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How does Manufacturing Strategy Impact the Goals of a Firm? A Relational Framework Characterizing the Related Business Models' Components

Eleonora BOFFA, Antonio MAFFEI

Production Engineering, KTH – The Royal Institute of Technology, Sweden

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Abstract
The fourth industrial revolution has resulted in technology advancements in the manufacturing industry. However, the innovation potential embedded in these technologies should be unlocked by a viable application, i.e., the business model (BM). The BM as a holistic concept featuring different interacting elements is thus emerging as a promising vehicle for innovation. Current BM research describes the entire domain but lacks depth in the characterization of its individual components. This paper investigates the available manufacturing literature through the lens of the BM concept performing a scientometric analysis. The results are presented in a relational framework that provides an in-depth characterization of the manufacturing element of the BM and highlights identified connections that link the BM components. This is the basis for tools that will support firms in developing manufacturing portfolios aligned with their strategic goals.

Keywords
Business models; Manufacturing model; Scientometric analysis; Topic modelling; Latent Dirichlet Allocation.

Introduction

The fourth industrial revolution, or Industry 4.0 (I4.0), is rapidly transforming the design, manufacturing, operation, and services related to manufacturing systems or products (Davies, 2015). I4.0 implementation is mainly focused on adopting several recent technological advancements. In view of this, I4.0 is conveying new digital technologies in manufacturing such as the Internet of Things, Cloud Computing, Big Data, and Analytics (Frank et al., 2019) that are changing traditional value creation mechanisms (Ibarra et al., 2018).

Technology per se has no value: the potential of technological advancement can be only defined when applied to solve concrete problems, i.e., the innovation happens when an invention is brought to the market through a suitable Business Model (BM) (Chesbrough, 2007a; 2007b). In the case of manufacturing companies, this means that the adoption of new technologies is not simply the process to introduce an invention to solve problems, but is a process often involving a structural rethink of how companies do business (McKinsey Digital, 2015). This process is called Business Model Innovation (BMI). Although both BM and BMI have been recognized as powerful tools for unlocking the value of technologies (Chesbrough, 2002), the existing innovation related literature in the domain of manufacturing overlooks the potential role of the BM in the process and focuses, instead, primarily on technology development (Ibarra et al., 2018; Weking et al., 2020).

In order to use the BM concept to support the innovation process it is necessary to move beyond the simple mainstream view of the BM as explicitation of Value capturing strategies, strategic literature presents the BM as a holistic concept that can help identify and put in relation the different aspects of the technology application process. Several authors have proposed descriptive BM frameworks covering the BM core components, e.g., BM ontology by Osterwalder (2004), and the IBM by Wirtz (Wirtz et al., 2016). Although the last and most sophisticated models proposed are very successful in identifying and

***Corresponding author**: Eleonora Boffa – KTH – The royal institute of technology, Sweden; e-mail: boffa@kth.se*

mapping all the relevant dimensions of the innovation process (aka: Business Model components or sub-models), a comprehensive and standardized characterization of the BM sub-models is still elusive.

As mentioned above, introducing new technologies into the manufacturing domain often demands a radical change in the mechanisms of creating, delivering, and capturing value (Björkdahl, 2020; Mugge et al., 2020). Therefore, studying the underlying BMI process requires a comprehensive understanding of the relationship between BM components and the impact of changes in one component on the others.

This paper contributes to the extant manufacturing literature discussing the manufacturing domain from a BM perspective. In particular, this paper presents a relational framework that proposes a characterization of the Manufacturing Model (MM) as framed in the IBM. Furthermore, the relational framework describes the components of the BM that are linked to the MM and provides insights into the linkages among the BM's components. The relational framework is built analysing the literature related to the domain of "Operation management", "Manufacturing strategy" and "Value creation" performing a scientometric analysis. Finally, the proposed framework contributes to establishing a supporting tool for firms to develop a manufacturing portfolio that aligns with their strategic goals.

Literature review

BM definition

Scientific discussion of the BM concept has been ongoing for the last 50 years, becoming strategically significant during the internet boom, (Magretta, 2002; George & Bock, 2011). Scholars in the mainstream literature present a convergent perspective on the BM's abstraction level. The modern BM sphere suggests that the BM presents a static picture of the entire company (Wirtz et al., 2016; Demil & Lecocq, 2010). In particular, the BM outlines what a business does and how (Zott et al., 2011).

