardisation increased from 20% to an incredible 70%, excluding just the lug-chain conveyor of the machine, since it strongly depends on products' dimensions and formats.

After a careful design, using commercial components instead of design items where applicable, costs of this new M60 machine are around the 30% of the cost of M120 before-standardisation.

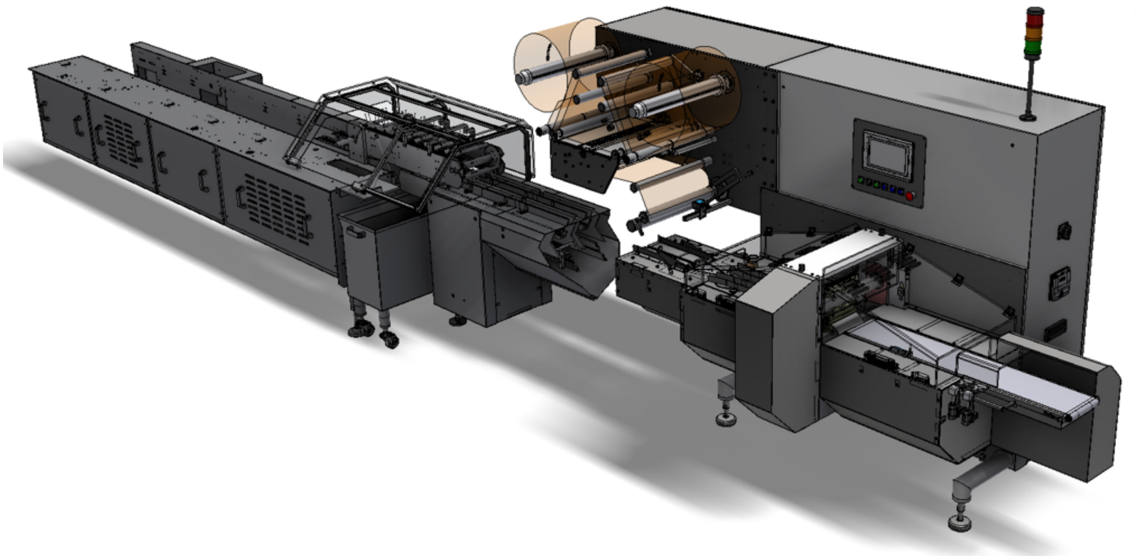


Figure 32: example of the brand new M60 horizontal flowpack machine.

After M60 new-design validation, the main groups such as frame, reels-holders, splicer (for the automatic reel change), guards, hardware components and ready to use software packages were transported to M120 and M240 with the needed adjustments due to the high-speed of the machines.
These activities led to a very satisfying 33% of cost reduction on these machines versus the cost before-standardisation.

This was the occasion to a complete review of the infeed devices as well (when machines are not manually loaded smart belts are used for handling, sorting, grouping and preparation of products to be processed in flowpack), creating a ready-to-use interface (mechanical, electrical and software) between infeed smart belts and the flowpack machines.

In conclusion of this standardisation and new-design chapter, the brand new horizontal continuous cartoner machine HCC (see Figure 33 as reference) has to be mentioned. Indeed, this improvement project covered a big strategic target of the company since this wasn’t a product inside the portfolio and let the company complete the offers with a factory made, line-integrated, solution.

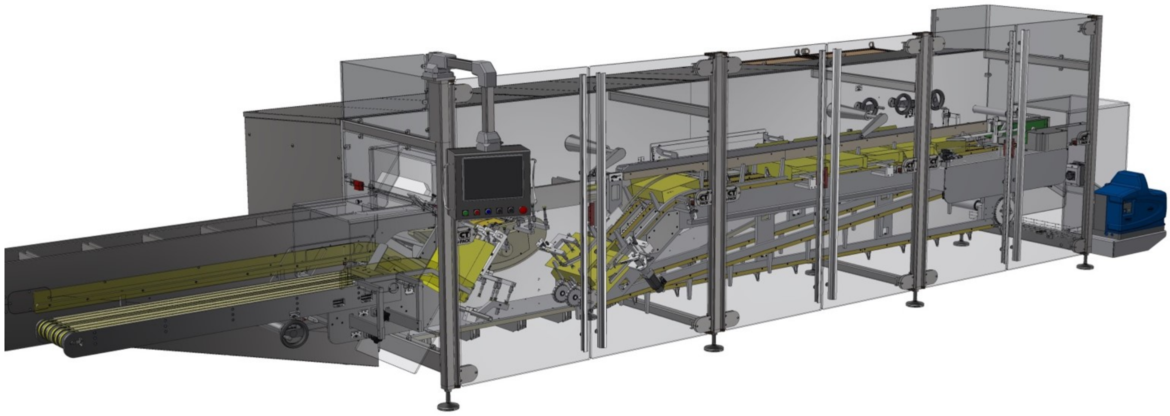


Figure 33: brand new HCC, horizontal continuous cartoner machine.
This machine collects products onto a pocket conveyor, pick and erect carton blanks, synchronise products and blanks and push products inside blanks. At the end boxes are closed. To be underlined unusual and unique characteristics for this kind of machine: the total visibility and accessibility and the fact that blanks magazine and blanks forming are below the level of product, in order to avoid any kind of jam and/or contamination in case of failures and to assure a perfect ergonomic for operators.

