Determinants for Order Fulfilment Strategies in Engineer-to-Order companies: insights from the Machinery Industry

Abstract

Recent empirical studies have refined our understanding of Engineer-to-order (ETO) situations, supporting the existence of different order fulfilment strategies based on the degree of customer involvement in the engineering and production activities, which differs depending on the strategic fit with the environment where the company operates. Despite the importance of this finding, limited attempts have been made to provide a comprehensive understanding of the determinants for this strategic choice in ETO companies. To overcome this gap, this study aims at investigating what are the sources of differentiation between the environments that ETO companies can face and how they react to strategically fit the order fulfilment strategy. In doing so, this research analyses the existing literature through a contingency theory lens and performs a multiple case study research in a specific ETO sector, i.e., the machinery industry. The study identifies five different order fulfilment strategies implemented in the machinery industry to provide different product families to the market. For each of them, the different environment characteristics have been defined and the performance outcome has been measured, explaining the rationale for the positioning of the product families in different strategies. The findings of this paper suggest two main contributions. First, the study contributes to theory, by deepening and refining the analysis of contingencies for choosing different order fulfilment strategies in the ETO context. Second, the study provides practical guidelines to ETO companies that want to adapt their order fulfilment strategy to the unexpected or planned changes in their environment.

Keywords. Engineer-to-order, Machinery Industry, Order fulfilment strategy, Customer order decoupling point, Case study research

1 Introduction

The order fulfilment strategy defines the way that a company responds to a customer order, i.e., the activities performed from the sales inquiry to the delivery of the product (Kritchanchai and MacCarthy, 1999; Lambert and Cooper, 2000; Shapiro et al., 1992). Thus, a strategic choice is related to the location of the customer order decoupling point (CODP), which separates forecast-driven and order-driven activities (Hoekstra and Romme, 1992; Sharman, 1984; Wemmerlöv, 1984; Wortmann, 1983). A range of possible order fulfilment strategies can be identified based on the location of the CODP (Lampel and Mintzberg, 1996): from pure customised Engineer-to-Order (ETO), where products are designed and produced according to customer specifications, to pure standardised Make-to-Stock (MTS), where products are delivered from finished goods (Wortmann et al., 1997).

Engineer-to-order (ETO) companies can choose among different order fulfilment strategies. Literature suggests that ETO companies can perform different activities after the customer order, e.g. modify existing designs or develop an entirely new one for every customer order (Gosling and Naim, 2009). Typically, ETO companies perform a certain amount of engineering and manufacturing activities both before and after the order arrival (Adrodegari et al., 2015). The traditional understanding of ETO situations, i.e., companies designing and producing each product from scratch following customer specifications (Caron and Fiore, 1995), has been recently refined to a more comprehensive understanding (Gosling et al., 2017; Willner et al., 2016). Different archetypes have been identified depending on the degree of design standardisation and the consequent amount of engineering and production work performed after the order.

When dealing with the order fulfilment strategies in ETO companies, then, the traditional conceptualisation of the CODP is problematic. Seminal CODP studies (Hoekstra and Romme, 1992; Sharman, 1984; Wortmann, 1983) consider engineering as a part of a linear sequence of activities that can be performed before or after CODP. However, to remain competitive, ETO companies accommodate different order fulfilment strategies, thus facing the particular challenge of having to integrate and manage both order-driven and forecast-driven engineering and production activities (Cannas et al., 2019). Hence, it is more useful to follow a two-dimensional approach for the CODP positioning, by defining both the amount of engineering and production work to perform before and after the order (Dekkers, 2006; Wikner and Rudberg, 2005).

The choice of the order fulfilment strategy represents a significant decision for ETO companies, given its serious implications for performance in terms of lead time, price, flexibility and quality (Olhager, 2003). This is even more relevant in the recent competitive arena, where ETO companies are claimed to offer high product variety in short time (André and Elgh, 2018; Cannas et al., 2018; Haug et al., 2009; Kristjansdottir et al., 2018; Sylla et al., 2018). High customisation can increase costs and lead times. As ETO companies leverage on a range of different product customisation choices, some of them highly customised while others can be more standardised (Hicks et al., 2000; McGovern et al., 1999). Furthermore, the implications for standardisation and efficiency in ETO companies of anticipating engineering activities have been underlined also by very recent studies that analyse more in-depth the application of lean, modularity and product platforms techniques (André and Elgh, 2018; Birkie and Trucco, 2016; Johansson and Elgh, 2019; Johnsen and Hvam, 2018).

Many complex engineering projects are plagued by delays and cost overruns (Flyvbjerg, 2014). Practical examples can be found in the media concerning construction, aerospace, capital goods and shipbuilding industries; e.g., the project for the International Space Station was completed six years late and 186% over-budget (Forbes, 2018); Boeing 787 Dreamliner was billions of dollars over budget and three years behind schedule (Forbes, 2013). Despite the above, literature is falling short in providing adequate support to ETO companies in choosing the appropriate order fulfilment strategy (Sandrin et al., 2018).

The CODP positioning along the continuum of activities of the production process has been demonstrated to be contingent upon a set of external and internal factors: market, product and production process characteristics (Van Donk, 2001). Research that has addressed the classification of ETO companies based on the extent to which they exploit existing designs or explore new knowledge, demonstrates that it depends on the environment to which they have to adapt (Cannas et al., 2019; Dekkers, 2006; Gosling et al., 2017; Semini et al., 2014; Wikner and Rudberg, 2005; Willner et al., 2016). These studies have made significant efforts to integrate the engineering process in the CODP concept by empirically analysing the application of this concept to complex ETO realities. However, none of these studies provides a comprehensive and specific framework related to the determinants for the CODP positioning in both the engineering and the production processes.

Consequently, it is difficult to provide practical guidelines to support ETO companies in choosing the appropriate order fulfilment strategy. For example, should a producer of ETO products aim to develop a fulfilment strategy that delivers customised products reusing existing designs, or to create more standard offerings by pursuing modular principles? The response to this question could depend on the environment the ETO company operates in and would be helpful to understand whether the current order fulfilment strategy supports the achievement of the desired performance outcome (Haug et al., 2009; Kristianto et al., 2013; Schoenwitz et al., 2017).

Hence, this study aims at understanding the sources of differentiation between the environments that ETO companies can face and how ETO companies react to strategically fit the order fulfilment strategy to the environment. For this reason, this article seeks to explore and explain this phenomenon, by answering the following research questions:

RQ1. What are the determinants for the order fulfilment strategy choices within ETO companies?

RQ2. How can ETO companies fit their order fulfilment strategies to different environments?

To achieve this aim, the researchers first reviewed the previous literature related to the CODP positioning through a contingency theory lens. Based on the review of literature, the initial framework of the study was developed, and the current state-of-the-art and research gaps were identified. Then, a multiple case study research was conducted in a specific ETO sector, i.e., the machinery industry. The remainder of this paper is organized as follows. Section 2 presents the literature review and section 3 defines the research methodology. Section 4 and section 5 present the results of the case studies. Section 6 discusses the results and section 7 provides the conclusion of the research, presenting the main implications and limitations of the study.