Despite this, the literature shows a heterogeneous understanding of the BM concept, leading to a wide range of definitions (George & Bock, 2011; Ritter & Lettl, 2017; Teece, 2017). However, a guiding theme emerges, and it revolves around the concept of value. The notion of BM must reflect value creation and delivery logic, as well as the firm's capability to capture that value with coherent revenue mechanisms (Demil & Lecocq, 2010; Johnson et al., 2008; Osterwalder et al., 2010; Teece, 2017).

Components of the BM: existing frameworks

Companies design a BM that secures economic sustainability and sustain their competitive advantage in the long run (Magretta, 2002; Demil & Lecocq, 2010). Understanding what elements a BM is composed of is necessary to assess how a BM performs. Thus, academic contributions investigate each "piece" of a BM, and a content-related perspective of the BM concept emerges (Wirtz et al., 2016).

Nevertheless, a widely accepted framework has not been established yet: the aspects included in the BM frameworks are different. Demil et al. (2010) propose a relatively simple model that describes the BM with three core components: resources and competencies, organizational structure (i.e. value chain activities and value network), and value propositions to be delivered to customers. On the other hand, Hamel (2001) argues that the major components of a BM should also include a core strategy, aside from strategic resources, customer interfaces, and value networks. Likewise, Morris et al. (2005) present the BM aspects using six fundamental questions. These questions address: the competitive strategy that delineates the competitive position of a firm in the market; the market factors that identify the customer target; the offerings created and delivered; the firm's internal capabilities; the economic factors that highlight the revenue mechanisms; and the investor factors defining time, scope, and size objectives. Chesbrough (2002) followed a similar comprehensive approach. They suggested a more operational definition of the components listing the functions of a BM: the formulation of a competitive strategy is paramount source of competitive advantage; identify the firm position within the value network; define the value proposition; select the market segment; structure the value chain defined; determine cost structure and profit potential.

There have been several endeavours in the literature attempting to propose a uniform and standard framework for the BM components. Osterwalder et al. (2010) introduce the so-called BM Canvas adapted from its previous work on the BM ontology (Osterwalder, 2004). The intention was to introduce a standard and comprehensive BM framework that would simplify the exploitation and description of the BM concept. The BM Canvas addresses four business areas: customers, offers, infrastructure, and financial viability. These areas are then detailed in nine building blocks: customer segments, value propositions, channels, customer relationships, revenue streams, key re-

sources, key activities, key partnerships, and cost structure. Likewise, Wirtz et al. (2016) proposed the IBM to introduce a holistic picture of the BM's components. The framework was developed in light of previous work by carrying out an extensive literature analysis. Thus, the BM's essential components are presented in an integrated framework that distinguishes between external and internal factors. The external factors include customers and market components, which can be further differentiated into customer model, market offer model, and revenue model. The internal factors, i.e. manufacturing model, procurement model, and financial model, are included in the value creation components. The IBM consists of a third element, the strategic components. These concern the implication of a corporate strategy and its resource model, network model, and strategic model.

This paper builds upon the most recent framework presented: the IBM (Wirtz et al., 2016). In detail, the authors focus on the Manufacturing Model (hence MM) that emerged as a BM's component in the IBM. This work's research objective is to propose a comprehensive characterization of such a sub-model (MM) and it contributes to describe and identify the other BM components that are linked to MM.

The Manufacturing Model (MM)

The BM literature presents the MM in different ways. In particular, Yip et al. (2004) list "how to transform inputs" as an element of a BM. Similarly, Petrovic et al. (2001) introduce the production model in their framework. The production model depicts how elements are combined in the transformation process from the source to the output. Furthermore, it shows why a firm chooses a certain production process. Wirtz et al. (2016) associate the MM with the transformation process of raw materials (goods of lower level) into more refined products (goods of higher level). They argue that the MM may be included among the value creation components. Therefore, the MM is an integral part of the value creation process that aims to add value for the targeted customer to the offerings. Given this, the MM is linked to the value creation domain.