The new HCC was designed in order to be an a near-100% standard product from the beginning: this machine with a pitch of 340 mm is capable of work the most of products, boxes and formats in general, interesting for CT Pack's businesses.

5.2 Products digitalisation toward Industry 4.0

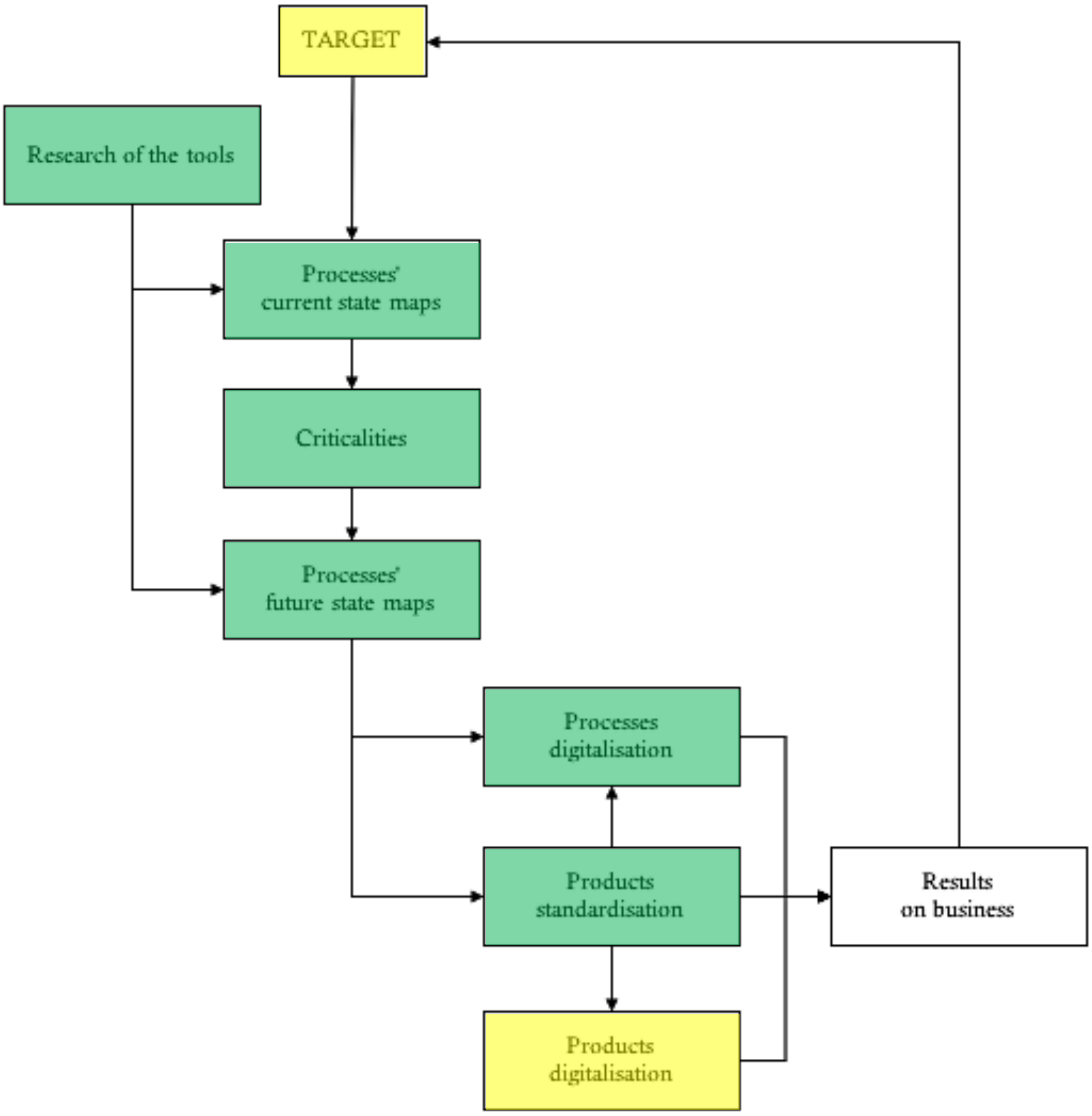


Figure 10.6: diagram that summarise the development of the research.
In this chapter the focus moves on a general overview of products digitalisation, in order to prepare the company to a consistent transition toward Industry 4.0.