2 Literature review

2.1 Order fulfilment strategies in ETO companies

The first studies related to CODP based order fulfilment strategies dated back to the 80s and the 90s (Hoekstra and Romme, 1992; Sharman, 1984; Wemmerlöv, 1984; Wortmann, 1983). In this period, the increasing demand for innovative products triggered the movement towards more customised manufacturing systems (Wortmann, 1992) with the beginning of a new industrial paradigm, i.e., mass customisation (Davis, 1989; Pine, 1993). Accordingly, a continuum of order fulfilment strategies was demonstrated to exist based on the point of customer involvement (Lampel and Mintzberg, 1996), i.e., the CODP location, from pure standardisation (i.e., MTS), to pure customisation (i.e., ETO): including segmented standardisation, i.e., delivery-to-order (DTO), customised standardisation, i.e., assembly-to-order (ATO), and tailored customisation, i.e., make-to-order (MTO). Since these seminal studies, the CODP positioning has been introduced as a strategic choice.

Further studies included engineering activities into the frameworks of CODP. Among the others, Amaro et al. (1999) included in their taxonomy of order fulfilment strategies the degree of design customisation, in line with Mintzberg (1988), from “pure” (engineer completely new designs) to “tailored” (adapt existing designs), “standardised” (combine existing options) and “none” (take the design as it is). They stated that there are no reasons to assume a one-to-one correlation between the activities performed after the customer order and the degree of design customisation. Thus, they increased the number of order fulfilment strategies according to the different potential combinations of these two dimensions. Similarly, a range of four different ideal ETO types has been proposed by Hicks et al. (2001), which analysed the new phenomenon of more standardised modular designs.

These studies were considered not sufficient to cover the gap between theory and practice existing in the ETO literature. Indeed, Rahim and Baksh (2003), analysing the differences between ETO and MTS, affirmed that the literature is too much focused on MTS, whereas ETO requires ad-hoc frameworks that show a structured approach to manage both engineering and production processes and include the possibility of concurrency between the engineering and production activities.

To fill this gap, as underlined by Gosling and Naim (2009) and Dekkers et al. (2013), the two-dimensional (2D) CODP concept was introduced in the literature (Dekkers, 2006; Wikner and Rudberg, 2005), which extended the applicability of the CODP concept to a more comprehensive view. The 2D-CODP defines a broader order fulfilment strategy, where companies choose: (i) the number of engineering activities to perform to order; (ii) the number of production activities to perform to order. Thus, it decouples also the engineering process and takes into account the possibility of hybrid and overlapped strategies where engineering adaptations of existing designs are performed to order, in concurrency with production activities.

Since the 2D-CODP seminal studies, some attempts have been made in the literature over the years to classify the order fulfilment strategies by empirically analysing ETO companies. Veldman and Alblas (2012) analysed different engineering fulfilment strategies employed by two ETO companies, based upon a specific technology, predefined sub-functions and solution principles, and predefined finished goods. Semini et al. (2014) empirically analysed different engineering customisation strategies to design shipbuilding: (i) customised design, where most of the engineering activities are performed to order; (ii) and standardised design, where most of the engineering activities are performed to forecast, based on standardisation and modularisation. Additionally, different engineering standardisation and automation strategies have been identified by Willner et al. (2016) based on the engineering complexity and the production volumes, and different products of seven companies have been classified within them. The application of the decoupling concept to the engineering process has been further developed by Gosling et al. (2017), which investigated eight cases in different ETO projects. This study shows that the engineering decoupling choice covers a continuum of nine potential locations. Recently, based on the review of all the different existing studies abovementioned, Cannas et al. (2019) categorised different order fulfilment strategies in a structured 2D-CODP framework, which has been validated through the empirical insights of a multiple case study research in the machinery industry. This study shows that the focus of the managerial approaches to manage and coordinate engineering and production processes, before and after the decoupling point, varies depending on the decoupling strategy chosen.

2.2 *Linking order fulfilment strategies and performance outcomes*

The order fulfilment strategy aims to satisfy customer expectations in terms of flexibility, time, price and quality performance (Olhager, 2003). However, these different performance outcomes imply a trade-off: the achievement of high flexibility increases costs and lead times, and vice versa (Barlow et al., 2003). Consequently, the literature suggests that an operation cannot excel simultaneously on all performance measures and a company must define what key performance will be used for its success and focus on it (Chase et al., 2001). Therefore, the order fulfilment strategy should be implemented against the criteria that are important to the customer (Hallgren and Olhager, 2006; Olhager, 2010).

In the traditional connotation, the CODP positioning is considered to be dependent on the balance between: (i) competitive pressure, which pushes companies through forward shifting to improve delivery and price performance; and (ii) product cost (inventory management cost) and design complexity (customisation options offered to the market), which push companies through backwards CODP shifting to increase the customer service level (Hoekstra and Romme, 1992; Olhager, 2003; Sharman, 1984). The literature suggests to find the optimal balance between performance and eliminate trade-offs through the application of intermediate positions in the engineering and production CODP frameworks (Rudberg and Wikner, 2004). The aim is to be “lean” before the customer order, i.e. efficiency as winning criterion, and “agile” after the order, i.e. effectiveness as the winning criterion, or hybrid “leagile”, i.e. both efficiency and effectiveness as winning criteria, in case of intermediate CODP positioning choices (Aitken et al., 2002; Christopher and Towill, 2001; Mason-Jones et al., 2000; Naylor et al., 1999).

The recent literature demonstrates that this assumption can also be appropriate to the 2D-CODP perspective and demands further analysis (Wikner and Rudberg, 2005). Therefore, the following studies analysed this topic and demonstrated that design reutilisation and standardisation in engineering work, i.e., forward shifting of the engineering CODP, reduces design costs and total lead time; whereas, design customisation, i.e., backwards shifting of the engineering CODP, increases the uniqueness and complexity of the design (i.e., innovativeness) as well as the lead times (Dekkers, 2006; Gosling et al., 2017). Recently, Cannas et al. (2019) empirically analysed the performance outcome of different order fulfilment strategies in ETO companies, demonstrating that they have an impact on five performance, including traditional measures of time, price, flexibility, and the innovativeness of the technology. They also included a new performance measure pertinent to the ETO sector, i.e., reliability, which refers to the extent of risk for early unexpected defects after sales. In particular, this study proves that, when the engineering and production activities are mostly performed after the CODP, the performance outcome is the capability to always meet customer requirements for customisation and provide high technological innovation; vice versa, when the engineering and production activities are mostly performed before the CODP, competition is very high, and competitive prices are required, as well as short lead times and high reliability.

2.3 Aligning order fulfilment strategy to environment

When choosing the order fulfilment strategy, scholars agree that "one size does not fit all" (Jonsson and Rudberg, 2014; MacCarthy, 2013; Olhager, 2010; Schoenwitz et al., 2017; Van Donk and Van Doorne, 2016; Willner et al., 2016). According to the manufacturing strategy theory, the company should always align the market, product and processes choices to achieve good business performance, consistently with the degree of product customisation (Sousa and da Silveira, 2018)

In the logistics and manufacturing literature, the CODP positioning has been considered dependent on: (i) the relationship between the production lead time (P) and the delivery lead time (D), i.e., P/D ratio; and (ii) a set of contextual factors characterising the external and internal environment where the company operates (Hill, 1993; Hoekstra and Romme, 1992; Olhager and Wikner, 2000; Van Donk, 2001). A conceptual model was developed in the literature (Hallgren and Olhager, 2006; Olhager, 2003) to define all the factors affecting the CODP positioning and explain the motivations for backwards or forward shifting. The factors were allocated in three categories: market, product and production related factors. High demand volatility and low product volumes, as well as high product range and customisation requirements, are considered market characteristics that make impossible to provide products on an MTS basis. The production lead time is affected by the product structure (such as modularity, material profile, breadth and depth of the product structure) and the production process characteristics (such as the number of planning points, production process flexibility, and position of bottlenecks). This conceptual model represented an important basis to study the consequences of shifting the stock point through the materials flow (see for example: Hedenstierna and Ng, 2011; Liu et al., 2015; Sun et al., 2008).