The combination of the activities and resources and competencies included in the value creation process is identified by the concept of value configuration of a BM (Osterwalder, 2004). In particular, the value chain, one type of value configuration (Osterwalder, 2004), frames what primary and supporting value activities the focal firm should perform. According to Michael E. Porter, the value chain includes external activities such as firm infrastructure, human resource management, technology development, and procurement. The value chain further specifies internal activities: inbound logistics, operations, outbound logistics, marketing and sales, and service. Within the internal activities, operations contribute to the transformation process of inputs into final outputs (e.g. machining, packaging, assembly, equipment maintenance, testing, printing, and facility).

Managing the company's operations is a major topic discussed in the operation management research stream. One of the key areas in operation management is technology management (Fettermann et al., 2018). This area is important because it identifies the technologies that are used in the operations and it will help assess the impact on the operation's performance. In view of the above, Fettermann et al. (2018) analyses the particular case of I4.0 technologies implementation that contributes to operation management. The analysis focuses on how those technologies have affected and improved the operations of an organization. The results show that I4.0 technologies have transformed the way operation management is carried out, and their application has brought several benefits to the management of operations (e.g., maintenance, logistic processes, production management). Having identified such technologies implies that decisions on crucial production resources involves operations (e.g. people, processes, and systems) (Chase & Prentis, 1987). Given this, the MM is linked to the operation management domain.

The selection of the firm's activities, and its resources and competencies, should be consistent with the value expected to be delivered to customers (Afuah & Tucci, 2001). This affects the manufacturing strategy of a firm, in terms of developing new or exploiting existing manufacturing competitive priorities (e.g., quality, delivery, cost, flexibility). The manufacturing strategy will consequently affect production process design. In this regard, the work of (Pooya, 2017) maps (1) competitive priorities, in order to identify clusters of manufacturing strategy, and (2) production decisions (e.g., work force management, production planning, quality management, process technology) to identify clusters of the production process. The authors further highlight that there is a dependent relation between manufacturing strategy and production process. This relation has been identified using a crosstab that reveals which production process is more frequent for each manufacturing strategy. Given the above, the MM is linked to the manufacturing strategy domain.

The literature that was reviewed points out that the

MM has been related to several concepts associated with three literature fields: value creation, manufacturing strategy, and operations management. These domains are individually investigated to present an in-depth characterization of the MM.

Dynamic perspective of the BM

Thus far in the scientific discussion, the BM has been considered a set of static entities (Afuah & Tucci, 2001), i.e., the necessary components that create, deliver, and capture value. This is a static view of the BM (Casadesus-Masanell & Ricart, 2010; DaSilva & Trkman, 2014), which provides a clear snapshot of a specific moment. However, scholars have started to address the problem of how a BM evolves (Demil & Lecocq, 2010) and is reshaped (Chesbrough, 2002) to maintain a competitive advantage, i.e., a BM innovation (BMI). A dynamic perspective of the BM concept addressing the process of BM evolution is now introduced (Schaffer et al., 2019). The BM cannot be considered as only a set of static entities (Afuah & Tucci, 2001), but it must be investigated as a "complex system", where its parts are all interdependent and complementary (Morris et al., 2005; Foss & Saebi, 2017; Schaffer et al., 2019). Wirtz et al. (2016) claims that presenting the BM's elements as a set of stand-alone and static systems is not correct. Johnson et al. (2008) and Schaffer et al. (2019) argue that any transformation that might occur within any component will impact other BM's elements due to complex interdependencies. Therefore, the effect of exogenous or endogenous changes on the BM's components can be understood by analysing the connections among them (Demil & Lecocq, 2010; Afuah & Tucci, 2001). Moreover, the interplay among BM's aspects has a fundamental role in contributing to an enterprise's success or failure (Ritter & Lettl, 2017). In a nutshell, broadly accepted and understood, authors have raised the awareness of interconnected and dependent BM's elements. Nevertheless, there is further need for research on how the elements interplay and how they are linked.