Products standardisation and new design completed company portfolio and greatly improved, empowered, business results jointly to process digitalisation.
In order to level up company portfolio of products and to prepare the basis for a consistent transformation, data gathering and analysis is an impacting factor to improve smart solutions and widen their application.
Thus, a new feature has been implemented on the whole portfolio of products: the Data Logger, a system that by means of the standard sensors pack present in the equipment, and a few additional ones, studies the performance and the health of the equipment, sending important data.

This service is divided in different area with different type of information:

1. Line Performance Monitoring: equipment shows in the human-machine-interface both instantaneous and historical performances of the line focusing on the Overall Equipment Efficiency as product of efficiency, availability and quality, but diving deep in important details such as number of products rejected, where was the rejection, machines stops, reason of the stops, number of infeed products, number of outfeed good products, etc.

   All the parameters of this feature can be easily integrated with customers' main control systems and corporate network.

   In general, these data are useful in order to understand where minor process improvements are possible and to monitor production.

2. Failure Analysis: gathering and statistical analysis of failures of the line, with graphs in order to quickly understand what and where the most redundant issues are.

   This feature is actually precious for the company, since can periodically study the issues occurred to improve products and increase customer satisfaction for maintaining excellent quality and performances of lines through many years of work.
   From these data company set periodical internal meetings in order to figure how to solve the most redundant failures in a products' continuous improvement mindset.

3. Critical components health status: by means of dedicated sensors (accelerometers, eddy-current, temperature, etc.), critical components are analysed in order to continuously check their status and avoid sudden failures.

Furthermore, all the products have the remote-connection hardware installed, so according to customers' will and in case of emergency, a technician can remotely connect 24h/day to address the emergency and possibly solve the issue during the same session.

Finally, the next step of product digitalisation, currently under evaluation, is to be able to create a digital twin for each product to be able to see in real time the operations of the lines and their status, in order to offer a comprehensive service and even smarter solutions to customers.
The introduction of a digital twin, with some additional devices, let operators and technicians interact with machines in a very intuitive way and hugely simplify both day-by-day activities (such as formats changeover and cleaning) and maintenance activities (implementing the predictive maintenance that can exactly show where there could be a future problem and when would be better to preventively change some items).

In the next and last section, in conclusion of the research work, the main results and conclusions are shown, and author proposes his version of general procedure to digitalise and improve small-medium-enterprises.

