Engineer-To-Order (ETO) production planning & control: an empirical framework for machinery-building companies

Federico Adrodegari[1], Andrea Bacchetti[1], Roberto Pinto[2], Fabiana Pirola[2], Massimo Zanardini[1]

[1]*Department of Mechanical and Industrial Engineering, University of Brescia, Brescia, via Branze 38, 25123 (BS) Italy (federico.adrodegari@ing.unibs.it, andrea.bacchetti@ing.unibs.it, massimo.zanardini@ing.unibs.it)*

[2]*CELS - Department of Management, Information and Production Engineering, University of Bergamo, Viale Marconi 5, 24044 Dalmine (BG) Italy (roberto.pinto@unibg.it, fabiana.pirola@unibg.it)*

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This paper illustrates the results of an empirical study involving 21 Engineer-to-order (ETO) companies, operating in the machinery-building industry. The study investigates the needs and requirements of such companies in terms of software support for governing the businesses, with particular emphasis on production planning and control (PPC) processes. An empirical analysis investigated two main aspects: (i) the set of business activities performed by the companies in the analysed industry, and (ii) the relevant, high-level software functionalities required for the execution of such activities. As an answer to the observed compelling need for reviewing the general approaches to PPC in machinery-building companies, we develop an empirical, high-level production planning and scheduling reference framework, encompassing all the activities involved in the order fulfilment process.

Keywords: Engineer-To-Order (ETO), machinery, Production Planning and Control (PPC), empirical framework

1. Introduction

The variability and the uncertainty characterizing project-based, Engineer-To-Order (ETO) companies generate a complexity that requires specifically tailored managerial approaches to handle all the processes, from design and engineering to production and delivery (Rahim and Baksh 2003). Adopting the ETO strategy for manufacturing one-of-a-kind products (OKP) (i.e. products designed and manufactured based on specific customer requirements), companies usually have to adapt managerial paradigms, business models and Information & Communication Technology (ICT) tools designed for other (i.e. the repetitive) sectors (Hicks and Braiden 2000).

From the managerial standpoint, Amaro et al. (1999) and Spring and Darlymple (2000) argue that few frameworks are available for managing production in ETO companies; moreover, such frameworks often consider only a part of the required functions and activities, or deal with a specific sub-process (see, for example, Ebadian et al. 2008; Kingsman et al. 1996). The reference model proposed by Little et al. (2000), for example, points out the inadequacy of existing master production scheduling tools and the lack of production planning and monitoring activities.

From the ICT and software support standpoint, the adaptation of existing tools leads often to (i) stand-alone software applications and (ii) a low level of integration among different software, weakly supporting the business objectives.

These findings, along with the relevance of the machinery sector (a typical ETO business) in the Italian economy, led us to investigate further the ICT support to the implementation of the ETO strategy in such an industry. The aim of this paper is thus to contribute to the design of an effective production planning and control (PPC) process overcoming the general limitations of existing frameworks, considering all the stages involved in a typical ETO company.

In this paper, we present the results of a study aimed at (firstly) identifying the software functionalities required to support and execute the most prominent activities underlying the business of machinery-building companies, assumed as an instance of the ETO strategy. In particular, we focused on PPC processes, which represent a challenge to both practitioners and academics.

Due to the exploratory intent of the study, we based our work on a multiple case studies empirical research (see, for example, Sousa and Voss 2001), aiming at answering the following research questions:

(1) Focusing on PPC, what are the main business processes and activities that ETO machinery-building companies need to perform?

(2) What are the main software functionalities necessary to satisfy the ETO machinery-building processes requirements?

(3) What is the level of integration among the different software solutions adopted to support the ETO machinery-building business processes?

In doing this, we identified levers for improvement, concerning methodological and ICT aspects. The result is summarised in a novel PPC, high-level reference model, illustrating all the activities involved in the order fulfilment process, overcoming the limitations of the few models already existing in literature.

The remainder of the paper is structured as follows: Section 2 describes the context of the study, while in Section 3 the adopted methodology is depicted. Section 4 outlines the main results of the research, while in Section 5 we describe in details the proposed reference framework. Conclusions are offered in Section 6 along with the main limitations of the study and the natural next steps of the research.

2. Context and focus of the study

As stated in the introduction, machinery-building companies that usually operate according to an ETO strategy, represent the target of our study. Thus, the objective of this section is to briefly describe the main characteristics of the ETO context of reference for our analysis.

In the first paragraph (2.1), a comparison between ETO, Mass Production (MP) and Mass Customization (MC) is presented in order to identify similarities and (especially) highlight differences between these production strategies.

The second paragraph (2.2) illustrates the existing lack of organizational methodologies specifically designed for the ETO context, in particular for PPC processes.

2.1. Overview on ETO strategy and relationship with Mass Production and Mass Customization

Our study focused on a set of companies operating according to an ETO strategy. There are several distinctive elements facing and differentiating this context among other production strategies. Firstly, according to such a strategy, each product has a distinctive degree of customization, and is designed and manufactured in conformity with individual customer requirements, to a large extent. For this reason, the ETO strategy is suitable for highly customized, usually non-repetitive products (Pandit and Zhu 2007, Amaro et al. 1999). A second key factor is that operating an ETO strategy involves both a non-physical stage (including tendering, engineering, design, and process planning activities), with different possible configurations (i.e. new product engineering or engineering modifications to an existing product) (Amaro et al 1999; Wikner and Rudberg 2005; Gosling and Naim 2009), and a physical stage (encompassing component manufacturing, assembly and installation), as suggested by Bertrand and Muntslag (1993). Both these stages have to be considered to manufacture each required product. Indeed, ETO strategy means a high level of uncertainty in terms of product specification, demand composition, supply and delivery lead times, and duration of the production processes (Wikner and Rudberg 2005). Not only the product structure and configuration can change depending on the customer, but also the market as a whole can change dramatically. As Anderson et al. (2000) depicted, ETO companies operate within an exceptionally volatile environment: from one year to another, customers' orders and products shipments can change by more than 50% in volumes.

Some other distinctive characteristics of the ETO strategy, as emerged from the literature review, are summarized in Table 1.

Characteristic	Description	References
Core competencies	Design, Assembly, Project management, Engineering, Logistics	Caron and Fiore, 1995 Wikner and Rudberg, 2005
Competitive advantage	Coordination of internal and external processes; high technological knowledge; production planning	Caron and Fiore, 1995 Amaro et al., 1999 Gosling et al., 2014
Vertical integration	Usually low, companies are independent entities	Anderson et al., 2000
Production volume	Small volume production; Unique products	Gelders, 1991 Tu, 1997 Wikner and Rudberg, 2005
Supplier	Partnership/Contractual	Hicks et al., 2001
Product customization	High; Deep and unique bills of material	Gelders, 1991 Hicks et al., 2001 Wikner and Rudberg, 2005
Product design and development	Many engineering changes during production phases; Concurrent production and design activities	Hameri, 1997 Hicks et al., 2001
Replenishment	Purchase material directly related to a project	Hicks et al., 2001 Caron and Fiore, 1995 Wikner and Rudberg, 2005
Demand forecasting	Low accuracy of independent demand forecast; Fluctuations in mix and sales volume	Anderson et al., 2000 Olhager, 2003
Risks	Sharing knowledge, capacity utilization, contractual risk	Anderson et al., 2000

Table 1 - Main characteristics of the ETO strategy

Due to the high degree of customization, and to the related low level of repetitiveness, the outputs of ETO companies are also referred to as one-of-a-kind products (OKP), in contrast with the outputs of mass production (MP) companies, which manufacture serial and undifferentiated products in large volumes. Some authors (Tu 1997; Wortmann et al. 1997) used the OKP acronym referred to manufacturing companies producing customized products within a product domain. Since such a definition overlaps the ETO companies' characteristics discussed above, in our study we consider OKP as a characteristic of a product rather than a production strategy, and we use the ETO acronym to refer to companies producing one-of-a-kind products (Caron and Fiore 1995). As a production strategy, ETO is usually opposed to MP, since product customization is customarily in conflict with the high efficiency level and the economies of scale pursued in traditional mass manufacturing.

In the last decade, the term mass customization (MC) emerged as a possible intermediate strategy between ETO and MP, attempting to conjugate the benefits of both approaches in producing customized products in extremely efficient ways. In fact, MC is defined by Selladurai (2003) as the integration of MP principles with processes that manufacture custom products. Mass customisation also implies high-volumes and high-variety, requiring specific mechanisms for managing the supply chain's complexity (Coronado et al. 2004).

An in-depth analysis of these strategies is beyond the scope of this paper; nevertheless, in order to provide a concise background, we compare, without any claim of exhaustiveness, ETO, MP and MC strategies according to the following three dimensions (Figure 1):

- *Strategy level*: we distinguish the three strategies, posing the MC as the strategy that aims at conjugating the efficiency of MP and the customization possibility provided by the ETO strategy.