In summary, the contribution of this paper to the existing literature is twofold. On the one hand, this study characterizes the MM from a BM perspective to come to a more comprehensive understanding of its aspects. For this purpose, three separate literature bodies are investigated: value creation, manufacturing strategy, and operations management. On the other hand, this paper proposes a relational framework that provides insights into the linkages among components. The connections highlighted emerge from the literature that is analysed. The literature review characterizes the MM and its connected components as framed in the IBM. The IBM is therefore taken as a reference in this study.

Research methodology

A literature review based on the scientometric analysis of a large number of related publications is carried out to investigate which aspects characterize the MM and identify significant links among BM's components. The first step of this process is the selection of the dataset in the domain of "Operation management", "Manufacturing strategy", and "Value creation", as mentioned in the Background section.

The prestigious Web of Science (WoS) database has been selected as initial input for this analysis: it offers a comprehensive coverage of the engineering field, including only high-relevance, peer-reviewed contributions. The following keywords were selected as they cover the full scope of the work: "Operation management", "Manufacturing strategy" and "Value creation". These keywords are used in three separate queries resulting in three bodies of literature featuring 1752 papers for OM, 1411 for MS and 5320 for VC. It is important to remark that the analysis has been conducted separately on the three datasets identified, so the existing overlap among them has not been filtered away.

The identified datasets were refined exploiting the WoS internal categorization of contributions labelled as "Engineering industrial". This category encompasses all the relevant topics for this analysis: i.e., operations research, process engineering, manufacturing, and industrial economics and thus provides a more relevant and focused body of knowledge for the investigation. The study has begun in 2018 and the literature body was based on the one available at that time. After the starting date, the authors have run the algorithm on the new literature and observed that the main results of the study such as clusterization and main themes were not significantly impacted by the new contributions. For this reason, the original dataset was retained.

At the end of this refining process, the three datasets have the following sizes: (a) Operation management 918, (b) Manufacturing strategy 528, (c) Value creation 446. The size of these datasets is perfectly in line with the capability of automatic text analysis. In particular, topic modelling is a powerful tool that quickly reveals major themes in a text collection. Various algorithms have been developed to perform topic modelling. Among these, Latent Dirich-

let Allocation (LDA) was selected for its simplicity and popularity in performing literature review studies (e.g., D'Amato D. et al., 2017; Pirola et al., 2020; Knutas et al., 2015). LDA is an unsupervised and generative probabilistic model (Blei et al., 2003). The basic components of LDA are the corpus, i.e., the text collection; the document, i.e., one instance of the corpus; and the term, i.e., a word in the document. The algorithm views the documents as a set of latent topics characterized by specific words that tend to co-occur with a certain probability. The purpose of LDA is to infer those latent topics in each document. In detail, the algorithm estimates the words that are likely for a topic and the topics that are likely for a particular document. The result is a list of probable terms for each topic, presenting a comprehensive overview of the corpus.

LDA has been implemented mainly in two different programming languages: Python and R. This work uses R because the source code is inspired by the Network Analysis Interface for Literature Studies (NAILS project) (Knutas et al., 2015) and the work published by Asmussen & Møller (2019), which also uses R.

The methodology proposed for the literature analysis is displayed in Figure 1 and described thereafter.

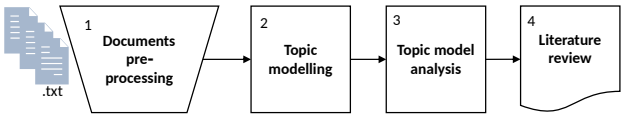

Fig. 1. Methodology flow chart

1. Data pre-processing

The main purposes of step 1 (see Figure 1) are to build the corpus and apply data pre-processing methods to it. As for building the corpus, the relevant data were contained in three datasets extracted from WoS in three different text files, one for each focal research domain detailed in the previous paragraph. Among all the information from the files, the "Abstract" is the most relevant for the text analysis: the abstracts contain the main source of text by which the corpus is built. Therefore, the corpus corresponds to the abstracts of the paper.

At this point, the corpus is pre-processed to remove punctuation, whitespace, and non-value-adding words (e.g., connecting words or terms that would not contribute to the specific analysis in this work such as research, paper, review, academic, journal). Furthermore, the corpus undergoes a lemmatizing process that is applied to convert the words to their basic form (e.g., modelling and models become model).