6. Results and Conclusions

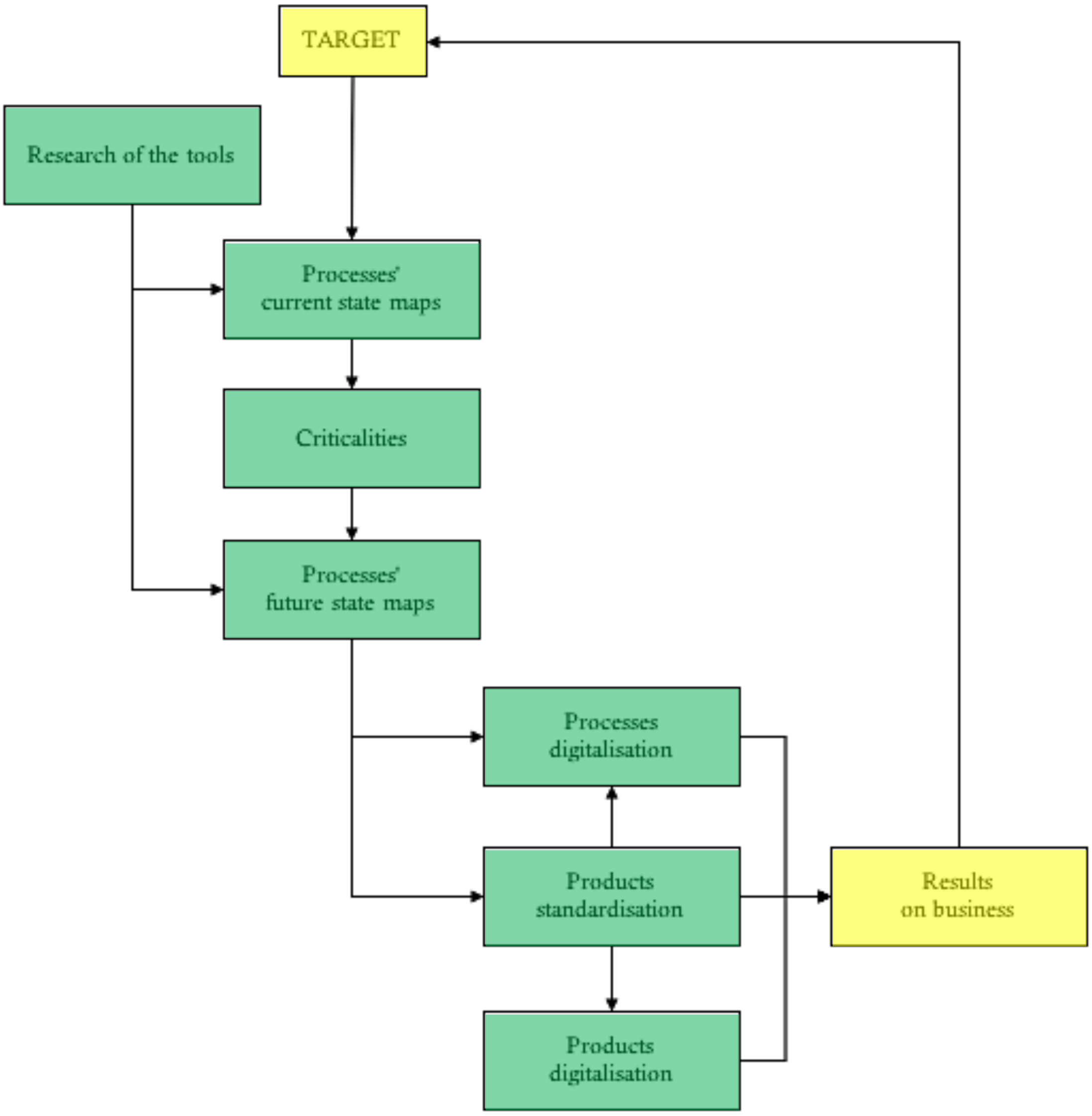


Figure 10.7: diagram that summarise the development of the research.

In this last section results on business will be discussed, and in conclusion to the whole research author will present his generalisation of the procedure implemented in the case study and suggestions about possible next steps and further research.

6.1 Operational results of 2018-2021 triennium

Operational results of 2018-2021 triennium are important to understand the extent and the outstanding outcome of this research for the company.
In particular, 2018-2019 in terms of operational numbers has to be considered as the base line, the starting point of the research, while 2019-2020 and 2020-2021 show the results of this research.

The main KPIs taken under consideration to measure the outcome are Projects' Gross Margin Rise (Figure 34 as reference) and Weighted Lead-Time (below is reported again Figure 29 as reference).
It was chosen Projects' Gross Margin instead of company overall Gross Margin, since it does not depend on business strategic decision outside the operations (such as a company acquisition or any other kind of investments that have an impact on company's overall Gross Margin). Projects' Gross Margin depend strictly on operational performances and it is a good indicator to evaluate the immense work done on internal processes (waste reduction, stabilisation, digitalisation), products (re-engineering, standardisation, industrialisation, new products' design, digitalisation) and the related synergies.

In particular, for Projects' Gross Margin Rise it was decided to take as baseline (0%) the result of year 2019, in order to have a term of comparison, then for 2020 and 2021, years in which the research started to have an impact, it was considered the following expression to determine the rise:

$$Gross\ Margin\ rise\ \%\ (n) = \frac{[Gross\ Margin\ (n) - Gross\ Margin\ (n-1)]}{Gross\ Margin\ (n-1)} * 100$$

where *n* is the year.

Results are outstanding: 2020 saw a +1000% of Projects' Gross Margin rise, while 2021 saw an additional +150%, for an overall rise of +1150% (Figure 34).

Moreover, diving deep can be outlined that there was an excellent result on the singular family of products as well.
Delta robot pick-and-place lines, mentioned in chapter 5.1, represent the top seller of the company, bringing up to the 70% of yearly revenue so it is interesting have some data: following the same consideration reported before, the Gross Margin variation of this type of projects had the same skyrocketing trend (Figure 35).
2020 saw a +330% rise in gross margin for this family of products, while 2021 saw an additional +50%, for an overall rise of +380%.
To be mentioned that these data refer to regular projects with different categories of products and a part of customisation. Indeed, the standardisation of the technical solution (chapter 5.1) led to the enormous advantage to be able to repeat the same project, with really minor adjustments, for the great part of products: for ice-cream cones or ice-cream sticks for instance, the design phase is almost inexistent, and the gross margin rise compared to a regular project is even more evident.