- *Process level*: the MP strategy is implemented using a push approach, where inventory management and demand forecasting play a substantial role in the management of all the activities. The ETO strategy, on the other side, is usually realized implementing mostly a pull approach, emphasizing flexibility and responsiveness, minimizing WIP and finished goods inventories, but creating an issue for processes and resource planning. The MC strategy lies in between, ideally leveraging the benefits of ETO/MP hybrid processes.
- *Product level*: the MP strategy is suitable for the production of large volumes at a relatively low unit cost, while in the opposite position the ETO strategy pursues the production of one-of-a-kind products, usually at a higher unit cost. In between, the MC strategy pursues the realization of (almost) one-of-a-kind products at a low unit cost, thanks to simpler and cost-effective manufacturing processes (Pine at al. 1993).

According to this discussion, Figure 1 provides a positioning of the context we have addressed in our research.

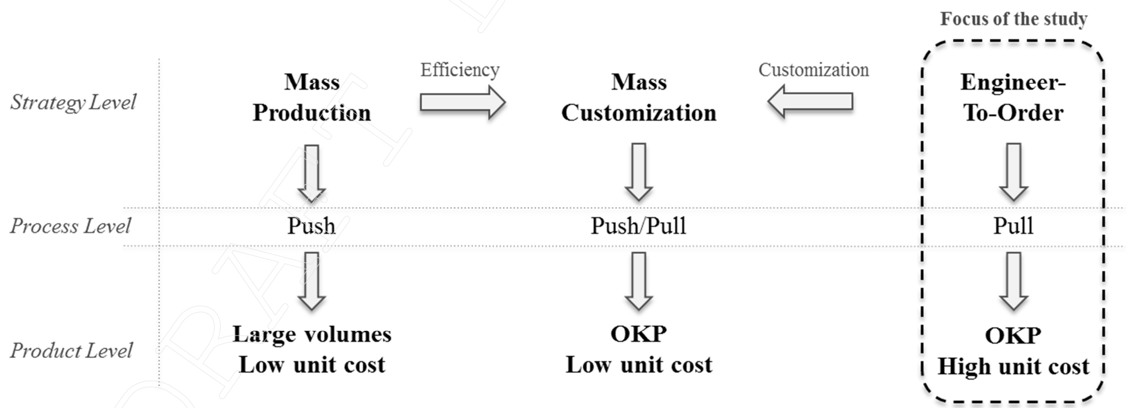

Figure 1 - Production strategies comparison

Despite the different uses of the ETO acronym, sometimes adopted to identify companies that modify existing orders (Wikner and Rudberg 2005; Porter et al. 1999) whereas in other cases it has been used to identify companies in which completely new designs are developed for each order (Haug et al. 2009; Hicks et al. 2001), according to the background previously described we assume that the main characteristic of an ETO company is that each product is either engineered from scratch or re-engineered starting from an existing design, according to the specific requirements of a customer.

Adopting the ETO strategy for manufacturing OKP products, companies usually face all the critical factors described above, with significant difficulties in managing labour force and reducing coordination between engineering and production activities (Anderson et al. 2000). In such a context, ETO companies have to adapt managerial paradigms, business models and ICT tools developed for other (i.e. the repetitive) sectors (Hicks and Braiden 2000). Especially from the ICT standpoint, the adaptation of existent tools leads too often to stand-alone applications and a low level of integration among different software, weakly supporting the business objectives, and it is still unclear which IT systems are actually suitable for ETO industry (Gosling and Naim 2009). For example, when selecting an information system, an organisation in such a context needs a tailored methodology and a list of key target areas to consider (Deep et al. 2007). How these organisations select their ERP and other information systems as enablers of growth needs to be investigated, because no extensive research is available. However, literature provides specific contributes with the aim to describe the use of enablers for controlling the on-going state of products in the different production phases, such as RFID system. For example, Pero and Rossi (2013) design and develop a system for monitoring the order completion status within an ETO company and sharing this data along the supply chain, through the application of an innovative system that integrates RFID and web technologies. However, they do not focus on the overall IT infrastructure required by ETO companies for improving both project management and planning activities.

To address the issues discussed above, we identified the typical processes for ETO companies, focusing in particular on PPC processes, which represent a significant challenge to both practitioners and academics.

2.2. ETO Manufacturing Planning & Control frameworks

Despite the specific set of companies underlying our study, for the sake of completeness we extended the area of analysis of PPC frameworks to general ETO companies.

The ETO industry suffers the lack of a specific PPC process: as underlined by Stevenson et al. (2005), the choice of a PPC process is often an ill-informed decision, based on superficial software features rather than a selection of features that are designed for a specific industry. The main consequence of the lack of specific organizational and managerial approaches for the ETO context is the incidence of re-work, with consequent time-to-finish delays and increased costs (Caron and Fiore 1995). The complexity and the variability of the products often result in the adoption of unsuitable, yet readily available approaches. In fact, due to the nature of the ETO context - in which different projects are carried out at the same time, at different stages, with different levels of completion, and subject to frequent changes - the adoption of methods successfully implemented in other contexts (i.e. make-to-stock or make-to-order) may not yield the same benefits (Rahim and Baksh 2003). This approach is well described by Gosling et al. (2014); in their work, they adapt and extend the typical MTS principles for the design & operations phases in order to (try to) match the specific requirements of the ETO context. Furthermore, production-related tasks such as production planning, costing, and shop floor control could be highly complex, due to the possible process variations related to high mix, low volume, and complex manufacturing instructions (Jiao et al. 2005).

The literature provides only few frameworks suitable for managing projects in ETO companies, as reported by Amaro et al. (1999) and Spring and Darlymple (2000), for example. As a first general reference for ETO companies, the Supply Chain Operations Reference model (SCOR 2010) provides an entry point for the description of the typical (standard) processes to be performed. Nonetheless, from one hand, the main purpose of the SCOR model is to provide a supply chain oriented representation of the processes, encompassing different companies from suppliers to distributors. On the other hand, the processes are described in a rather general way, since they should be adaptable to many different contexts.

Considering a single company as the objective of our study, the reference model proposed by Little et al. (2000), focused upon planning and scheduling, considers six sub-processes, from the product configuration, through project management and design planning, towards master production, shop floor and assembly scheduling, thus providing a sound reference point for the definition of the main activities required. Nonetheless, this framework requires substantial customization to reflect better the specificity of the machinery-building industry and to include the cost control phase.

Gelders (1991) proposed to distinguish between two different production planning levels: a first factory level suitable to monitor capacity load, lead times and activities budget, and a departmental level, that provides a more detailed order scheduling.

Dekker (2006) discussed the concepts of the Order Entry Points (also known as the Customer Order Decoupling Point) and modular design to address the conflicting requirements of productivity, lead-time and variety. The resulting framework is a high level representation suitable for strategic decisions about the structure and organization of the sales, engineering, procurement and manufacturing activities.

In some cases, MTO frameworks can be used as a starting base for the development of ETO frameworks since, to some extent, the latter can be considered as an extension of the former with the addition of the design and engineering phase. Ebadian et al. (2008) provide a decision-making structure, although limited to the order-entry stage, to evaluate the customers’ requests in an MTO context; the decisions about which of the arriving orders are feasible and profitable for the company are based only on price and delivery time criteria. This contribution underlines the relevance of an evaluation phase aimed to prioritize the arriving order, possibly rejecting those that are deemed as not profitable for the company. Similarly, Hemmati et al. (2012) discuss a comprehensive decision making structure for acceptance or rejection of incoming orders. Kingsman et al. (1996), instead, proposed a decision support system aiming at identifying the resources needed in terms of skills and machines to satisfy technical features in a multi-project environment, emphasizing the feasibility of being able to produce the order with the current work load at different delivery times. In a different industrial context than the main one considered in this paper, Kagioglou et al. (2000) identified six key principles, drawn heavily from the manufacturing sector, considered to provide the basis for an improved process performance in the construction sector. Many of these principles, such as the whole project view, the process consistency and the maintenance of a feedback loop have been reflected in our proposed framework.

Given this scientific background and considering our research and experience in the machinery-building industry, we were not able to find an existing framework fulfilling all the requirements gathered from the case studies: some existing frameworks were too general, others were incomplete with respect to the considered industry. Therefore, the reference framework proposed in this paper aims at contributing a novel PPC, high-level reference model for the machinery-building industry informed by existing frameworks, overcoming their limitations, and illustrating all the activities involved in the order fulfilment process.

3. Methodology

According to our research questions, we analysed the current practices in a number of leading firms operating in the machinery-building industry adopting an ETO strategy. Due to the nature of the research questions, and to the exploratory intent of the study, we opted for a multiple case studies empirical research (Sousa and Voss 2001).

In fact, case studies allow the questions of why, what and how, to be answered with a relatively full understanding of the nature and complexity of the complete phenomenon. Furthermore, case studies are recommended when dealing with complex adaptive systems, such as engineering and product development projects: in these cases, researchers should consider “insider” and “participatory” approaches to research (Gosling et al. 2011; Ottosson and Bjork 2004), to capture depth, nuance, and complex data during the interviews (Mason 2002).