The pre-processed corpus can now be input in the next phase: topic modelling.

2. Topic modelling

Step 2 consists of identifying the optimal LDA parameter to apply the algorithm to the pre-processed corpus. LDA works with a fixed and known a priori number of topics (k). The selection of the optimal value of k is a key step. To this purpose, the perplexity and the topic-coherence index are to be taken into account. Perplexity is conventionally used in information theory to evaluate how well a dataset is predicted by a probability model (Blei et al., 2003): the lower the perplexity measure, the better the estimation of the data (Zhao W. et al. 2015; Maier et al., 2018). In text analysis, a low value of perplexity indicates that the probability of topics being representative of the documents is high. Therefore, the topics give a good representation of the entire corpus.

However, the perplexity index does not give insight into the semantics of the topics. Research shows that LDA often produces few meaningless topics from a human judgment perspective, despite a low perplexity value (Chang et al., 2009). The topic's semantic needs to be assessed to cope with this limitation and it is a crucial aspect that affects the degree of interpretability of the topics. Topic-coherence measures have been proposed (Maier, 2018) for assessing the semantic of the topics. This metric takes into account the co-occurrence of words within the same document (Mimno et al., 2011). In detail, the degree of coherence will depend on the relation among words that are included in the same topic: words expressing the same concept will tend to co-occur within the same document. The higher their semantical correlation, the higher the resulting coherence index (Mimno et al., 2011).

The graphs in Figures 2, 4, and 6 show the perplexity calculation performed on the three datasets of interest using a k-interval decided a priori. The figures also highlight the k-interval that is restricted in correspondence to a low value of perplexity but minimizing the number of topics (Chang et al., 2009). Therefore, the restricted k-interval is identified where the trend line bends.

The restricted k-intervals were defined as:

- $20 < k < 30$ for the MS and the VC,
- $20 < k < 35$ for the OM.

These k-intervals were used to calculate the topic-coherence index for the three datasets. The results are shown in Figures 3, 5, and 7. The three graphs show a point of maximum that represents the highest

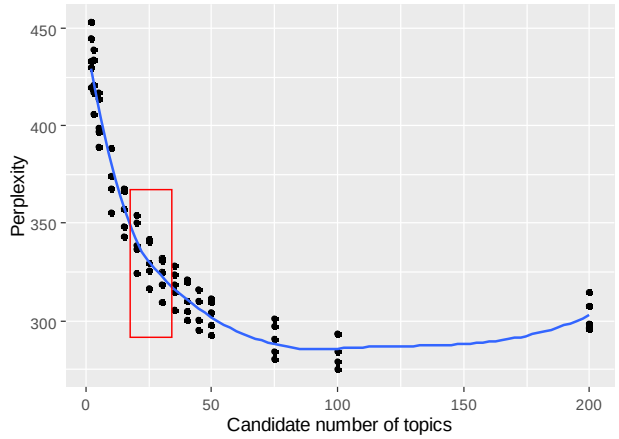

Fig. 2. Result of perplexity computation for MS. The trend line is in blue. Acceptable k-interval between 20 and 30 is highlighted in red, where the trend line bends

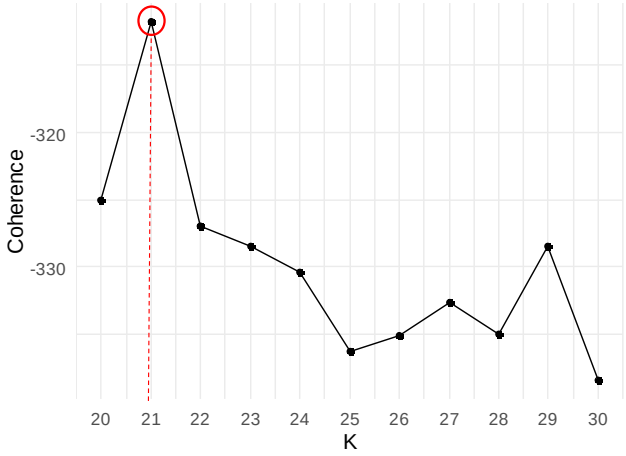

Fig. 3. Coherence score calculation for MS dataset. The most coherent topic model corresponds to $K = 21$ (highlighted in red)