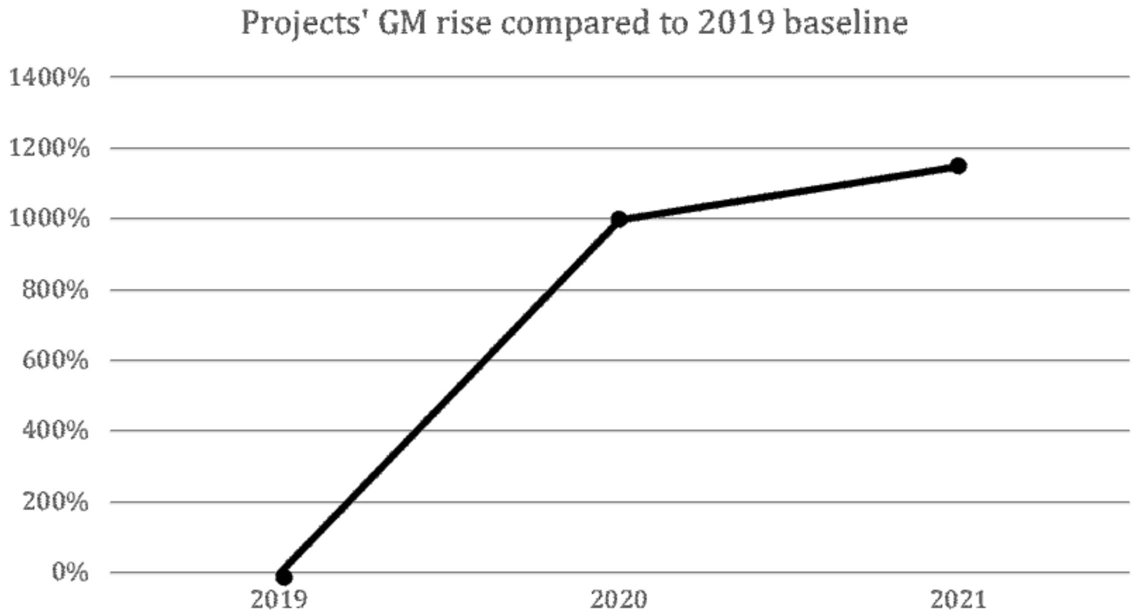


Figure 34: graphical representation of Projects’ Gross Margin Rise. 2019 is the baseline, the term of comparison in order to measure the rise in the following years, so it is shown as 0%. Then values of 2020 and 2021 clearly represent the rise compared to 2019.

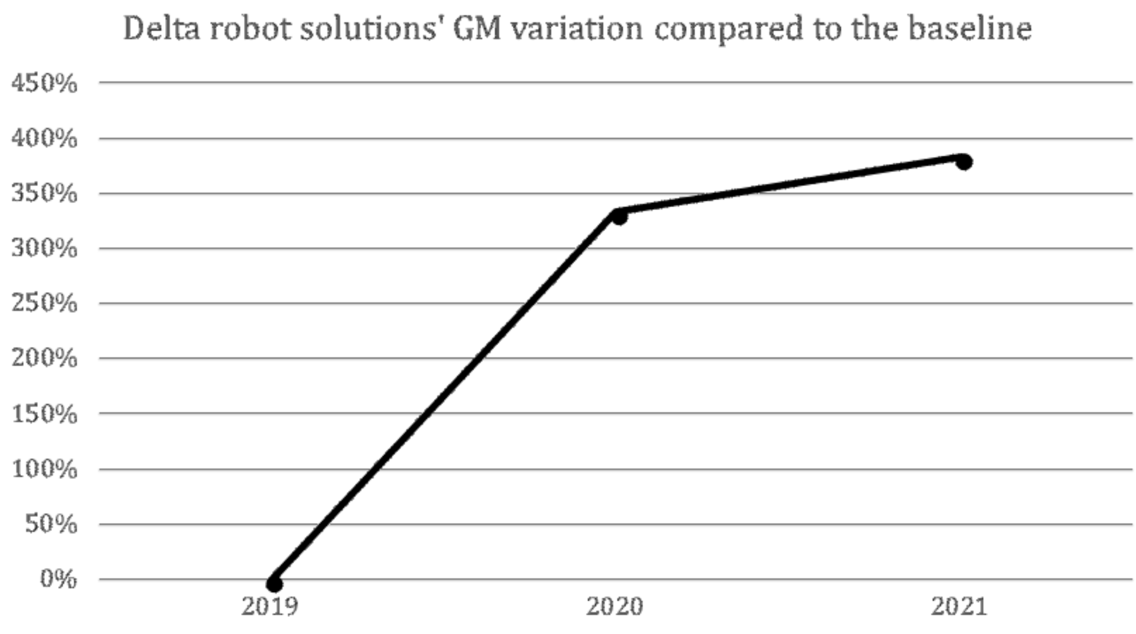


Figure 35: graphical representation of Delta robot solutions’ Gross Margin Rise. 2019 is the baseline, the term of comparison in order to measure the rise in the following years, so it is shown as 0%. Then values of 2020 and 2021 clearly represent the rise compared to 2019.

As far as Weighted Lead-Time is concerned, it is a complex matter for such a company, where customisation is part of the essence of its business.
Depending on the extent and nature of the particular project, Lead-Time may vary a lot: impacting factors are number of machines, types of products, types of packaging needed, variety of formats to be processed onto the same equipment and entity of customisations required by customers.

As reported in chapter 4.3 (see Figure 29 as reference), before the present research work Lead Time varied from a minimum of 220 days to a maximum of 1,000 days, with a weighted Lead Time (according to the business mix of projects) of 330 days.
After waste reduction, process improvement, standardisation and digitalisation the forecasted Lead Time vary from a minimum of 180 days to a maximum of 700 days, with a weighted Lead Time of 230 days (with the same business mix of projects).