To better understand the needs and the requirements in terms of software functionalities, we decided to invite companies with an already established basic knowledge of the subject. Therefore, the sample used within the research was built adopting a judgmental sampling (Hameri and Nihtilä 1998; Ferreira and Merchant 1992; Eisenhardt 1989) selecting cases according to different criteria (Yin 2009; Eisenhardt 1989). This technique is used in (exploratory) research projects and deemed as appropriate in case of limited resources (Henry 1990).

According to the judgmental sampling approach, our sample was based on available data from industrial associations, the authors’ experience, and their knowledge of the Italian machinery sector. We also considered the relevance of machinery-building companies in Italy in terms of presence on the territory, the overall turnover and employment level, as well as the peaks of excellence reached by many of them.

We selected 21 representative Italian-based companies (see details in Appendix A) where the unit of analysis was represented by the Italian production branch of the company. Since this study involved a large number of sites, we used multiple investigators (Voss et al. 2002; Eisenhardt 1989).

A well-designed protocol is particularly important in multi-case research (McCutcheon and Meredith 1993), in order to enhance the reliability and validity of case research (Yin 2009). Following these references, we built the research protocol summarized in Figure 2 and described hereafter.

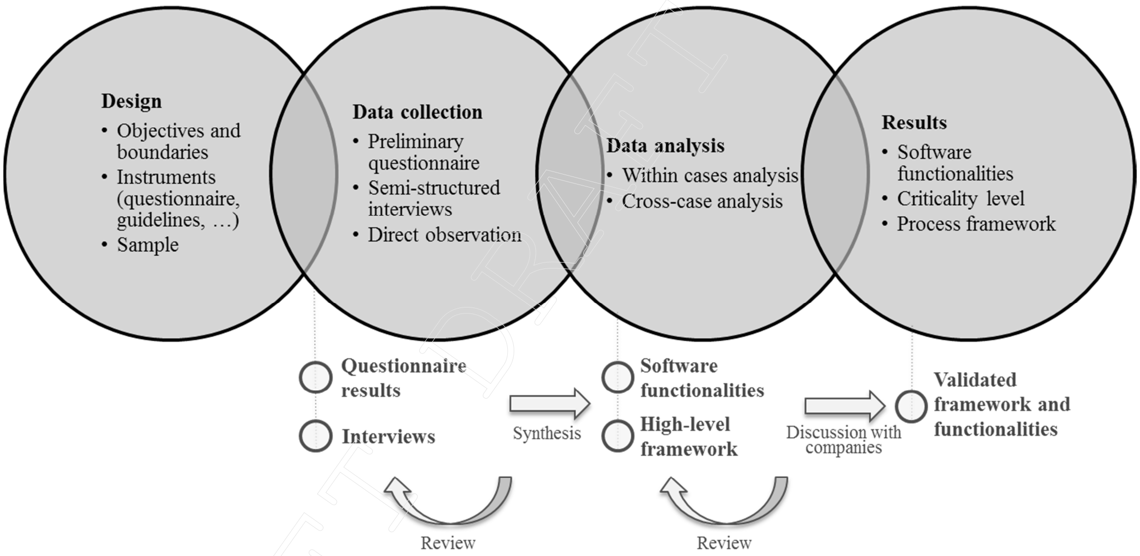

Figure 2 - The research protocol

Different data collection methods were used, including a preliminary questionnaire, semi-structured interviews, direct field observation, and a structured database to collect and store the information after each interview. According to the designed protocol, the preliminary questionnaire was used to gather general demographic information about the specific industry the companies are involved in, the manufactured products, the turnover, the number of employees, the amount of investments in ICT, and so forth. The semi-structured interviews were then used to gather other specific data related to the way companies do their business, in terms of process and software support. To this end, the core of the designed protocol included the “guideline for interview” (see Appendix B), a document designed for interviewers, outlining the subjects to be covered during an interview, stated the questions to be asked, and indicated the specific data required (Voss et al. 2002). Therefore, the “guideline for interview” served both as a prompt for the interview and a checklist to make sure that all topics were covered.

Each interview required between one and two days: in particular, each interview had a variable duration depending on the number of questions and on people availability. For each company, about five people from different business roles were interviewed, for a total of 112 interviews within the 21 case studies. Different respondents from the same company were sometimes inquired on the same questions to cross-verify the accuracy of the answers. The interviews were mainly directed to: CEO/entrepreneur (19% of the cases), CIO (19%), sales/marketing manager (10%), project managers (9%) and R&D manager (8%). Whenever necessary, other managers of specific areas, such as production, logistics and purchasing, were involved in the interviews (35%).

Key respondents were inquired about the main issues addressed by the research questions as the objectives in terms of cost, time and profitability of the order, the peculiar features of a custom order, the description of the main activities (primary and support) that are involved in the custom order fulfillment, the description of the company information system(s) and of its main features and criticalities due to its use in an ETO context, developing a list of supported (or desired) software functionalities (see section 4 and Appendix C).

Upon the completion of the interviews, we analysed the pattern of data within cases to become intimately familiar with each case as a standalone entity, and to allow the unique patterns of each case to emerge before seeking to generalise across cases (Eisenhardt 1989). This preliminary analysis allowed performing cross-case analyses related to the investigated issues (Yin 2009), as reported in the remainder.

Then, we performed the final phase in which we designed and developed a high-level process framework (and the related software functionalities), with the aim at supporting the development of processes to fill the main gaps highlighted during the cross-case analysis, and discussed in Section 4.

The evaluation of the functionalities identified during the interviews and the framework validation process were conducted through a discussion with the companies during an *ad hoc* workshop. A validation workshop is very useful in case studies research: in fact, as presented in Baines and Lightfoot (2013), in this phase some refinements could be made, inconsistencies identified, and additional anecdotal evidence offered. The workshop was structured along a day entirely dedicated to the analysis of the case results. The discussion involved 32 managers (at least one person per company, see Appendix D), and helped us bringing together practical and experiential knowledge of processes and patterns, along with consideration of propositions and theory (Gosling et al. 2011). Moreover, the workshop, as suggested by Kagioglou et al. (2000), was also implemented in order to:

- Collect feedback: we illustrated the proposed framework “step-by-step”; managers were asked to review our work in terms of completeness, correctness and practical applicability. They discussed all the activities involved in the order fulfilment process, providing feedback to refine or confirm them;
- Validate the process framework: in the final phase of the workshop, we made a comprehensive re-reading of the new version of the framework, highlighting the

main changes to ensure their correctness. After this step, the process framework (and the related functionalities) was considered validated. The final version is presented in section 5.

4. Case study results and insights

One of the first results emerging from the case studies, answering the first research question, was the identification of the main activities of a typical ETO machinery-building company, concerning PPC processes.

As reported in section 2.2, the extant literature suggests the distinctive elements of an ETO company, but a comprehensive framework related to the PPC processes is still missing. Thus, starting from the ETO characteristics reported in literature (section 2.1 and Table 1), we drew from the interviews the main PPC activities performed by a typical machinery-building company. For the sake of clarity, we organized the gathered information according to the widely adopted definition of primary and support activities provided by Porter (1985). The results are summarized in Table 2.

Depending on the company strategy, some activities may be outsourced; nonetheless, this does not affect the following data analysis and the framework definition.

Primary activities (Activities performed for the manufacturing and delivery of a product or the provision of a service)	*Quotation and order management:* it consists in preparing an offer in response to a customer request for proposal (RFP), and subsequently to process the order received from the customer.
	Technical and commercial development: it deals with the definition of the product's technical features starting from customer's requirements.
	Design: it consists of mechanical, electrical and software design to meet the customer's requirements.
	Purchasing: it refers to the procurement of material and components needed to fulfil customer orders.
	Production, assembly and testing: it refers to assembly and test of the product after the completion of the design and purchasing activities.
	Delivery: it refers to the disassembly of the product for the delivery to the customer.

	Commissioning: companies' technicians are responsible for reassembling the product at the customer's site and putting it into service.
	After-Sales service: it consists in providing services to support customers in case of malfunctions or breakdowns.
Support activities (Activities helping the improvement of efficiency and effectiveness of primary activities to gain competitive advantage)	*Project management*: it is related to the identification of order phases, their sequence, resources (both human and technical), constraints, and the time needed to complete each phase. This activity also encompasses order progress monitoring in terms of time, and planning and implementation of corrective actions.
	Planning: it consists in scheduling the primary activities and allocating the resources (equipment, people, and materials). Scheduling and resource allocation have to respect all the constraints (capacity constraints, precedence constraints, and other constraints coming from the project management) and assume a multi-project point of view.
	Cost control: it deals with the on-going and final monitoring of the main financial performance, in order to measure objectives achievements of an entire order (or a single activity) and to provide feedbacks to project management for planning corrective actions. It also addresses the definition of the order budget and performance objectives.