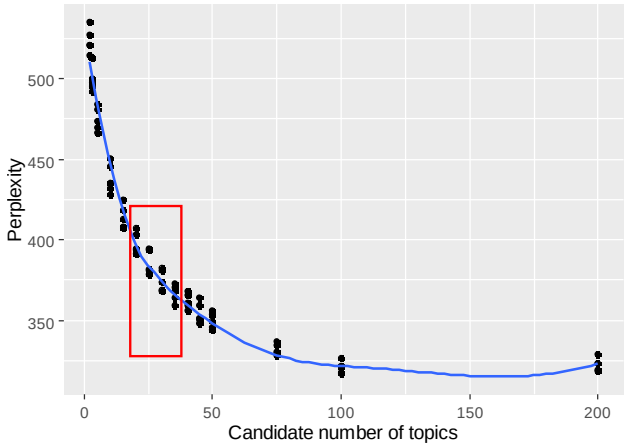

Fig. 4. Result of perplexity computation for OM. The trend line is in blue. Acceptable k-interval between 20 and 35 is highlighted in red, where the trend line bends

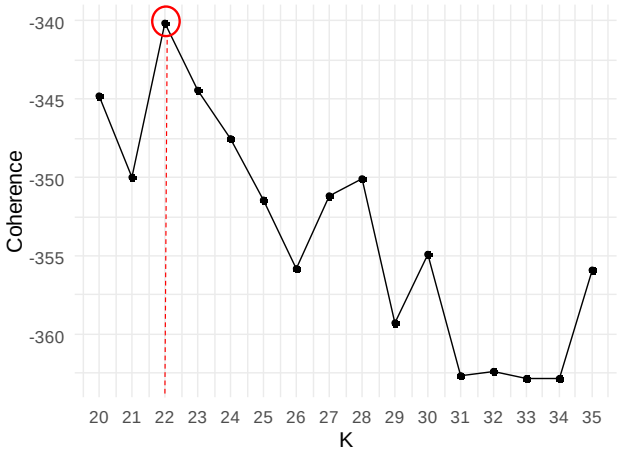

Fig. 5. Coherence score calculation for OM dataset. The most coherent topic model corresponds to $K = 22$ (highlighted in red)

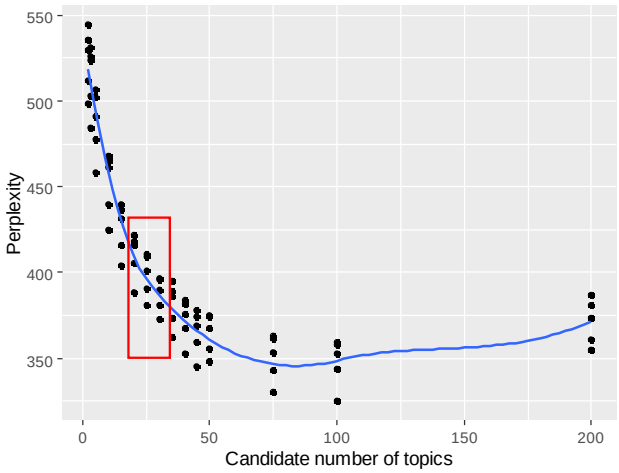

Fig. 6. Result of perplexity computation for VC. The trend line is in blue. Acceptable k-interval between 20 and 30 highlighted in red, where the trend line bends

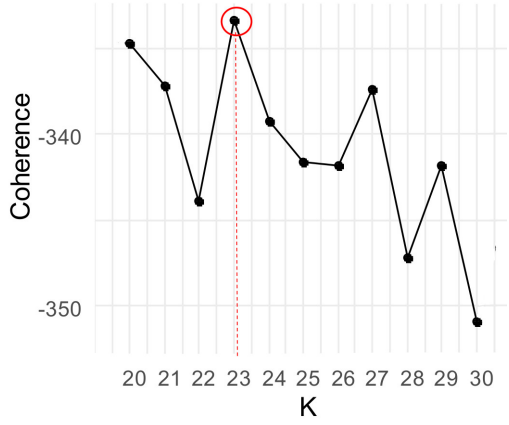

Fig. 7. Coherence score calculation for VC dataset. The most coherent topic model corresponds to $K = 23$ (highlighted in red)

coherence in the focal k-interval. In detail, the analysis of the graph shows:

- 21 for MS,
- 22 for OM,
- 23 for VC.