In the supply chain management literature, Fisher (1997) was the first to introduce a model to match supply, product and demand and meet the needs of both the end consumers and the supply chains. In this study, the design of lean (i.e., physically efficient) or agile (market-responsive) supply chains was defined as matched respectively to functional (i.e., predictable demand) and innovative (i.e., unpredictable demand) products. Following studies (Aitken et al., 2002; Christopher and Towill, 2001, 2002, 2000; Mason-Jones et al., 2000; Naylor et al., 1999) related the lean and agile supply chain concept to the CODP framework, associating the two paradigms to different order fulfilment strategies. The lean paradigm has been associated with the supply activities performed before the CODP, while the agile paradigm to the supply activities performed after the CODP. Accordingly, these works identified more than two distinguishing classes of supply chains and included the "leagile" concept, i.e., the possibility to combine lean and agile paradigms when companies apply hybrid standardisation and customisation strategies, such as the ATO one. In this sense, a taxonomy for defining the optimal strategy has been proposed by Cristopher et al. (2006). This study enriched the model previously proposed, analysing the supply chain design for global operations and defining three key factors affecting the strategic fulfilment choice: (i) supply characteristics (short/long replenishment lead time); (ii) product characteristics (special/standard); (iii) demand characteristics (predictable/unpredictable).

All these studies have contributed to support companies in facing the continuously changing market conditions and the increasing pressure on multiple competitive priorities. However, they present some limitations. The models proposed are focused mainly on the production dimension and the material flow, being very general about the engineering dimension and the design flow. Also, they do not consider any interfaces between engineering and production, looking at these processes as sequential. Therefore, these studies cannot be considered suitable to reflect the complexity that the ETO reality entails, where the products include different degrees of standardised and customised bill of materials (BoM) and engineering and production processes are strongly interconnected (Bozarth and Chapman, 1996; Giesberts and van der Tang, 1992; Hicks et al., 2000; Konijnendijk, 1993).

Some of the studies investigating the order fulfilment strategies in ETO companies suggest possible environmental factors affecting them. In particular, the environmental factors suggested to affect the order fulfilment strategies in ETO contexts can be grouped into three categories, namely: (i) market, (ii) product and (iii) process related factors (Hallgren and Olhager, 2006; Olhager, 2003). As far as market related factors are concerned, Schoenwitz et al. (2017) shown the importance of the alignment of customer preferences with the product design and process configuration. The market-related factors refer to the average annual units sold, market growth or general market changes, and customer requirements (Willner et al., 2016). As far as product related factors are concerned, Semini et al. (2014) proposed the product customisation/variety and modularity. Additionally, Willner et al. (2016) indicated the engineering complexity as a determinant of customer order decoupling point positioning. As far as process related factors are concerned, with the addition of the engineering dimension, the P/D ratio has been demonstrated to be not sufficient anymore: the inclusion of the engineering lead time was needed (Wikner and Rudberg, 2005). In this case, the literature suggested that the major factor affecting the positioning is the relationship between the total lead time, which includes the engineering and production lead times, and the delivery lead time (Dekkers, 2006). In particular, Wikner and Rudberg (2005) considered the sum of engineering and production lead times as affected by a "delta value": null if they are sequential, or negative if they are overlapped. Moreover, Gosling et al. (2017) claimed that the engineering decoupling choice is contingent upon the engineering process characteristics, i.e., abilities and capabilities of the engineering resources in relation to knowledge.

2.4 Research gaps

In conclusion, the recent studies and, in particular, the most recent one by Cannas et al. (2019), can be considered very helpful to increase our understanding of engineering and production decoupling configurations in the ETO sector, as well as their performance outcomes. Cannas et al. (2019) considered all the previous literature, developing and empirically refining a 2D-CODP framework, which classifies the different order fulfilment strategies employed by ETO companies. Also, it categorised the performance outcomes of different 2D-CODP positioning choices. However, no attention was given in this study to the contextual factors influencing the choices of 2D-CODP positioning. In particular, this study, as well as the previous ones, did not consider the environment where the companies operate and the characteristics of their products and processes.

For this reason, our research is focused on this specific gap, i.e., the determinants for order fulfilment strategy choices. Regarding this issue, Table 1 summarises the different approaches found in the extant literature. The results show that, while recent work is very helpful in increasing our understanding of order fulfilment strategies in the ETO sector, there is still a gap between theory and practice when analysing engineering and production coordination to support ETO companies in adapting their order fulfilment strategy to the market (Mello et al., 2017; Sandrin et al., 2018). As transpires from the review of the literature and the synthesis in Table 1, in the CODP positioning field, there are still some limitations to be solved. The main focus of the recent studies has been on the customisation choices in the engineering process, with little attention to the interactions with production. As a consequence, the determinants for the positioning were mainly related to the product design and the market characteristics, without deeply analysing the process dimension. This implies the need to consider the process characteristics, especially in terms of coordination, to understand which strategies are suitable to specific situations and avoid late design changes and production reworks (Mello et al., 2017, 2015a, 2015b).

None of the existing studies addresses a comprehensive understanding of the contingencies driving the 2D-CODP positioning, as previously done in the production-focused CODP literature. As a consequence, there is no guidance for ETO companies to understand what order fulfilment strategy to implement to suit different contextual factors. Therefore, there is a need for a profound analysis of the market, product and process characteristics. These characteristics, at the moment, represent for the ETO industry a "black-box" that requires to be opened in order to deeply understand the dynamics of 2D-CODP positioning. Consequently, our research aims at filling these gaps, by integrating the literature that explores the ETO strategies with the one related to the CODP concept, as suggested by Gosling and Naim (2009) and Dekkers et al. (2013). The goal is to build an initial framework of contingencies driving these applications and empirically explore it through multiple case studies research.

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3 Methodology

This study applies an abductive approach that combines both theoretical and empirical insights. The goal of the study is to refine existing theory with new concepts, by interpreting an individual phenomenon in a contextual framework offering a new perspective (Kovács and Spens, 2005). Accordingly, the study follows a non-linear process: the results are obtained through the combination of literature and practice, through back and forth exchanges (Dubois and Gadde, 2002). Therefore, the literature review performed has been combined with direct empirical observations through case study research, which is considered a good method to refine theory based on empirical evidence (Eisenhardt, 1989). According to what the recent literature on case study research suggests (Hancock and Algozzine, 2016; Voss et al., 2016; Yin, 2018), the study has been conducted following 5 steps: first, we defined what we wanted to study based on the literature review, i.e., the research framework and constructs (subsection 3.1); second, we defined how we wanted to study it, i.e., the case study design (subsection 3.2); third, we defined whom we wanted to study, i.e., the case selection (subsection 3.3); fourth, we defined how to acquire the information, i.e., the data collection (subsection 3.4); fifth, we defined how to analyse the information we acquired, i.e. the data analysis (subsection 3.5). Figure 1 summarises the steps followed in this research.