Table 2 – Primary and support activities for machinery-building companies

Regarding the second and the third research questions, the definition of the typical primary and support activities was a precursor for the subsequent identification of the most relevant high-level software functionalities required for the execution of these activities in a machinery-building company. We identified 42 software functionalities spanning over all the primary and support activities, from "Contract management" to "Packing list management" (the full list of software functionalities is reported in Appendix C). The way such functionalities are implemented varies from company to company. Therefore, to perform a cross-case analysis, and identify some behavioural patterns among companies, we classified the sample on the basis of the following two ratios:

- **SF** = the number of *supported software functionalities* over the *total number of identified functionalities*. A software functionality is considered *supported* if it is actually implemented in the ERP system (or similar integrated software solutions) or in a stand-alone application. For our purpose, an integrated software solution is a software tool interacting with the ERP, guaranteeing full tracking and data integration across the company. Conversely, a stand-alone application is not synchronized with the ERP system (i.e. office productivity suites), and does not allow seamless data integration across the company.

- **IF** = the number of *integrated software functionalities* over *the total number of identified functionalities*. The integrated software functionalities are those implemented in the ERP system (or in an integrated software solution), thus excluding those implemented in a stand-alone software. Clearly, IF ≤ SF since the IF ratio may include a subset of the functionalities considered for the evaluation of the SF ratio.

Figure 3 depicts the positioning of the sample companies related to the IF ratio (horizontal-axis) and the SF ratio (vertical-axis).

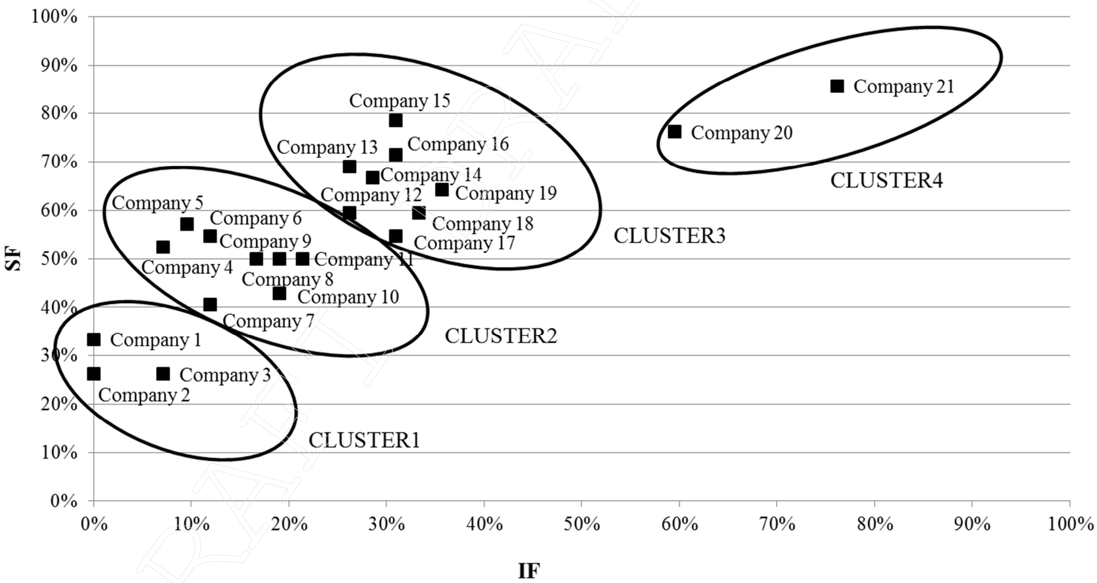

Figure 3 - Clusters of sample companies

We then classified the sample in the following four clusters, which minimize the loss of information consequent the merge of different observation points (Aggarwal and Reddy, 2014):

- *Cluster 1*: it includes companies (14% of the sample) that implement less than 35% of the identified functionalities with a very low level of integration (less than 10% of the software functionalities performed using the ERP or an integrated software solution). This cluster encompasses mainly those companies that still do not have a fully-fledged ERP system in place, and mainly implement the activities through stand-alone software applications.
- *Cluster 2*: it includes companies (38% of the sample) that implement between 40% and 60% of the identified software functionalities with a rather modest level of integration (less than 25%). Companies in this cluster do have an ERP system in place, but stand-alone applications prevail over the integrated systems.
- *Cluster 3*: it includes companies (38% of the sample) that implement between 50% and 80% of the software functionalities, mainly with the support of the ERP system or integrated applications.
- *Cluster 4*: it includes companies (10% of the sample) implementing and supporting through the ERP or integrated applications the highest number of software functionalities.

Starting from this company classification, to understand better the similarities within the clusters we investigated three main dimensions, referred to as *activity formalization level*, *ICT software support*, and *software functionality criticality level*. In the remainder of this section, we further define and discuss in detail the above reported dimensions.

4.1. Activity formalization level

With regard to the primary and support activities presented in Table 2, for each company we identified the subset of activities actually *formalized*, that is the activities present in the company's organization and governed by procedures and rules. In almost all the companies of the sample, the primary activities are formalized; the only exception is represented by the technical and commercial development activity, formalized only in the 19% of the sample (Figure 4). This result stems from the fact that 19% of the interviewed companies consider the technical and commercial development as a separate activity, while in the remaining 81% of the sample this activity belongs to the design phase. Designers themselves, without an intermediate function, define the machine technical features.

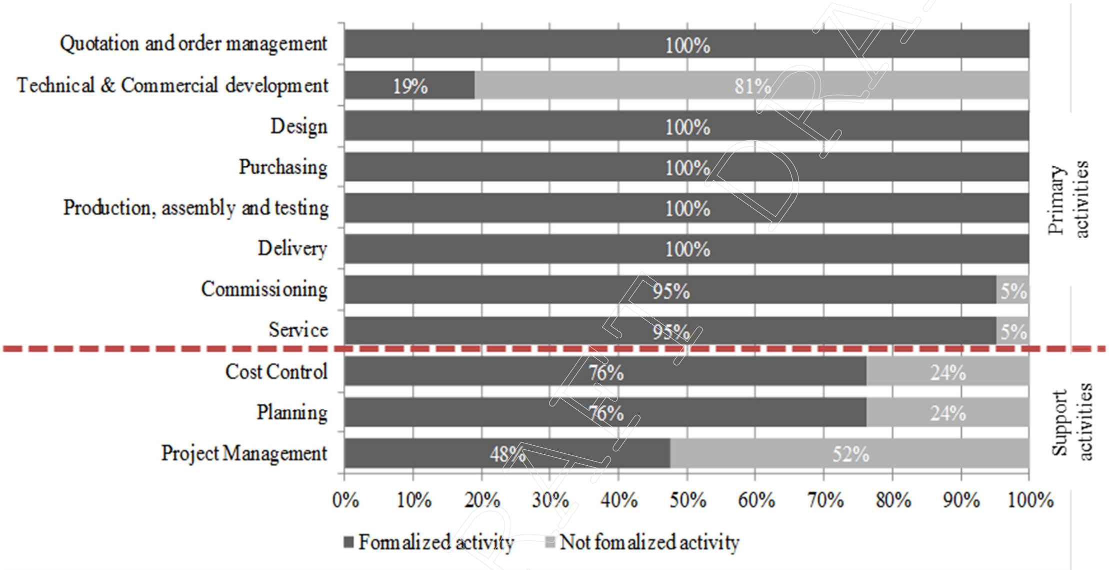

Figure 4 - Formalization level of primary and support activities

Conversely, the level of activity formalization is substantially lower for the support activities: in fact, fewer companies formalize cost control and project management. In particular, 33% of companies belonging to clusters 1 and 75% of companies belonging to cluster 2 consider cost control activities as formalized. Only 33% and 25% of clusters 1 and 2, respectively, define specific procedures and rules for project management activities. In addition, among the three support activities, project management is the less formalized one. In fact, as emerged from the interviews, project management is still based on people expertise, and a structured process with a well-defined procedure and a shared outcome (i.e., a Gantt chart showing projects schedule) is often missing. As a consequence, a large number of companies, especially belonging to clusters 1 and 2, claimed that the on-going projects status, in terms of both time and costs, is not monitored: updates related to order timeliness are tracked only through weekly meetings with the different process managers, while cost deviations from budget are calculated only after the product has been delivered to customer and the order closed.

4.2. Software support

We further investigated the software support to the primary and support activities, distinguishing between ERP, Integrated applications support and stand-alone applications support, as reported in Figure 5.