In order to have strong statistic, and depending on projects' category, this research work started to collect real lead time after improvements, however the Covid-19 pandemic heavily affected the global supply chain, creating lack of materials and enlarging delivery times. Not reliable data related to Lead Time have been collected since 2020.

Nevertheless, a small amount of data has been collected without pandemic affections related to supplies and confirmed the forecasted Lead Time after improvements: overall, considering the business mix of projects, a reduction around 30% has been confirmed. Obviously, data are currently still collected in order to have strong statistic based on a reliable amount of data.

Actual	Forecast after improvements
Lead Time (min) ~ 220 gg	Lead Time (min) ~ 180 gg
Lead Time (max) ~ 1000 gg	Lead Time (max) ~ 700 gg
Weighted Lead Time ~ 330 gg	Weighted Lead Time ~ 230 gg

Figure 29: representation of Lead Time KPI. On the left, measurements made at research's beginning, whereas on the right the forecasted reduction based on processes and products improvements.
In the lower area a timeline is reported and both weighted lead time (before improvements and after) are highlighted.

To be mentioned that, besides the outstanding operational results, lead time reduction, products standardisation and digitalisation (particularly the delta robot solutions) and new products introduction (such as the HCC mentioned in chapter 5.1) made possible the realisation of some multi-annual supply agreement with multinational customers, providing with a sure cash flow for solutions that will have great gross margins thanks to standardisation, industrialisation, digitalisation and process improvements. Indeed, the agreed solutions are mostly quite similar to each other, almost identical in certain cases, and that amplifies internal advantages in terms of time, cost, quality, performances.

Finally, through the work performed at an Italian manufacturing company, the present research sought to answer research questions connected with the use of Lean Six-Sigma methodologies integrated with Industry 4.0 principles. The research questions were:

RQa – Is Makigami an effective tool to map business processes, and can its features be a plus for transactional processes, streamlining the work of practitioners?

RQb – Can the integration between Lean Manufacturing and Digitalisation synergistically create tangible value for a company? In other words, are waste reduction, process improvement and digitalisation key impacting factors on business results nowadays?

Specifically, concerning the RQa:
Chiarini and Gabberi (2020) found that, in general, the Makigami is a more powerful magnifier for mapping activities, sub-activities, and even tasks within a process. According to the literature review results, this is the main characteristic of the swim-lane approach, a tool that shares similarities with the Makigami.
The results from this research clearly indicated the Makigami tendency to strongly customise metrics and indicators, even in terms of qualitative information linked with the activities.

Furthermore, the Makigami provides with clear visual information in terms of activities sequence and waste linked to loops among activities, as well as the possibility of identifying all the stakeholders for each activity, the time stakeholders devote to certain activities, and stakeholders' workloads.

In addition, the Makigami, in its future-state version, can easily highlight all types of improvements to be managed, including more organisational improvements connected with job descriptions, skills, and organisation chart positions.

However, the Makigami is also affected by some negative characteristics, such as the difficulty in immediately visualising backlogs and WIPs, as well as non-synchronised activities. Moreover, the Makigami does not indicate how the process is planned, scheduled, and controlled in its progress.

Apart from the above limited issues, the Makigami seems to be a better vehicle for mapping a transactional office process, in contrast to other well-known mapping tools, giving to practitioners the flexibility to be adapted to very different contexts in a very simple way.
In conclusion, flexibility and customisability of this tool are definitely two strong plus in a transactional-processes environment, streamlining the job of practitioners belonging to different sectors and with different needs in terms of detail grade and KPIs.

Concerning the RQb:
It is author's belief, confirmed by the outstanding results of the research, that waste reduction, process improvement and digitalisation are key impacting factors to create value nowadays.

In particular, Lean-Six-Sigma and Industry 4.0 principles cannot nowadays be separated: in order to have a strong beneficial impact on any kind of business and to create value, all these principles should be used together, integrated, synergistically.

According to the specific case study of this research, the separated use of one of the two philosophies would not have produced the same results and maybe, could have been counterproductive.
On the one hand, Industry 4.0 principles such as digitalisation, cannot be effective if processes are not streamlined and wastes eliminated, otherwise there is high risk to automate wastes. The integration of different processes or the automation of some transactions in the same process through digital tools have to be neat and lean in order to be practically feasible.
On the other hand, the impact of Lean-Six-Sigma alone, in a preponderant transactional environment, would not have been such outstanding without the help of digitalisation, which add incomparable speed and value in all the transactions where human activity is not strictly required.
The integration of Lean-Six-Sigma and Industry 4.0 principles is perhaps the focal point to be faced in SMEs to be competitive and prosperous in the global market.