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3.1 Research framework and constructs

The first step in the case study research consisted of defining a "road map" of the route that the study aimed to follow, to be used as an aid for the researchers in collecting answers to the research questions (Hancock and Algozzine, 2016). This has been possible by means of the development of an organized research framework, presented in Figure 2 and Table 2. The research framework built a conceptual foundation for the empirical study and supported it in defining the concepts that were to be studied, i.e., the key constructs and variables, and the assumed relationships among them (Voss et al., 2016).

The literature review confirmed what the contingency theory claims: i.e., there is a need for a strategic fit with different types of environment (Lawrence and Lorsch, 1967; Luthans and Stewart, 1977; Thompson, 1967). The contingency perspective of the CODP positioning is based on the concept of "fit as moderation", which needs to be well clarified so that can be operationalised within the research framework and validated through empirical data (Venkatraman, 1989). According to the moderation perspective, the impact of the order fulfilment strategy implemented by the company (i.e., the predictor variable) on the performance outcome, (i.e., the criterion variable), depends on the alignment with a set of contextual variables (i.e., the moderator variable). Consequently, the constructs of the research framework, shown in Figure 2, include the main object of interest of the study, organised according to the classification of contingency theory models (Sousa and Voss, 2008).

Then, Table 2 lists these constructs and the variables to measure them, providing detailed definitions, and specifies the references based on the literature review presented in section 2. Reading them through a contingency theory lens, the order fulfilment strategy represents the strategic choice made by the company related to the 2D-CODP positioning: a set of strategies can be identified depending on the number of engineering and production activities performed after the order. As far as contextual factors concern, the market-related factors can be considered environmental variables that are not subject to direct control of the company and affect the system with which the company interacts. Whereas, product- and process-related factors can be defined as resource variables over which the company has direct control but that can change only in the long-term and with substantial efforts. Finally, the performance outcome represents the dependent measure that can be used to assess the fit between the contextual factors and order fulfilment strategy and includes the traditional performance measured in the CODP literature: price, time, flexibility, reliability and innovativeness.

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3.2 Case study design

The methodology applied in this study is a multiple case studies research. The exploratory aim of this study makes the collection of data from multiple cases preferable since it increases the external validity of the findings (Yin, 2018). However, the population addressed belongs to one industry in one country, i.e., the Italian machinery industry, to increase the control of variations within the population by limiting the research domain (Voss et al., 2016). The decision to address the Italian machinery industry was made for three main reasons. First, the companies operating in the machinery industry design and manufacture capital goods, which are considered as well representative of ETO issues (Adrodegari et al., 2015; Cannas et al., 2019; Dekkers, 2006; Veldman and Alblas, 2012). Second, Italian companies are among the world's top producers and exporters in the machinery industry, thanks to high customisation and flexibility, and a high level of technological innovation (source: Federmacchine, 2017). Third, the challenges that the Italian machinery industry faced in recent decades, due to globalisation, make this population representative of the research problem. In particular, the emerging markets of the Asia-Pacific region have had a big impact on the global competitive environment, offering low costs and short lead times with low added value. In 2016 (source: Goh, 2017), the percentage distribution of the global machinery production was about $ 680 billion in the Asia-Pacific area (49.1%), $406 billion in the European area (29.3%), and $ 299 billion in the Americas (21.6%). The key players changed, and many companies in Italy, but also in the entire European area, according to McKinsey & Company (2016), are struggling in facing this global pressure and are starting asking themselves if the actual strategies applied in product development and production are sufficient to keep the pace of the recent developments.

3.3 Case Selection

The complete list of companies operating in the Italian machinery industry was found in the database "AIDA" (https://aida.bvdinfo.com/) selecting only medium and big companies (according to EU recommendation 2003/361), to be sure that companies perform both engineering and production processes. The unit of analysis of the study is the product family since a company can implement more than one strategy to provide the different product families to market.

Within this pre-defined list, case selection carefully followed theoretical reasons, based on a replication logic (Miles and Huberman, 1994): literal replication, i.e., companies were selected based on the expectation that they have similar contextual variables and performance outcomes since they offer product families that employ the same engineering and production decoupling configuration (i.e. the order fulfilment strategy); and theoretical replication, i.e., companies were selected based on the expectation that they have different contextual variables and performance outcomes, but for predictable reasons, i.e., they offer product families that employed a different order fulfilment strategy. Accordingly, in line with the main hypothesis of the study, the sample was selected for ensuring the maximum variation within the population and finding subgroups to compare and identify common patterns. This information was found in the reports developed by national industrial associations (Federmacchine, UCIMU, Amaplast, etc.), the Italian National Institute of Statistics (ISTAT), universities or consultancy reports as well as companies' websites. Moreover, the authors had experience in the machinery sector thanks to previous research projects conducted.

In total, eleven Italian machinery industry companies were selected, all recognised to be market leaders and located in Northern Italy, relevant geographical area in terms of impact on the total Italian machinery industry turnover. Eleven companies were considered sufficient, according to the replication logic applied, because they provided twenty-four cases and a good number of literal and theoretical replications, i.e., similar and rival order fulfilment strategies, which strength and support the findings of the study (Yin, 2018). In Table 3, the case study overview is presented. The percentage between brackets, next to the case studies, shows the total impact of the product analysed on the turnover.

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3.4 Data collection

The data collection was performed through multiple data collection methods, to ensure the presence of different sources of evidence (Stuart et al., 2002). The primary source was the face-to-face interview (source 1), always done by at least two researchers. The questionnaire has been organised as a semi-structured interview, to conduct the interview maintaining a logical order, while collecting open comments. The protocol was organised based on the constructs (i.e., order fulfilment strategy, contextual factors, performance outcome) defined in the research framework presented in subsection 3.1 (see Figure 2 and Table 2). Importance was given to spontaneous deviations to preserve possible contradictory views with respect to the initial framework (Stake, 1995). The interviews were always recorded and transcribed. Based on the cultural context of the study, and the fact that both, the participants and the researchers that conducted the cases, spoke the same non-English native language, the interviews were conducted entirely in Italian. Therefore, maximum attention was given while translating from Italian to English to keep the validity of the findings (the details of the translation procedure are reported in the next section).

The participants were experts in the engineering and production processes (e.g. plant manager, operations manager, engineering manager, project manager), who knew the current situation and issues very well, and each case lasted on average 4 hours. Multiple interviews are missing in some cases because of constraints beyond the researchers' control, i.e., the availability of the company and its human resources. To overcome this issue and avoid the subjectivity typical of the single respondent (Voss et al., 2016) the use of different sources were essential: (i) direct observations (source 2) during plant and engineering department tours; (ii) company's website and official documents available in the web (source 3); (iii) product catalogue and other internal documents (source 4). The collection of this additional information helped in obtaining rigorous results thanks to the triangulation of evidence (Hays, 2004). The case study protocol used to collect data is shown in Appendix 1.

3.5 Data analysis

Data were analysed by implementing a content analysis approach. The coding was executed manually by the authors: they independently read and coded the transcriptions, and then discussed the results to reach a common understanding of them. Finally, triangulation with additional insights from secondary data was performed in order to enrich the findings and overcome possible missing information. In this phase, maximum attention was given in keeping the meaning interpreted and communicated in the findings (English language) as close as possible to the meaning expressed by the interviewees (Italian language). According to the recommendations provided by van Nes et al. (2010), the data analysis was conducted in the original language as much as possible (first step coding), to avoid limitations in the analysis and reduce influences provided by studying the contents in another language. Secondly, when the translation was needed (second step coding and discussion of results), multiple in-depth discussions among the authors were performed to find the best translation, through fluid descriptions and various English formulations. It is important to underline that the research team included, since the beginning, one native English researcher, expert in the field.