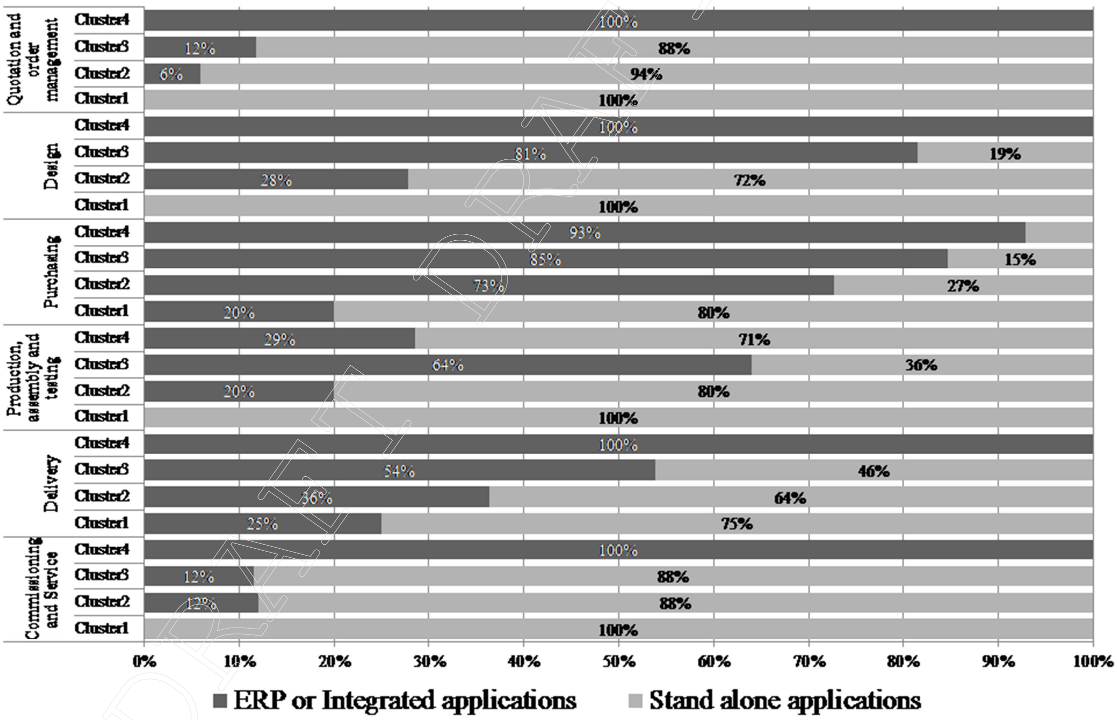

Figure 5 - Software support level of primary activities by cluster

Integrated software tools, especially in companies belonging to clusters 3 and 4, support primary activities, besides being properly structured and governed by procedures and rules. On the contrary, clusters 1 and 2, which comprise more than 50%

of the total sample, support most of the primary activities through stand-alone applications. According to our experience and research in this field, companies operating in the ETO context are often trapped in a trade-off between premium software solutions and more economic, entry level solutions. The former usually offer a relevant part of the functionalities useful for these companies, but with relevant costs that SMEs may not be willing to afford, and without the desired interoperability among different systems. Conversely, the latter offer basic functionalities, due to the reason that this type of software has been developed for the repetitive production sector, and subsequently adapted to the non-repetitive one, highlighting some lacks even in the functionalities that should be considered as basic of an ERP software.

Similarly to Figure 5, Figure 6 shows the software support level of project management, planning and cost control divided by clusters. The results reported in this chart, along with those reported in Figure 4, highlight that these three fundamental supporting activities are not well supported by the majority of the sample. This suggests room for improvements in both the managerial principles and procedures, and in the software support of these processes. Indeed, they may be considered the core of project-based enterprises, since the high customization results in frequent changes of product design, process planning and production routines (Tu and Dean 2011), and resource usage has to be carefully handled and monitored.

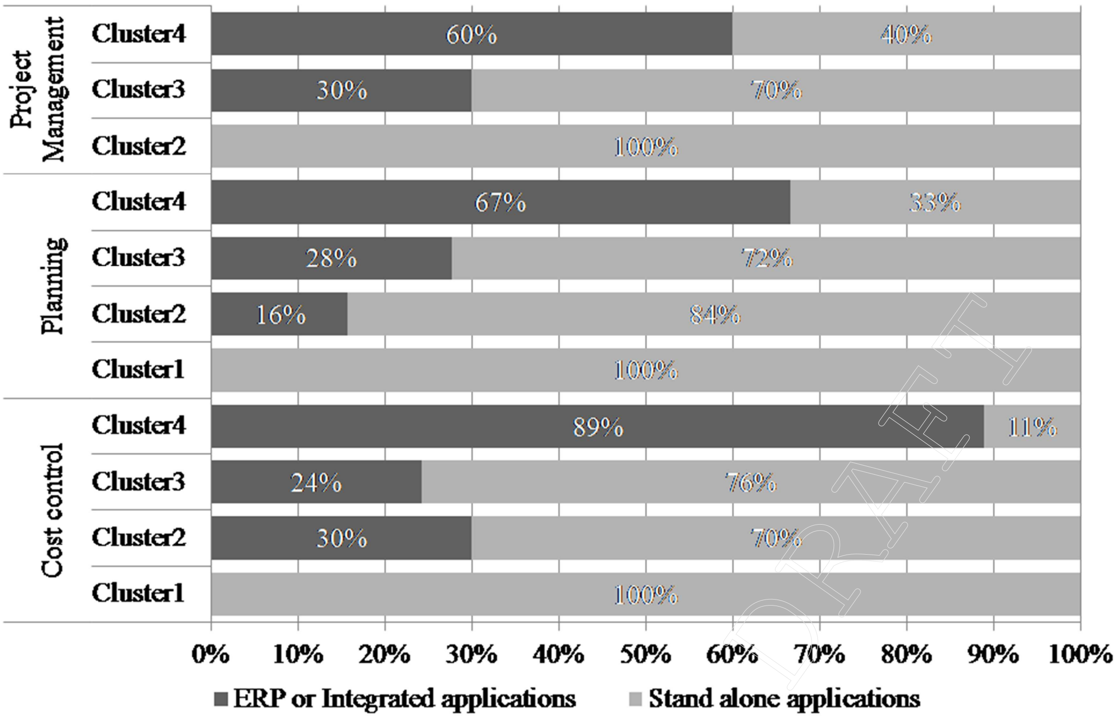

Figure 6 – Software support level of support activities by cluster

4.3. Software functionalities criticality level

We analysed the criticality level of the software functionalities. To this end, we distinguished between:

- *Critical functionalities*: a functionality is deemed as critical if an improvement in the software support, or the implementation of a new one (if not supported yet), is required by the interviewed companies.
- *Non-critical functionalities*: a functionality is deemed as non-critical if the company does not need any improvement in the current software support, or does not require any implementation at all.

Clusters 1 and 2 deemed as critical the majority of functionalities (respectively, 93% and 72% of all the identified functionalities are considered critical), confirming that an improvement in the software support is needed.

In particular, the criticality level analysed on the activity basis (Figure 7) suggested that the support activities are generally considered more critical by the majority of interviewed companies.

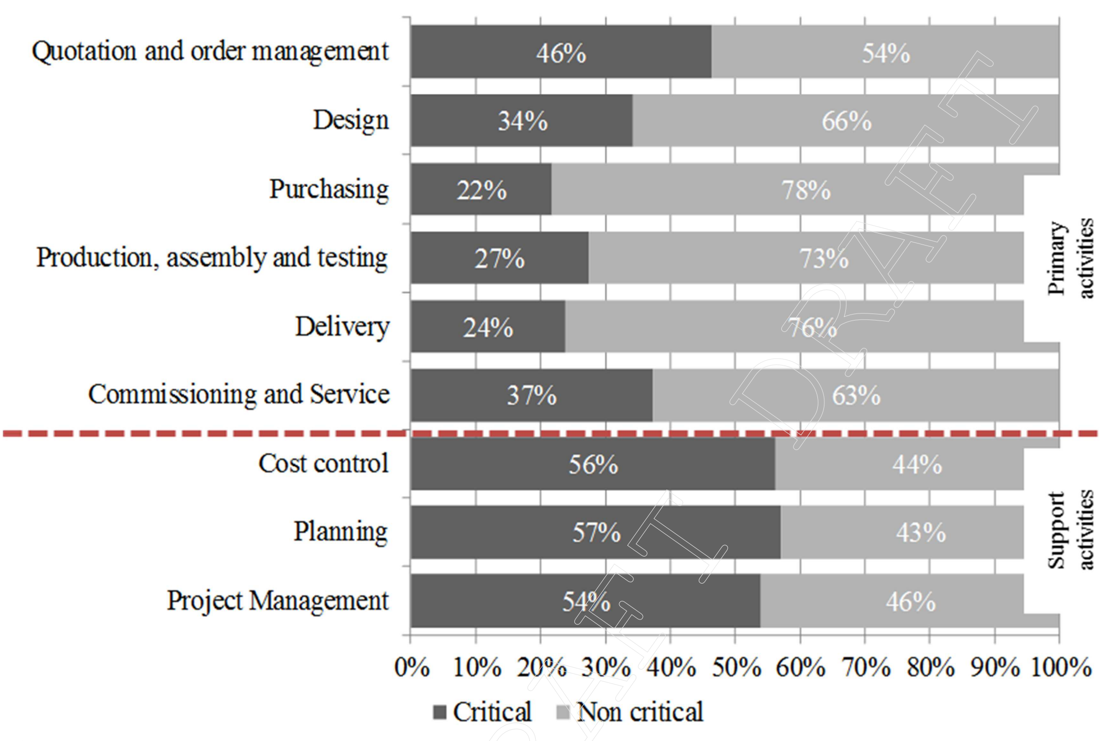

Figure 7 - Criticality level of software functionalities by activities

Recalling the results related to the formalization and the support level of the different activities, a common weakness emerged from the case studies is the lack of managerial procedures and software support, especially in the production planning and project management area. In the investigated environment, each customer order is like a new project for the company, sometimes substantially different or with few commonalities with previous projects. For this reason, project management and production planning should be well known disciplines in ETO machinery-building companies, to optimize project sequences, activities scheduling, and project status monitoring. On the contrary, software functionalities such as resource allocation (planning), project activities modification (project management), activity status monitoring (project management), activity planning (planning), and activity plan representation (planning) are perceived as critical from the majority of companies, and are either not implemented at all or supported by stand-alone applications.