In conclusion, the above-mentioned reasons and the development and conclusion of this research applied to a specific case study, led the author to believe that a generalisation of the procedure to integrate Lean-Six-Sigma and Industry 4.0 principles is possible, in order to help practitioners in the hard but necessary job of digital transformation in SMEs to create value.

In the next chapter, author proposes his generalisation of the procedure followed in this case study, to be, hopefully, helpful in some ways to practitioners involved in SMEs digital transformation.

6.2 Generalisation of SMEs digitalisation procedure

Some researchers claim that a lean implementation necessarily must be seen as a prerequisite for a successful Industry 4.0 transformation (Kaspar and Schneider, 2015; Staufen AG, 2016). Based on a survey of 179 industrial companies, Staufen AG (2016) find that the similarity between the Industry 4.0 pioneers is that they have already implemented a lean manufacturing system, which may show lean is an ideal foundation when shifting towards Industry 4.0. Khanchanapong et al. (2014) similarly suggest that advanced manufacturing technologies (AMTs) may need to be supported by lean practices to maximise the manufacturing performance increase.
The performance benefits of implementing lean manufacturing are proven in numerous cases and concern a broad range of different performance metrics.
Regarding the performance impacts of combining lean manufacturing with AMTs, Khanchanapong et al. (2014) find that the synergistic performance impact of such an integration motivates the joint optimisation of the two rather than optimising either resource alone.
Through a multiple case study, Strandhagen et al. (2017) find that companies with repetitive production systems on a general basis should have an easier transition to Industry 4.0 than non-repetitive production systems. Other researchers claim that only big enterprises will be able to reap the benefits from Industry 4.0 and that small and medium-sized enterprises (SMEs) can quickly become the victims of Industry 4.0 (Sommer, 2015).

It is author's belief that the integration between Lean-Six-Sigma and Industry 4.0 not only is possible in non-repetitive production systems as well, but also is necessary for SMEs in order to not become victims, but rather be active players in the global market.

For all the above-mentioned reasons, in this chapter the author tries to generalise the procedure that gave such outstanding results limited to the case study in which the present research has been developed (a small-medium sized manufacturing company that integrates the most of its processes, transactional, with a manufacturing environment). Should more explicative examples be necessary to better understand the generalisation, readers can find real detailed examples through the whole research.

The proposed generalisation is based on the logic flow of activities carried out in the case study, assuming that Lean-Six-Sigma principles have to be implemented before the Industry 4.0 ones in order to avoid "waste automation".
As demonstrated in the present research, in order to successfully carry out a transformation and improvement project, author prefers the iterative DMAIC approach, following the continuous improvement state of mind.

Independently from the nature of the business the first step to be carried out is the definition of a project charter with the scope of the transformation project and the people involved (the RACI matrix is a good tool for the purpose). In particular, it is fundamental to have a strong sponsor of the transformation, such as the managing director or a figure belonging to board management (the optimum would be having all the management deeply involved and motivated to complete the transformation project since perceived as necessary). Real and active involvement of management and strong sponsorship is one of the critical success factors for any transformation project.

As second step it is important deeply understand the current situation of the company, so a first current state map should be developed.
In this step both extent and level of detail are discretionally, however it could be really useful to define processes under review and level of detail with the stakeholders, the sponsor and eventually with project team in order to have shared information.
For this second step, according to author's experience, the mapping tool plays an important role: indeed, for transactional processes the Makigami seems to be really effective and multi-purpose, with the possibility to customise KPIs for the process, level of detail and to be able to gather important information or comments related to each activity of the process. As far as manufacturing processes are concerned, the classic Value Stream Mapping does its job very well and can be integrated with the Makigami if needed (Chiarini and Gabberi, 2020).
In the meantime, the study of company products can be done in order to understand market target, positioning, costs and related processes to develop products.
At the end of this second step, practitioners should have a clear situation and a deep understanding of the business before the transformation.

The third step is related to the analysis of data to investigate and verify cause and effect. Determine what the relationships are and attempt to ensure that all factors have been considered. In this step practitioners should clearly see wastes and chances of improvement to develop and design alternatives where needed for both processes and products.
Within this third step, practitioners could find useful some tools belonging to Lean Six Sigma such as: 5 whys, variance analysis, correlation, regression analysis, Ishikawa diagram, cost-benefit analysis, design of experiments, Pareto analysis, Quality Function Deployment, quantitative marketing research, SIPOC analysis, and so on.

In the fourth step practitioners are going to develop the future state map of the whole business. Using the same tools of step two, with possibly a deep level of detail, and according to targets defined with stakeholders in the step one, processes are re-engineered, streamlined and stabilised according to the analysis carried out in step three.
Planning of the improvements and transformations projects are crucial, so it is author advice to take time to develop a structured and clear plan, then act to materially improve business.
In this step it could be useful to consider separately processes and products in order to understand what of the numerous alternatives belonging to Industry 4.0 fit to the organisation, the processes and the products.