The content analysis allowed us to explore the differences between the cases and search for patterns to compare with the initial tentative conceptual framework developed from the literature (Almutairi et al., 2014). The interviews and the documents were systematically analysed by evaluating the material and classifying the contents in the analytic categories taken from the literature and refined, enriched and extended, with additional insights coming from the empirical findings. In this sense, the main categories used to classify the literature were the ones related to the main constructs of the research framework (i.e., order fulfilment strategy, contextual factors, performance outcomes). A detailed description of all the cases within each construct and variable has been developed in structured tables.

The scoring method used for the analysis has been based on a relative and qualitative evaluation, with respect to the market analysed, as usual in qualitative research based on a narrow number of companies analysed. Given the exploratory nature, the final patterns could not be defined before the study but emerged from the collected data (Sinkovics, 2017). Therefore, the construct measures have been continuously validated during the study checking their consistency in the subsequent interviews and calling back the companies, if any unreliable measure emerged. In this way, the researchers assured the coherence of the analysis and the possibility to reach general conclusions.

Finally, to ensure the maximum transparency, the paper illustrates the chains of evidence from raw data to interpretation through a careful documentation of the data analysis, provided in Appendix 2, which shows a complete example of the data analysis performed for case H1, and in the next section 4, which deeply reports the results from the cases, with the support of interviews quotes (Caniato et al., 2018; Yin, 2018).

4 Order fulfilment strategy and contextual factors alignment

4.1 Understanding order fulfilment strategies across the ETO case studies

The first output of the data analysis is the classification of the case studies according to the order fulfilment strategy implemented. Within our case studies, the data suggest that the companies implemented different order fulfilment strategies to provide their product families to the market. Figure 3 shows the final classification of the cases according to the number of engineering and production activities performed to order. The classification is based on the 2D-CODP positioning matrix proposed by Cannas et al. (2019) for the classification of product families provided by companies operating in the machinery industry. This choice was made because Cannas et al. (2019) framework, as anticipated in the literature review section, can be considered the most recent and comprehensive to date. Indeed, it classifies all the previous literature on ETO order fulfilment strategies (as, for example, Dekkers, 2006; Gosling et al., 2017; Wikner and Rudberg, 2005; Willner et al., 2016) and includes new decoupling strategies identified through an extended qualitative field study in the machinery industry.

The engineering process activities to perform can be divided into two main sub-processes: (i) research and development, which involves the research, test and prototype of a new product concept; (ii) design of product Bill of Material (BoM), including the list of components required to build the machine along with the technical specifications, the instructions for production processes and the instructions for final assembly. In the cases analysed, research and development are always performed to forecast, as well as the design of the "general" BoM, because the new products are first presented to industrial fairs (Plast, BI-MU, etc.). Adaptations of the product BoM can then be performed completely to order (with major modifications, adapting the existing components to order, or eliminating/adding components), partially to forecast (with minor modifications or only final combinations to order) or completely to forecast (by taking the design as it is). Whereas, the production process activities to perform can be divided into three main sub-processes: (i) purchase, which involves the procurement of the raw materials; (ii) manufacturing, which involves the physical realisation of the components, either produced internally or outsourced to specialised suppliers; and (iii) assembly, which involves the assembly of the components. In the cases studied, the procurement of the raw materials is always performed to forecast. The manufacturing and assembly, instead, can be performed completely to order (make to order), partially to forecast (finalise the production/procurement of customised components to order or assemble to order), or completely to forecast (make to stock).

Five different order fulfilment strategies have been identified. They range from "special" to "standard". It can be seen in Figure 3 that standard machines represent an unusual strategy in this sector, only two cases were related to this strategy, related to a small percentage of the product portfolio. Also, special machines are related to a small number of cases, only three, but two out of three are related to the more than 90% of the product portfolio. While intermediate strategies, i.e., "customised", "standard-customised" and "modular", are the most applied ones. Product family F4 is characterised by "special" machines, vice versa, product family F3, is characterised by "standard" machines. According to the plant manager of company F, "*F4 is the most customised case. The engineering department, in collaboration with the sales, develops the concept of the machine starting from the catalogue but applying technical modification to more than 70% of the product BoM and producing all the components* *to order […] In the case of F3, instead, the design is taken as it is from the product catalogue and the production and assembly activities are planned to forecast"*. Product family H1, already described in Appendix 2, is characterised by "customised" machines. This implies that the engineering activities after the order consist in a major modification of some existing components (30% on average, in this specific case) while manufacturing activities can only partially start before the order, by purchasing or producing the strategic components. While the order fulfilment strategy for products belonging to product family such as H2 is "standard-customised". Meaning that the products are already designed and introduced in the product portfolio but slightly modified after the order to achieve specific requirements. As a consequence, according to the plant manager of company H interviewed, "*the minor modifications of the design allow the company to produce all the components of the BoM to forecast and producing or adjusting the customised components to order*". Finally, product family H3 is characterised by "modular" products, meaning that they are already designed and introduced in the product portfolio and only finalised to order based on the combination of the design options to obtain the desired BoM configuration. As a consequence, according to the plant manager of company H interviewed, "*thanks to the high engineering standardisation level, in this case, the company prefers to perform the manufacturing activities of the components completely to forecast*".

----------------- *PLEASE INSERT FIGURE 3 HERE* -----------------

4.2 Market-related factors

The evidence of the cases shows that the order fulfilment strategies implemented by the companies are aligned to the different customer typologies. One of the factors characterising the different customer typologies is the knowledge, which has been measured by all the companies as technical knowledge, i.e., experience and know-how in the actual development of the machine, and functional knowledge, i.e., experience and know-how in the utilisation of the machine, in a qualitative rating scale from "high" to "low/none". *"If the customer has low technical knowledge, we have a higher degree of freedom in developing the machine using the existing technical specification and we can reduce the number of engineering and production activities performed to order"* (D's engineering manager). Another factor to consider when companies align the order fulfilment strategy to the market is the customer size. The customer size has been measured by all the companies distinguishing from multinational companies and medium/small subcontractors. *"There are two types of customers, big customers, which are multinational companies that demand high flexibility and customisation but accept premium* *prices and longer delivery lead times, and the smaller, cost-conscious subcontractors, which want a quick product delivery to satisfy a current market trend"* (E's sales manager). Finally, the demand variety represents an important market factor to consider. The demand variety has been measured by all companies as a percentage, by evaluating how many customers – out of ten – on average, ask for changes after the order. "*We have customers that often change their mind after the order. In this case, it is better to wait for the order before to perform the engineering and production activities, otherwise, we risk to rework the components many times"* (G's engineering manager).

In particular, as shown in Table 4, to respond to knowledgeable and demanding multinational customers, it is necessary to implement special or customised strategies. In fact, they leverage the flexibility they still have on design and production to accommodate customer needs. Vice versa, standard and modular strategies are implemented for subcontractors that choose the product from the catalogue looking for the desired product functionalities, having little or none technical knowledge. In the case F4, for example, "*The customer is a big customer, with high technical know-how and experience related to the product, which defined the desired technical specifications and often asks for changes. 8-9 customers out of 10 require for changes after the order*. […] *In the case F3, customers are small subcontractors not specialised in specific production activity, because they depend on the market trends. They have little (or none) experience and knowledge related to the product and express only a preference for general functionalities. In this case, the probability for late changes is almost null: we provide F3 as it is, without any changes*" (F's plant manager). There are also intermediate cases, such as H2, where "*the customers interested in the product family are mixed, both big multinational companies and small subcontractors, which search for high-precision machines in short lead time and at a competitive price. They ask for some technical specifications but mainly expressing preferences for specific functionalities. In this case, on average, 4-5 customers out of 10 require changes after the order*" (H's plant manager).