A possible motivation underlying this finding resides in the evolution of the business context that Italian ETO machinery-building companies are facing. As emerged from different interviews, up to some years ago the business of these companies was blooming, margins were rather high, projects and activities planning were headed by few experienced people - usually the company owner or the operations manager - and some cost inefficiencies were tolerated. Nowadays, customers are requiring more and more customized machines, shorter lead times, and lower prices. Consequently, cost and time efficiency has become one the most important factors to allow companies to make profit and survive. For this reason, project management and planning have become very critical processes, since they can help these companies to optimize resource allocation, minimize costs, maximize delivery timeliness, monitor project status, check deviations from budget, and plan corrective actions. Furthermore, since these companies focus more and more on costs, also cost control becomes a crucial support activity to allow a better evaluation of costs and financial performance.

As a conclusion of the analysis, it is possible to state that, regarding company allocation to the different clusters (Figure 3), the more a company is closed to the top right corner of the graph (cluster 4) the more it is structured and supported from the ICT viewpoint. This kind of companies formalizes a large portion of the identified high-level software functionalities required for the execution of the primary and support activities. In addition, they support these activities through ERP or integrated software applications; thus, all the information is tracked and theoretically always available and updated. However, another aspect to be considered in the analysis is also the criticality level, since the ERP (or the integrated software application) should really facilitate the functionalities execution and fully satisfy the users. Thus, a company should aim at reaching cluster 4 position but, in the meantime, it should minimize the criticality level. Regarding the sample, the companies belonging to cluster 4 declared an average low criticality level (5% of functionalities are critical), meaning that their ICT support is quite effective. In line with the general results, the only critical functionalities for the cluster 4 companies are those related to the planning and project management activities.

5. Proposal of a reference framework

Through the 21 industrial case studies performed in this study, we identified a compelling need for reviewing the general approaches to the planning, scheduling, and control activities in typical ETO machinery-building companies. Such a need led us to the development of an empirical (i.e. derived from observation rather than theory), high-level production planning reference framework, encompassing all the activities involved in the order fulfilment process. As the analysis of the case studies underlined, the production management processes in the analysed companies play an important yet often underrated role.

Starting from the maps of the companies' main activities, we outlined a general reference model aiming at assisting company management in the review of their processes. Such a framework, graphically summarized in Figure 8, encompasses all the tasks supporting the primary activities related to PPC processes, resulted as the most critical and less implemented for the involved sample of companies. The support activities are further intertwined with other activities in an ideal flow from the request for proposal to the cost assessment and control.

In the development of the framework we aimed at including the best practices identified through the interview process. The preliminary model was presented and discussed in a dedicated workshop with a panel of production planners and managers from the companies involved in the study. The final version was amended according to the feedbacks received during the workshop with the professional partners. Although of a relatively high-level, the logical flow of the activities was judged reasonable and coherent with the goals of the involved companies. The most relevant feedbacks leading to changes in the framework were related to:

- *the name of the activities*: in two cases, it was deemed useful to adjust the name of the activities to make their content more explicit (i.e. from “RFP Management” to “RFP Management and preliminary product engineering”, and from “Product design review” to “Product design review & update”);
- *the level of detail of the activities*: in one case, it was requested to split one activity into two activities, to provide a better representation of the content. In particular, the former “Project management” activity has been split into the “Project planning and management” and “Aggregate and capacity planning” activities in the final version of the framework.

We provide a description of the final result (i.e. the proposed framework) in the next section.

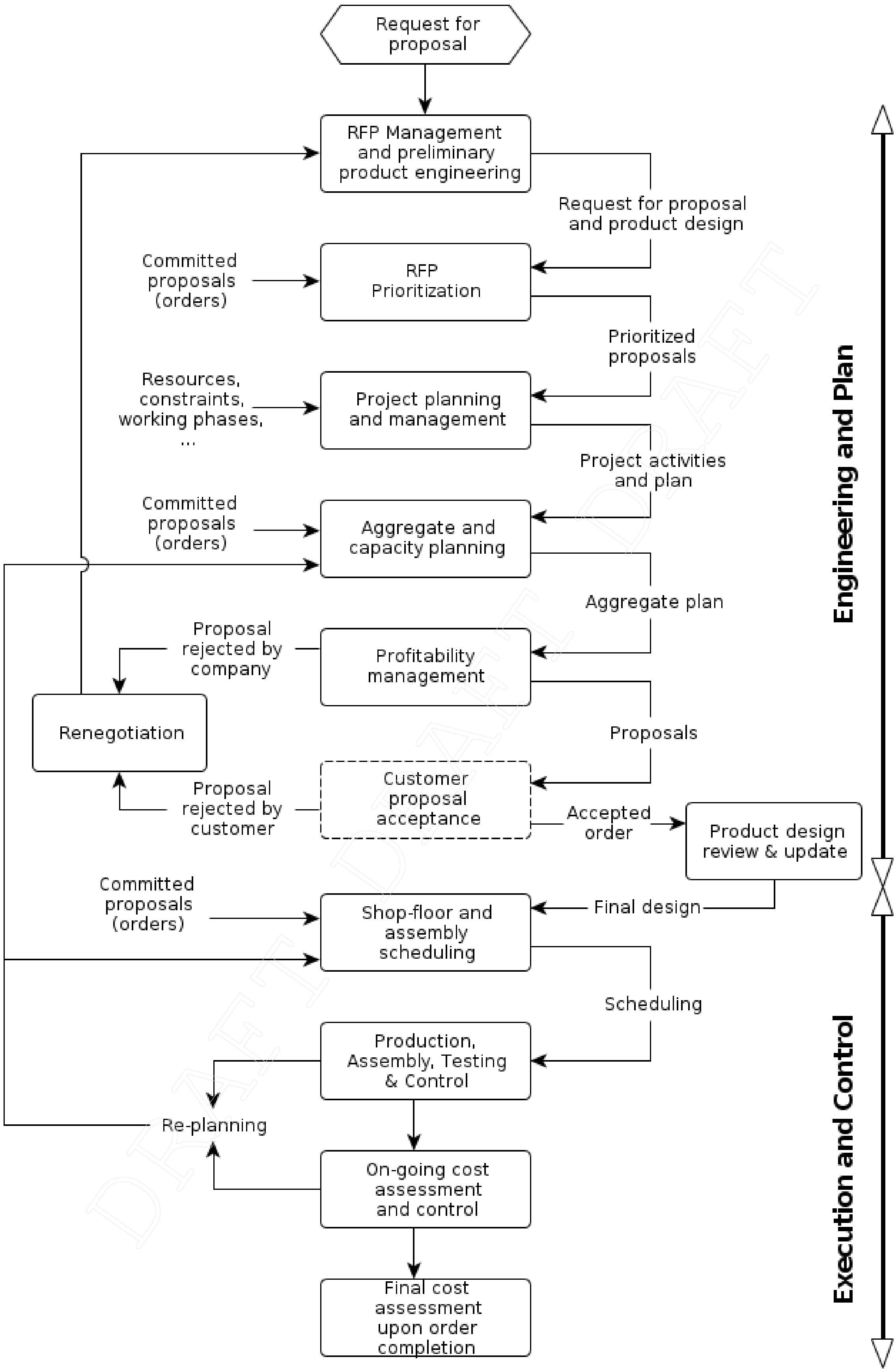

Figure 8 - Process reference framework

5.1. Framework description

The proposed framework encompasses two main phases: i) an *Engineering and plan phase*, where the company manages the first contact with the customer gathering his requirements, designs and engineers the requested product, and plans the future activities to define the proposal for the customer, and ii) an *Execution and control phase*, during which the company actually manufactures the product through production and assembly activities. Further details about the contents of these phases are provided hereafter.

Upon the receipt of a request for proposal (RFP) specifying the customer's needs and requirements, the company performs a first evaluation to define the product technical characteristics, features and design that best match the requirements. This engineering task is a critical task of the whole process; in fact, it contributes to the definition of the activities to be performed, to the decision about which parts must be planned for purchasing or manufacturing, and which resources should be used or acquired. During this specific task, designers can reuse existing solutions and former bids to shorten the lead time, and improve the product design reliability. The level of detail required in this task depends upon the specific context. Nonetheless, at this stage of the whole process the company should be able to generate a draft design effectively, accurate enough to allow for a proper understanding of the required activities and resources.