As far as processes are concerned, waste elimination and streamlining get along with digitalisation very well. Industry 4.0 is based on cyber-physical systems integration, introducing digital solution to enable processes and automate them where human activity is not necessary to achieve incomparable speed and adding value.

As far as practical examples are concerned, chapter 4.4 gives the overall analysis of what done inside a specific company, however, practitioners who want to start transition projects in any SME should focus on the organisational structure in order to introduce specific tools to add value.

Some examples just to clear ideas:

In Sales Department could be integrated a CRM software that could be integrated to a configurator for products (that speeds up proposal phase) and the company management information system, to monitor business trends and act proactively.

In Technical Department, over and above computer aided tools, a PLM software could be effective to have a great organisation of products' technical files. This software should be integrated to the company management information system in order to have real and updated data in terms of cost, lead time and delivery time of products, but also to the product configurator of the sales department.

Furthermore, the PLM software should be integrated to the ERP software in order to be able to empower the Purchasing department.

In Purchasing Department, a supply chain collaborative software can increase the efficiency of buyers, since some transactions/activities are automated.

Manufacturing/Assembly can be enabled by digital solutions such as automatic storage and logistic through RFID systems and/or robotic solutions and in certain businesses additive manufacturing could be a winning solution to increase flexibility and speed.

In general, there are a variety of possible solutions and all of them are scalable: depending on the organisation and the specific needs, practitioners can tailor the extent of transformation projects accordingly.

Ideally, automation and integration of business processes could lead to a fully digital company, where, starting from an input, most of the transactions are automated, integrated and connected.

On the other hand, as far as products/services are concerned, industrialisation and standardisation (according to Design For Manufacturing and Design For Assembly principles), where applicable, are the basis in order to boost the benefits related to processes' digitalisation and integration. Then, the introduction of smart features such as predictive maintenance or data self-analysis (with the possibility to have a digital twin of the product to dive deep in analysis and simulations) and a remote connection support (smart-glasses aided for example in a manufacturing environment) contribute to the digital transformation of the company.

Finally, the fifth and last step to transform the business is the control: once all the improvement and digitalisation projects are successfully implemented, a variety of smart data will be available to be analysed and to assure that transformation effectiveness is persistent. Moreover, analysis of smart data can suggest further incremental improvement both in processes and products, as pillar of continuous improvement and evolution of business.

In conclusion, a brief recap of the five steps that can help practitioners to digitalise SMEs:

1. Define the project charter: scope and targets of the transformation project should be clearly identified as well as people involved and their responsibilities. The RACI matrix could be a useful tool for the purpose.

2. Define the current state map of the business (both processes and products) to have a deep understanding of the situation before transformation. As suggested by Chiarini and Gabberi (2020), Makigami could be an incredibly useful tool for transactional processes in particular, whereas for manufacturing processes Makigami can integrate if needed the well-know Value Stream Mapping. In this phase is important to measure KPIs and to gather information and comments on each activity.

3. Analyse data, determine relationships, identify wastes and chances of improvement related to both processes and products.

4. Improvement phase: develop the future state map and introduce improvement and transformation projects. This step can be divided in two transformation projects: the first one related to business processes and the second one related to products/services.
   Digitalisation is the key to have smart processes and smart products and can be reached in a variety of ways according to the nature of business under consideration (industrialisation, data self-analysis, predictive maintenance, creation of a digital twin, remote connection through different devices are just a few of the possible available solutions).

5. Control phase: assure that transformation projects' effectiveness is persistent through the analysis of data gathered by digital processes and smart products. Further incremental improvements could be revealed by data as pillar of continuous improvement mindset.

It is author belief that from this historical period on, digital transformation is a process without an end: continuously, processes and products should be analysed and improved in order to remain up to date to the latest technological innovations.
Embracing this mindset gives to companies the necessary flexibility to evolve continuously and keep a competitive advantage in the market independently on the nature of the business.

6.3 Limitations and agenda for further research

In conclusion of the whole research work, few words to outline its limitations and author's suggestions for further research.

This research was exploratory and based on a specific case study, which implies that it has some limitations in terms of generalising the results, albeit outstanding and as outcome of neat a procedure.
Thus, author requires further researches to confirm findings and the generalisation of digitalisation procedure, especially through case studies of diverse businesses: impacts may be different in different environments.
Practitioners could implement in action the theory developed in this paper, while academics could more systematically research the topic to classify and compare different digital solutions and integrate the procedure.
A national database of digital solutions could be created in order to gather information and technical data, creating the state-of-the-art of italian digital transformation: this could give some inputs about the development of smarter technologies or the introduction of new ones to cover the current uncovered areas.

Finally, future researches will need to examine another important factor related to the topic but not considered in this work: all the digital solution to make smart companies sustainable as well, integrating the energy management and smart energy tools in SMEs transformation as added value. Indeed, it is author belief that sustainability and smart energy concepts should be seen as great business opportunities rather than obstacles.

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