---------------- *PLEASE INSERT TABLE 4 HERE* ---------------

4.3 Product-related factors

Table 5 shows the results obtained from the analysis of the cases in terms of product characteristics. When talking about the product, the technology life cycle was of significant interest to the cases analysed. All the interviewed people refer to it as: new/emerging, growing or mature. "*New technologies make necessary to keep high customisation since they are still not as stable as the mature ones, and it is difficult to forecast the customer needs*" (A's engineering manager). Family F4, for example, is characterised by new/emerging technologies, "*the customer asks for new technical characteristics and functionalities. The innovation typically consists of increasing the production capacity with the same machine. This means to find new geometries, to improve materials, to change components, etc. Thus, it is highly certain that new components and major modifications will be added, and it is better to wait for the customer order to produce the product*" (F's plant manager). While family H3 is related to mature and stable technologies. "*H3 demand is easy to forecast and the risk of uncertainty is low. This makes possible to rely on design modularity and combination of modules, in case of changes in the design requirements.*" (H's plant manager).

Moreover, the customisation opportunities impact to the order fulfilment strategy, and it has been measured by all the companies as the range of choices provided to the customer: only catalogue with standard products; catalogue and modular options (fundamental characteristics of the product that increase the perception of variety); catalogue, modular and additional options (not fully needed but make the customer satisfied); catalogue, modular, additional and superior options (delighters that exceed customer expectations); complete customisation with no catalogue or catalogue only as a guideline. "*If the variety in terms of customisation opportunities is high, the company increases the range of choices for the customer. Thus, it is hard to forecast the demand and keep stock of components and spare parts, because the stock holding cost would be excessive. While the reduction of customisation opportunities decreases the variety but also the uncertainty*" (D's engineering manager). For instance, the product family H1 is composed of 8 different products in the catalogue, H2 of 6 products and H3 of 2 products. Each of the products is proposed with different options. To confirm this, the plant manager showed a set of internal documents containing the technical specifications (i.e., the different design options proposed to the customer when the order arrives): "*We propose to the customer different options: modular options, additional options, and superior options. As you can see, the H1 document is about 90 pages characterised by all modular, additional and superior options; H2 document is about 50 pages characterised by modular and additional options; and, finally, H3 document is 20 pages characterised by only modular options*". In case of F3 and F4, "*F3 is composed of only two different machines without any option/variants, provided as they are in the catalogue with their fundamental characteristics. While F4 has almost infinite customisation opportunities, the only constraint is the milling technology. In this case, we use the catalogue only as a guideline and we fulfil the order exploiting experience and knowledge*" (F's plant manager).

Finally, the modular product structure represents an important factor. The companies refer to it as non-existent, partial or complete. The modular product structure was identified as a common characteristic of all the product families offered by company H. In particular, H1 and H2 are partially modular and H3 completely modular. All the companies that have intermediate configurations (i.e., customised, standard-customised and modular machines) leverage on modules to anticipate some engineering and production activity before the order and adapt the remaining ones to order. Interestingly, all cases of the pure customised (i.e., special machines) and pure standardised (i.e., standard machines) configurations have been identified as non-modular. In these cases, modularity is not considered worthy because, as stated by company F, "*the level of design modularity helps to increase production responsiveness, but it also increases cost. This is because it is necessary to (at least) duplicate the production activities but use only a part of what you produced. And, if the customer order is always different, I could produce 100 pieces with 48 holes each, to have the highest possible modular interface in the assembly activities, but then, I exploit only 2 holes for each order. In this case, I decided to reduce the modular configurability, producing the holes to order, with longer lead times but saving a lot of money*".

---------------- *PLEASE INSERT TABLE 5 HERE* ----------------

4.4 Process-related factors

In Table 6, the list of process factors related to each different order fulfilment strategy is provided. The cases analysed defined as important factors affecting the order fulfilment strategy choice, the sales and engineering processes structure, the production flexibility and the sales, engineering and production interface.

All case studies highlight that the sales and engineering processes structure is related to the degree of freedom given to the resources in proposing solutions. A qualitative scale has been defined, ranging from "loosely structured process with high degrees of freedom" to "process guided by a procedure with no degrees of freedom". In this sense, data show that the higher the customisation the looser the structure of the sales and engineering processes. "*The engineering process of product F4 does not follow any specific procedures so that it is possible to completely meet the customer requirements. Therefore, the salesmen and the engineers act with a high degree of freedom but being aware of the impact of their decisions on the other supply chain processes and the entire value chain. Vice versa, in case of F3, sales and engineering departments deal with standard machines, based on mature technology. Therefore, they apply rigorous procedures, with no need to consider the impact of their choices on the other* *departments*" (F's plant manager). In the intermediate strategies, instead, there is always a procedure, but with different degrees of freedom. In this sense, the plant manager of company H showed to us the internal procedure followed by the sales and engineering departments: "*As you can see it is divided into various sections: the performance that the machine must guarantee, the technical characteristics, the sales plan, the list of the various configurations already provided to the market. These different configurations are already planned and proposed to the customer and each of them corresponds to a specific budget of costs and lead times. This document helps the salesmen and engineers to understand the impact of each machine configuration to the entire supply chain. Then, in the case of H1, the choice is to keep a high degree of freedom in changing the initial characteristics, being aware of the impact on the value chain. This freedom is lower for H2 and null for H3".*

All the companies consider production flexibility as the capability to manage unexpected requirements for reworks in a short time after the order. They use a qualitative scale to assess this factor, comparing them with the market average and following this classification: "very quick in managing reworks", "quick in managing reworks", "managing reworks with negative impact on delivery lead times ", "managing reworks with heavy negative impact on delivery lead times", or "not managing reworks". This factor resulted to be very important in case of high customised strategies. "*We are accustomed to late and unexpected design changes and production reworks. Therefore, we organise our production activities so to be flexible and ready to face reworks very quickly"* (I's production manager). Instead, the standard and modular order fulfilment strategies are less ready to face reworks and the impact on lead times is higher. For example, in the case H3 "*the company completes all the procurement and production activities of the modules before the customer order. This reduces the production flexibility and means that in case of special requirements included in the customer order what has been purchased/produced is not suitable anymore. The reworks heavily affect the delivery lead time*".

Finally, sales, engineering and production interface is a relevant factor that the companies measured as the need for exchanges of information and warning and synchronous communication. They refer to it by using a qualitative rating that ranges from "continuous need" to "limited" to "sporadic". An important finding is that the higher is the customisation, the more important is to continuously engage the interfaces and synergy among the departments and to employ synchronous communication (i.e., simultaneously and in real time, such as face to face meetings or calls) after the order. For example, according to case F "*improving the interface between the sales, engineering and production departments is* *fundamental in the case F4, to facilitate activities overlapping and reduce delivery lead times. For example, we leverage on a real-time data sharing between the functions, important to increase the visibility and traceability of the information related to the order management. This implies a reduction of errors and, consequently, a reduction of costs and lead times thanks to real time problem solving, workloads balancing optimisation, etc.*" (F's plant manager). Whereas, in case of high standardisation the interfaces among the departments after the order are sporadic and asynchronous (i.e., not live and deferred, such as emails).