The preliminary product design and the RFP are then evaluated to define the RFP priority compared to already committed orders. The priority index is based on several parameters such as the requested delivery date, the relevance of the customer, the resource requirements, the degree of similarity with other orders, and so forth. Therefore, the specific rules and policies governing this task depend mainly upon the company's orders management strategy and the customers segmentation strategy. The priority index defines the access precedence to scarce resources. Each prioritized RFP then passes to a project-planning task under the responsibility of a project manager, who refines the product design when needed, and elaborates a project plan defining all the required activities and sequences required for the final production. In case of many, simultaneous RFPs (or in case the company elaborates the RFPs on a batch-base) each one is evaluated independently (i.e. considering the production system as empty, and all the resources immediately available). In this way, the theoretical amount of resources required to manufacture each proposal is determined, as well as the hypothetical duration of each activity and the delivery date of the final product.

With these resource requirements, an assessment of the potential load imposed upon critical resources must be made before accepting the order. Therefore, the subsequent task in the framework is the integration of the RFP with the already committed orders, to evaluate the impact of the new, potential orders on the production system at an aggregate capacity planning level. Considering the RFPs' priority indexes, the advancement status of on going orders, and the resources availability, the aggregate planning activity aims to generate an aggregate plan showing the projected load profile of the production system. This load projection allows for the identification of the impacts of new orders upon critical resources, supporting the decision makers in managing the workflow and delivery dates. The assessment of the impact of the new RFP on the company's system is a pillar of the profitability management task: the company can now decide whether to proceed with the proposal asking the confirmation to the customer, or reject it and return to a negotiation stage with the customer in order to change RFP's parameters, such as the general requirements or the delivery date.

Once the customer accepts the proposal, the RFP becomes a committed order. Therefore, it is possible to process the information at a higher detail level, reviewing and refining the product design, if needed. The resulting final design can thus be used to perform a detailed production planning at the shop-floor level, and scheduling all the activities of the production process, to drive the managerial decisions in the short-medium term. The detailed plans are then passed to production-floor manager, and the cost assessment and control activities are continuously performed until the end of the order delivery. This on-going monitoring can raise the need of a re-planning, either at an aggregate or at a detailed level, that can be a consequence of internal or external time deviations, or requirement changes. Table 3 summarizes the activities in the proposed framework.

Activity	**Tasks description**
RFP management and preliminary product engineering	• Receives the RFP from the customers • Elaborates the preliminary technical and commercial characteristics of the product • Manages the RFP during its life cycle
RFP Prioritization	• Defines the priority of the RFP according to multiple criteria (i.e. relevance of the customer, type of the order, products, existing contracts and agreements…).
Project planning and management	• Defines the required design activities on the basis of the preliminary design • Defines the required resource and manufacturing activities (production, assembly, purchasing…) • Defines the preliminary sequence of the manufacturing, assembly, and purchasing activities
Aggregate and capacity planning	• Elaborates the aggregate requirements • Elaborates the capacity planning and resource requirements
Profitability management	• Evaluates the profitability of the proposals • Provides information for the acceptance/rejection decision
Customer proposal acceptance	• The customer decides whether to accept or reject the proposal
Product design review & update	• Reviews and/or updates the product design upon customer request • Engineers the final version of the product, settling the product design for the next tasks
Renegotiation	• Supports the renegotiation of the RFP or of the proposal in case of rejection
Shop-floor and assembly scheduling	• Defines the detailed sequence of the manufacturing, assembly, and purchasing activities • Provides medium- to short-term scheduling to manufacturing and assembly departments
Production, Assembly, Testing & Control	• Executes the production and assembly tasks • Surveys the production advancement • Monitors the exceptions • Resolves operational issues and defines counter actions • Controls the execution of the required activities
On-going cost assessment & control	• Monitors the execution of the tasks • Monitors the costs

Final cost assessment upon order completion	• Monitors the final cost • Archives costs data for future budgeting activities

Table 3 - Activities in the proposed framework

This framework aims at representing an initial and reasonably comprehensive model of the logical, high-level flow of the required activities, which could serve as a reference for the development of new processes and software support.

6. Conclusions

Today’s competitive pressure often emphasizes the customer’s requirement for highly customized products. For this reason, Engineer-to-Order companies play a pivotal role in many industries, allowing for the realization of one-of-a-kind products upon customer’s specification. Due to the peculiarities of the ETO manufacturing strategy and of machinery-building companies, carefully tailored managerial paradigms, methods, and supporting tools are required for an effective and efficient management. Nowadays, these companies are becoming aware of the need of suitable tools and managerial paradigms to handle the multi-faceted activity flows from order receipt to product delivery and commissioning.

In our opinion, the results of the 21 case studies, illustrated throughout the paper, support the relevance of the addressed research questions. As a matter of fact, many activities are still performed in inconsistent ways, using different software supporting tools (implying possible redundancy and misalignment), or even manually. Therefore, as the feedbacks from the involved managers underline, the machinery-building companies still suffer the lack of comprehensive process frameworks and related software tools encompassing the whole set of activities required to develop the business (RQ 3).

One major contribution of this study, as the results of the study underline, is the clear identification of a lack of ICT support of two fundamental tasks such as project management and planning. This evidence, in conjunction with the analysis of the criticalities of software functionalities (RQ 2) expressed by the participants to the study (see Appendix C), led us to infer that there is substantial room for improvement in this concern. To this regards, although this aspect goes beyond the specific goal of this paper, we envision the possibility of extending the existing software offering, designing and providing tailored applications for the machinery context. The development of an integrated software environment to support (in particular) project management and planning activities, specifically addressed to this kind of ETO companies, could help them in improving their performance and competitiveness.

Another contribution to the current body of knowledge is the identification of a compelling need for reviewing the general approaches to the planning, scheduling, and control tasks in ETO machinery-building companies. To this end, the proposed framework aims at representing an initial and reasonably comprehensive reference model of the logical, high-level flow of the required activities (RQ 1). Being based on a selected sample, the framework includes good practices from different machinery-building companies operating according to the ETO strategy. It is noteworthy to mention that the specific contents of each activity and task, as well as the mode of implementation of the required functionalities, is bound to the specific industry, product and context being realized. Therefore, due to the high variety of industries for which the ETO strategy is suitable, it is not possible to be in any sense exhaustive.

Considering both the practitioners and researchers points of view, further investigations are required to tailor the framework to other real cases, even involving other ETO industries (e.g. special earth-moving machine, offshore platform), with companies coming also from other countries. Secondly, we envision the possibility to apply the proposed framework in real companies through *ad hoc* intensive case studies, in order to drive the design and implementation of new managerial processes in the PPC area. A longitudinal study, in fact, could allow for a stronger validation of the framework, and for a factual measure of the potential benefits. To this end, both organizational and technical questions should be addressed. Considering the latter aspect, the framework can serve as a reference for the design of a tailored ETO software support, providing a sort of checklist of the main software functionalities required for managing the business.

Appendix A – Sample demographics

Company	Employee class [number]	Turnover class [mio €]	Company size	Industry	% of products designed on customer requirements (P)
Company 1	< 50	< 10	Small	Mechatronic systems	P ≥80%
Company 2	< 50	< 10	Small	Grinding	60%< P < 80%
Company 3	< 50	< 10	Small	Industrial automation, especially in the steel industry	P ≥80%
Company 4	50 - 250	10 - 50	Medium	Special fire fighting vehicles	60%< P < 80%
Company 5	50 - 250	10 - 50	Medium	CNC machining centers	P ≥80%
Company 6	50 - 250	10 - 50	Medium	Electric ovens	60%< P < 80%
Company 7	50 - 250	10 - 50	Medium	Automated assembly systems for batteries	P ≥80%
Company 8	50 - 250	10 - 50	Medium	Machines for food packaging	P ≥80%
Company 9	< 50	< 10	Small	Test benches	P ≥80%
Company 10	50 - 250	10 - 50	Medium	Rolling steel plants	P ≥80%
Company 11	50 - 250	10 - 50	Medium	Milling Systems	60%< P < 80%
Company 12	50 - 250	10 - 50	Medium	Calenders	60%< P < 80%
Company 13	50 - 250	10 - 50	Medium	Balancing, measuring and testing systems	60%< P < 80%
Company 14	< 50	< 10	Small	Assembly lines and machines, palletizing systems and testing	P ≥80%
Company 15	50 - 250	10 - 50	Medium	Automatic washing systems	60%< P < 80%
Company 16	50 - 250	10 - 50	Medium	Machines for processing different materials (wood, glass, plastic, ...)	60%< P < 80%
Company 17	> 250	> 50	Large	Trencher for excavating machines and machines for stringing cables	60%< P < 80%
Company 18	50 - 250	10 - 50	Medium	Equipment for the extrusion	P ≥80%
Company 19	< 50	< 10	Small	Dies and molds for casting aluminium veneer	P ≥80%
Company 20	50 - 250	< 10	Medium	Machines for the automation of assembly processes	P ≥80%
Company 21	> 250	> 50	Large	Machines for hosiery	60%< P < 80%