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5 Performance outcomes and strategic fit

The insights from the case study research confirm the initial assumption that ETO companies focus their efforts in carefully aligning their order fulfilment strategy to the contextual factors to achieve the desired performance outcomes. The performance identified as relevant outcome of the strategic alignment between strategy and context are time, price, flexibility, reliability and innovativeness, and the companies interviewed assess them, referring to each product family, with respect to the market average (0 – not competitive, 1 – low competitive, 2 – on market average, 3 – competitive, 4 – very competitive).

If the fully customised strategy (i.e., special machines) is implemented to address the right market segment (i.e., niche market, composed by knowledgeable and demanding customers), supported by the suitable product (i.e., innovative and customised product) and processes (i.e., loosely structured but highly flexible and strongly aligned), the final performance outcome expected is the capability to always meet the customer requirements for customisation, i.e., high flexibility, and provide them with high innovativeness in terms of technologies. This justifies a premium price and longer delivery lead times, compared with the competitors. Moreover, the customer accepts the risk of unexpected defects, because the number of errors increases in new designs and there is a lack of previous feedbacks from the production department and suppliers. "*When the customer asks for F4, asks for a new machine model, a special machine. The competition is on technology and flexibility. This is the most complicated case; the machine does not exist yet. And, of course, already in the initial phase the sales department leverages the engineering department to understand the machine, the feasibility, etc. Therefore, the costs will be higher, and all the subsequent steps will be much slower, making the delivery lead time longer than 10 months. For example, the purchasing department may have to buy things for the first time, there are new production cycles, etc.*"

Vice versa, the standard machines are addressed to a stable market (i.e., predictable customers with no specific requests) that must be served with mature and standardised products and supported by not flexible but highly structured processes. This alignment aims to assure the capability to achieve high performance in terms of price, delivery lead times and reliability, at the expenses of flexibility, because customer requirements for customisation are never met, and innovativeness, because the technology is already mature. "*Product family F3 addresses a market segment where the product is not required with special technological skills. Instead, it opens up a world of competitors larger and more aggressive than F4. The competition is no longer on technology but on price and delivery lead time, as well as reliability. We exploit our standard product configurations and standard procedures to achieve this goal.*" (F's plant manager).

Finally, intermediate strategies allow companies to achieve a good compromise between different competitive proprieties. For example, H1 has a dominant market positioning, namely, as the plant manager explained, "*it is a leader in a specialised market, where it is distinguished from competitors thanks to the possibility to provide state-of-the-art technologies that satisfy almost all customer requirements*". The price and delivery lead time are higher than competitors but reduced at minimum, only to justify the additional customised components: price 20% higher than the market average and delivery lead time 5-8 months, depending on the extent and complexity of design modifications required by the customer. The risk of unexpected defects is related only to the components strongly modified, usually not more than 30% of the product BoM. H2 has a strong market positioning, as the plant manager specified: "*H2 is among the leaders in a specialised market, thanks to the capability to provide customers with economic complete machines with state-of-the-art technologies*". H2 partially meets the customer requirements for customisation and the price is competitive and comparable to the market average. Additionally, the delivery lead time is 2-4 months, based on the extent of design modifications required by the customer and the risk for defects is contained since the changes applied to the existing design are only minor. Finally, H3, as the plant manager specified: "*is a follower in a specialised market, looking at the first three leading companies. It tries to accomplish the same product quality and precision, at competitive prices, for customers that need conventional machines in short lead times, 1-2 weeks at maximum*". H3 rarely meets requirements for customisation and the innovativeness is little, but still offers variety concerning general personalisation, thanks to modularity. Also, the risk for defects is almost null because it exploits mature technologies.

Figure 4 shows in detail the main results observed in the cases to help readers better understand differences performance outcomes of the range of order fulfilment strategies within the same ETO industry, when well aligned to the context.

---------------- PLEASE INSERT FIGURE 4 HERE ----------------

6 Discussion

This study empirically investigated the order fulfilment strategies implemented in eleven ETO companies through a contingency theory lens. Twenty-four different product families and five different order fulfilment strategies have been identified, i.e., standard machines, modular machines, standard customised machines, customised machines, special machines. For each order fulfilment strategy, the sources of differentiation between the environments have been defined and structured within the market, product and processes constructs, answering to RQ1. Then, the performance outcome of each strategy has been measured, explaining the rationale for the positioning of the product families in different 2D-CODP locations, answering to RQ2.

6.1 Answering RQ1: What are the determinants for the order fulfilment strategy choices within ETO companies?

The results shown that the determinants for order fulfilment strategy choices within ETO companies are contextual factors characterising the market (i.e., customer product knowledge, customer size, and demand variety), the product (i.e., technology life-cycle, customisation opportunities, and modular design), and the processes (i.e., sales and engineering process structure, production flexibility, and sales, engineering and production interface).

The results confirm the validity and meaningfulness of classifying the determinants into market and product characteristics, as suggested by past CODP studies (Hallgren and Olhager, 2006; Olhager, 2003), and process characteristics as recently underlined by 2D-CODP and ETO studies (Dekkers, 2006; Gosling et al., 2017; Schoenwitz et al., 2017; Wikner and Rudberg, 2005). By opening the "black-box" of the market, product and process related factors, the existing literature has been refined to a greater level of detail for the ETO sector. Indeed, many factors identified and classified in Table 1 according to the three different literature streams (production, supply chain management, ETO), were initially considered too general to become meaningful in distinguishing the different strategies employed by the companies analysed. Therefore, the study built on the existing literature but extended it, by revisiting the existing determinants and developing additional factors, as explained below, to cater for the ETO context.

As far as market-related factors concern, the average annual units sold and the market growth or changes, as introduced by the recent ETO literature, resulted too generic to describe and classify the market contextual factors of the companies analysed. Whereas, the characteristics typically related to ETO and agile configurations by the production and supply chain management literature, i.e., unpredictable demand, low volumes, wide product range, and high customisation requirements, were confirmed as existent by all the companies analysed, for all the product families. Thus, they did not result as determinants for order fulfilment strategies choices in the machinery industry; rather, they appear as qualifiers of the ETO sector where they operate. The companies interviewed underlined that their customers expect to be given high room for customisation and a wide range of choices. However, customers are diverse and have very different ways to interact with the machinery manufacturer when placing an order. In particular, they can be profiled in different groups based on three characteristics: (i) their knowledge regarding the product, (ii) their size, and (iii) their requirements for changes after the order. For this reason, the definition of a portrait of customers based on these characteristics is considered fundamental to make the strategic decision of the order fulfilment strategy for a product family. Therefore, as result of this research, new factors were introduced, mostly related to the characteristics of every single customer: (i) the customer technical and functional product knowledge; (ii) the customer size; and (iii), the customer requirements for late changes after the order (demand variety).

As far as product-related factors concern, all the product families analysed in the study had complex deep structures. Thus, these two characteristics proposed by the production literature were not considered determinants for order fulfilment strategies choices by the companies analysed; rather, they are considered peculiarities of the ETO products provided in the machinery industry. However, the other determinants did not differ from the literature, building on it and confirming the contingency of three variables: (i) modularity, as suggested by production and ETO literature; (ii) technology life-cycle (new technologies – innovative products vs mature technologies – functional products), as suggested by the supply chain management literature; and (iii), the customisation opportunities offered to the customers, as suggested by the ETO literature.

As far as process-related factors concern, on the one hand, the results differed from the literature regarding variables such as the number of planning points and bottlenecks, as well as the abilities and capabilities of the engineering resources, which were not considered by the companies analysed as characteristics that determine their order fulfilment strategy choices. On the other hand, the findings confirmed the literature and built on the determinant "production flexibility". If the production department is flexible to solve very quickly requirements for reworks, high-customised order fulfilment strategies can be employed; whereas if it takes an increasing amount of time to react to unexpected changes, the standardisation of the order fulfilment strategy should increase. Also, new interesting insights emerged. First, the presence of standard procedures for the upstream processes (sales and engineering) was underlined as an important determinant for order fulfilment strategy choices. Indeed, if the degree of freedom is high when proposing and designing the solution, i.e., the sales and engineering processes are loosely structured, it is an ideal condition for special machines, but it makes very difficult to introduce standards in the products. Second, continuous inter-functional interfaces after the order (i.e., the exchange of information and warnings and synchronous communication) were underlined as not necessary when standard machines are provided, but very important in the case of special machines.

6.2 Answering RQ2: How can ETO companies fit the order fulfilment strategies to contextual factors?

The findings from the cases demonstrated that the values of the determinants for order fulfilment strategies gradually change based on the customisation level of the order fulfilment strategy employed. From high standardised to high customised fulfilment strategies: (i) the market-related factors range from predictable customers with no specific requests to knowledgeable and demanding customers; (ii) the product-related factors range from mature and standardised products to innovative and customised products; (iii) the process-related factors range from highly structured, loosely flexible and not aligned processes and loosely structured, highly flexible and strongly aligned process. The fit of these characteristics with the suitable order fulfilment strategy has been demonstrated to provide the desired performance outcomes, which range from very competitive price, time and reliability for high standardised strategies to very competitive flexibility and innovativeness for high customised ones.

By comparing the empirical results with the literature, we confirm the existence of a trade-off between performance outcomes shifting from high standardised to high customised strategies, as underlined over years by several production and ETO studies (Barlow et al., 2003; Cannas et al., 2019; Chase et al., 2001; Gosling et al., 2017; Rudberg and Wikner, 2004). Also, the cases confirm the current paradox of ETO companies aiming at multiple conflicting competitive priorities by implementing hybrid strategies and achieve the benefits of mass customisation (Mello et al., 2017; Sandrin et al., 2018). Additionally, the study brought innovativeness to the previous literature, by adding the reasons for forward and backwards shifting of the 2D-CODP. As already underlined in the literature review, this topic was under-researched by the previous literature, which deeply explored the dynamics of the shifting only in the one-dimensional framework (Hallgren and Olhager, 2006; Olhager, 2003).

The results show that the companies analysed fit existing environments to strengthen specific competitive priorities and achieve definite market positioning (i.e., niche, dominant, strong, follower or stable). In particular, the 2D-CODP positioning requires to carefully consider the interfaces between engineering and production. In fact, the production standardisation increases hand in hand with engineering: the case companies leverage engineering standardisation to exploit economies of scale and learning curves in the sales, procurement and production activities, implementing production strategies different from MTO with competitive costs and lead times. The efforts made, in this sense, is mainly related to: (i) defining a product catalogue supported by modular design architectures and technology development efforts; (ii) investing in procedures to guide both the sales and engineering processes, without losing too much production flexibility and coordination between the functions; (iii) facing new barriers in the market due to changes in customer characteristics, and the possible entrance of new customers.

7 Conclusion

The purpose of this paper was to better understand the determinants of order fulfilment strategies for ETO companies, and, via our empirical study, to give insights into how organisations in the machinery sector react to strategically fit the order fulfilment strategy to their environment in order to achieve the desired performance outcomes. The overview of the performance outcome, provided in Figure 4, is one of the main outputs of this paper, which shows the determinants (i.e., the contextual factors) for order fulfilment strategies in one specific ETO industry (i.e., the machinery industry). It also indicates the effects that the strategic fit of the order fulfilment strategies with the contextual factors characterising the market, product and processes of the companies analysed has on performance.

The contributions of this paper are both theoretical and empirical. From a theoretical point of view, this paper increases the understanding of the determinants for order fulfilment strategies in ETO companies, and the reasoning for shifting from one strategy to another, exploring contingencies affecting the CODP positioning in the two-dimensional framework recently introduced by Cannas et al. (2019). Very little research has addressed these issues in the past, even if recent studies underlined the importance to explore the topic, deepen and refine the outdated production literature, by addressing empirical data in the ETO area (Gosling et al., 2017; Willner et al., 2016). Previous studies in the ETO literature supported the idea of the "one-size-does-not-fit-all" and the importance of the strategic fit in stable and closed MTS context, but none of them provided a rich description of contingencies affecting this choice in the ETO context. The discussion of the findings in this paper shows how the cases provide new insights, building on the literature and introducing new interesting concepts, that progress the theory and knowledge of the ETO realities. The market-, product- and production-related factors identified in the literature have been enriched with the inclusion of the engineering perspective and its integration with production. Also, the company perspective has been substituted with the product family perspective, including the possibility of multiple strategies in the same company. This increases the effectiveness of the analysis in representing reality and reducing the gap between theory and practice. In conclusion, these results further the ETO research, renovating the seminal studies on CODP positioning (Hallgren and Olhager, 2006; Olhager, 2003) and providing foundations for future research on this topic.

From an empirical point of view, this study presents an example of the application of the 2D-CODP framework to the machinery industry, providing empirical evidence of its power in representing the order fulfilment strategies employed in real ETO contexts. Also, the paper shows practical examples of how companies leading different market segments in the machinery industry define their order fulfilment strategies. The results show that this strategic choice is not pre-defined and unique, and the best optimal strategy does not exist. This can be translated into a practical tool for companies. In fact, the cases analysed exemplifies how the contingency-based framework can be practically used, opening the "black box" of the theoretical constructs and providing practical examples of what are the contextual factors suitable to each strategy and the performance outcomes expectations. Moreover, the empirical study shows how the different order fulfilment strategies can be compared, providing a model for strategic decision-making. This paper is a first attempt to help ETO managers in understanding if they are implementing the suitable strategy for achieving the desired performance outcome and what are the key resources that must be improved when facing changes in their competitive environment, to align the organizational goals to new desirable performance. This contribution supports decision making in the challenging phenomenon of ETO companies that are pursuing the achievement of good performance in multiple conflicting competitive priorities shifting towards mass customisation strategies.

Finally, although this study has been carefully designed taking into consideration all the essential aspects for assuring high qualitative outcomes, some limitations exist, which are not under the control of the researchers, opening interesting opportunities for further research. The case study research is a qualitative approach, primarily exploratory. On the one hand, this method helped the researchers for building and refining the extant theory; on the other hand, it limited the possibility to use measurable data to quantify the problem and perform statistical analysis. For this reason, the application of quantitative methodologies to the framework developed in this study is considered a relevant opportunity for future research, helping to validate the findings obtained. Also, even if the conceptual framework has been developed considering literature studies conducted in other industries, this study assessed it only in one specific industry and one specific country. As a consequence, further research is welcome to endorse and extend the findings of this research, by addressing other ETO sectors.

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