Table 4 - Sample demographics

Appendix B – Guidelines for interview

ID	Source	Domain	Topic	Variable/Question	(possible) Respondents
1	Preliminary Questionnaire	Company Overview	Demographic information	Company name	Entrepreneur / CEO
2	Preliminary Questionnaire	Company Overview	Demographic information	Corporate designation	Entrepreneur / CEO
3	Preliminary Questionnaire	Company Overview	Sector of application	ATECO Code	Entrepreneur / CEO
4	Preliminary Questionnaire	Company Overview	Demographic information	Location (City/Address/…)	Entrepreneur / CEO
5	Preliminary Questionnaire	Company Overview	Demographic information	Web site	Entrepreneur / CEO
6	Preliminary Questionnaire	Company Overview	Demographic information	Foundation year	Entrepreneur / CEO
7	Preliminary Questionnaire	Company Overview	Company governance	Does the company belong to a corporate group?	Entrepreneur / CEO
8	Preliminary Questionnaire	Company Overview	Company structure	Indicate the number of production plants	Entrepreneur / CEO
9	Preliminary Questionnaire	Structural characteristics	Economics	Yearly turnover	Entrepreneur / CEO
10	Preliminary Questionnaire	Structural characteristics	Demographic information	Number of employees	Entrepreneur / CEO
11	Preliminary Questionnaire	Structural characteristics	Company structure	Yearly investment in ICT	Entrepreneur / CEO / CIO
12	Interview	Context	Market	Has the sector been hit by the crisis? Is it recovering? How your company see the future?	Entrepreneur / CEO / Sales manager
13	Interview	Context	Market	What is the market growth expectation?	Sales manager / CEO
14	Interview	Company Overview	Critical success factors	Which are the critical success factors in the industry? Which are your strengths and weaknesses?	Sales manager /Marketing manager
15	Interview	Company Overview	Critical success factors	Which are your core activities? Do specific ICT tools adequately support them?	Entrepreneur / CEO / Project manager / CIO
16	Interview	Custom order features	Product characteristics	Describe the main features, objective and specificity of your product/orders, in terms of cost, quality, time and profitability	Entrepreneur / CEO / Project manager
17	Interview	Custom order features	Product characteristics	Describe the value for the customers (for what are they willing to pay?)	Entrepreneur / CEO / Project manager / Sales Manager

ID	Source	Domain	Topic	Variable/Question	(possible) Respondents
18	Interview	Custom order features	Product characteristics	How would you describe your typical product?	Sales manager / Marketing manager / Project manager /
19	Interview	Custom order features	Product personalization	Relevance of the design phase on your typical product. (identify which are the "real" ETO product in the company)	Project Manager / R&D Manager /
20	Interview	Custom order features	Product personalization	Which is the % of products designed based on customer requirements?	Project Manager / R&D manager /
21	Interview	Custom order features	Product personalization	How does your company mainly answer to customer orders? (Engineering to order; Make to order; Assembly to order… Mixed or other)	Project Manager / R&D manager /
22	Interview	Custom order fulfilment	Processes	What processes and company's functions are necessary for the customer order fulfilment?	Entrepreneur / CEO / Project manager /
23	Interview	Custom order fulfilment	Processes	Is there a specific responsible for each order? Is the role of "project manager" formalized?	Entrepreneur / CEO / Sales manager /
24	Interview	Custom order fulfilment	Processes	Level of collaboration between the different business functions: specific meeting, deliverable, information exchange, progress analysis…	Entrepreneur / CEO / CEO Assistant / Sales manager /
25	Interview	Custom order fulfilment	Activities composition	Which are the primary and support company activities?	Entrepreneur / CEO / Project manager / R&D manager
26	Interview	Description of main activities	Processes	For each activity (see # 25): Is this activity formalized inside the company (described in the company quality manual)? Which are the main objectives of this activity? Which are the main tasks and connected input/output?	Specific function manager /Project manager
27	Interview	Description of main activities	Processes	For each activity (see # 25): - have you defined specific roles and responsibilities? - have you defined performance indicators and targets? - have you defined structured formal procedures/rules to manage this activity and its main tasks? - have you defined specific methods and implemented IT tools to support this activity? - which are the main features/criticalities of this activity?	Specific function manager /Project manager
28	Interview	Description of main activities	Company information systems	For each activity (see # 25): What kind of IT tool is used to support the activity? Is this tool adequate for you? Which are its main criticalities? (list of IT tool mainly used to support the specific process)	Specific function manager / CIO
29	Interview	Description of main activities	Company information systems	For each activity (see # 25): Which is the integration level of this tool with other company' software? (e.g. Integrated with ERP, stand-alone...)	Specific function manager / CIO

ID	Source	Domain	Topic	Variable/Question	(possible) Respondents
30	Interview	IT tools	Software functionalities	Which of these software functionalities (see SW functionality check list) are supported by the information systems? (Analyse also the main features and criticalities due to its use in an ETO context)	Specific function manager / CIO

Table 5 – Guidelines for interview

Appendix C – Software functionalities

#	Activity	Functionalities
1	Quotation and order management	Product Configurator
2	Quotation and order management	Customer Relationship Management (CRM)
3	Quotation and order management	Order quotation database
4	Quotation and order management	Order quotation
5	Technical & Commercial development	Technical specifications management
6	Design	Bill of Materials generation
7	Design	Bill of Materials change management
8	Design	Synchronization of electrical design software data with ERP
9	Design	Synchronization of mechanical design software data with ERP
10	Design	Software versioning
11	Purchasing	Purchase order request
12	Purchasing	Item classification
13	Purchasing	Purchasing cycle management
14	Purchasing	Management of supplier master data
15	Purchasing	Contract Management
16	Purchasing	Stock movements
17	Purchasing	Labels/barcode printing
18	Production, assembly and testing	Items allocation
19	Production, assembly and testing	Order production management
20	Production, assembly and testing	Order assembly management
21	Production, assembly and testing	Testing report
22	Delivery	Determination of loading production plans
23	Delivery	Supporting documentation
24	Delivery	Packing list management
25	Delivery	Missing material list reporting
26	Commissioning and service	Commissioning activity log
27	Commissioning and service	Commissioning problem management
28	Commissioning and service	Complaints management
29	Commissioning and service	Technical assistance management
30	Commissioning and service	Remote monitoring
31	Commissioning and service	Service reporting
32	Project Management	Activities plan sharing
33	Project Management	Project activities modification
34	Project Management	Activity status monitoring
35	Planning	Resource allocation
36	Planning	Activity planning
37	Planning	Activity plan representation
38	Cost Control	Man-hour and cost allocation to order
39	Cost Control	Deviations analysis
40	Cost Control	Order accounting
41	Cost Control	Order budget issuance
42	Cost Control	Budget modification

Table 6 - List of 42 identified software functionalities

Appendix D – Workshop attendance

Domain	Gender	Experience	Job position	Role in the meeting
Academic	M	Over 10 years	Full professor	Moderator
Academic	M	Over 5 years	Assistant professor	Workshop coordinator
Academic	M	Over 5 years	Post-doctoral researcher	Workshop coordinator
Academic	F	Over 5 years	Post-doctoral researcher	Observer
Academic	M	5 years or less	PhD student	Observer
Academic	M	5 years or less	PhD student	Observer
Professional	M	Over 10 years	CEO	Domain expert
Professional	M	Over 10 years	CEO	Domain expert
Professional	M	Over 10 years	CEO	Domain expert
Professional	M	Over 10 years	CEO assistant	Domain expert
Professional	F	Over 10 years	CEO assistant	Domain expert
Professional	F	Over 10 years	CEO assistant	Domain expert
Professional	M	Over 10 years	Entrepreneur	Domain expert
Professional	M	Over 10 years	Entrepreneur	Domain expert
Professional	F	Over 10 years	Entrepreneur	Domain expert
Professional	M	Over 10 years	CIO	Domain expert
Professional	M	Over 10 years	CIO	Domain expert
Professional	M	Over 10 years	EDP manager	Domain expert
Professional	M	Over 10 years	EDP manager	Domain expert
Professional	M	Over 10 years	EDP manager	Domain expert
Professional	M	Over 10 years	EDP manager	Domain expert
Professional	M	Over 5 years	EDP manager	Domain expert
Professional	F	Over 10 years	Project manager	Domain expert
Professional	M	Over 10 years	Project manager	Domain expert
Professional	M	Over 10 years	Project manager	Domain expert
Professional	M	Over 10 years	Project manager	Domain expert
Professional	M	Over 10 years	Project manager	Domain expert
Professional	M	Over 5 years	Project manager	Domain expert
Professional	F	Over 10 years	Sales and marketing manager	Domain expert
Professional	M	Over 10 years	Sales and marketing manager	Domain expert
Professional	M	Over 10 years	R&D manager	Domain expert
Professional	M	Over 5 years	R&D manager	Domain expert
Professional	M	Over 5 years	R&D manager	Domain expert
Professional	M	Over 10 years	R&D manager	Domain expert
Professional	F	Over 10 years	Purchasing manager	Domain expert
Professional	M	Over 10 years	Purchasing manager	Domain expert
Professional	M	Over 10 years	Production and logistic manager	Domain expert
Professional	M	Over 10 years	Production and logistic manager	Domain expert

Table 7 - List of people attending the workshop

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