These k values allow for an effective and efficient running of the LDA algorithm for the analysed datasets. The LDA results are displayed in in Figures 8, 9, and 10. These figures include two parts:

– The Intertopic distance map on the right side. The topics are visualized as circles on a two-dimensional plane. The topics' projection on a reduced number of dimensions is based on multidimensional scaling (MDS) that aims to preserve as much as possible the distances among topics (Sievert et al., 2014).

– A bar chart on the left side, displaying the list of the 30 most frequent words. If none of the topics in the intertopic distance map is selected, the bar chart lists the 30 most probable terms in all of the corpus. In this case, the bar's value for each word is the overall term frequency, i.e. saliency (Chuang et al., 2012). If a specific topic is selected, the bar chart displays the 30 most frequent words of that specific topic. For each term, the bar shows the relevance value, i.e. the estimated term frequency within the selected topic (Sievert et al., 2014).

The intertopic distance map combined with the bar chart facilitates the analysis of LDA results. The next section will explain in greater detail how the graphic interface is used to analyse the list of words associated with each topic displayed in the intertopic distance map.

3. Topic model analysis

Topic model analysis aims to identify a meaningful description for each topic in the LDA results. This is achieved by analysing the list of the most frequent words related to each topic. The graphic interface presented above facilitates the visualization of such a list, selecting the topics in the intertopic distance map. Then, the bar chart provides the most frequent terms corresponding to a selected topic. The authors then conducted a discretional analysis of the list of the words and the typical topic naming found in the state-of-the-art, which resulted in an adequate description and label for the selected topic. This process is repeated for the k topics in the MS, OM, and VC research areas. The topic model analysis results in three lists of labels and descriptions that are used as input in the next phase, i.e., the literature review.

4. Literature review

The outcome of the topic model analysis provides a good overview of the relevant topics discussed in the three focal research areas, but there is a lack of structure. For the scope of this paper, a rigorous classification of the topics is necessary. The criteria used for the classification depend on similarity: in line with the literature, this study considers the topics to be similar if they have a common semantic value. The similarity among the topics can be visualised in the intertopic distance map. The map places similar topics close to each other and dissimilar ones apart. Therefore, it is the distance among the topics that give insight into semantic connections.

Accordingly, the relevant common groups of topics are identified in the map. Those groups are then assigned to a theme that summarizes the core concept encapsulated in the topics. This classification process is repeated for the MS, OM, and VC research areas.

The presented methodological approach leads to a comprehensive and structured overview of the aspects discussed in the three domains of interest (MS, OM, and VC). Therefore, the literature review is completed and it is used to describe the MM and its connected components as framed in the IBM. The IBM is therefore taken as a reference BM framework. While IBM provides a holistic view of the business model concept, it is limited in capturing the external factors affecting the focal firm: i.e. globalization, competition, technology, labor market, political and legal factors, socio-cultural factors, demographic factors. Additionally, the IBM presents only a high-level view of the internal process, without detailing the dimension of analysis such as internal relations, employee competences, organizational culture, structure. While many other specific contributions are available in this domain, they are often inhomogeneous in regard to vertical level and unit of analysis as well as overlapping in scope. As the purpose of this study is the further characterization of the business model of a focal firm, to enable a higher descriptive capability, the authors have limited the bibliographic analysis to the proposed framework to ensure coherence of the effort.

Results

This section outlines the contribution of the present work as a result of the process displayed in Figure 1. In particular, the final phase 4 (literature review) provides two contributions that address the original gap.

Firstly, it gives an overview of the focal research areas of MS, OM, and VC; Table 1 shows the list of

themes assigned to each field. A more detailed and comprehensive explanation of the themes is presented in Appendix 1, 2, and 3. Secondly, these findings are deployed to extensively characterize: (1) the MM and

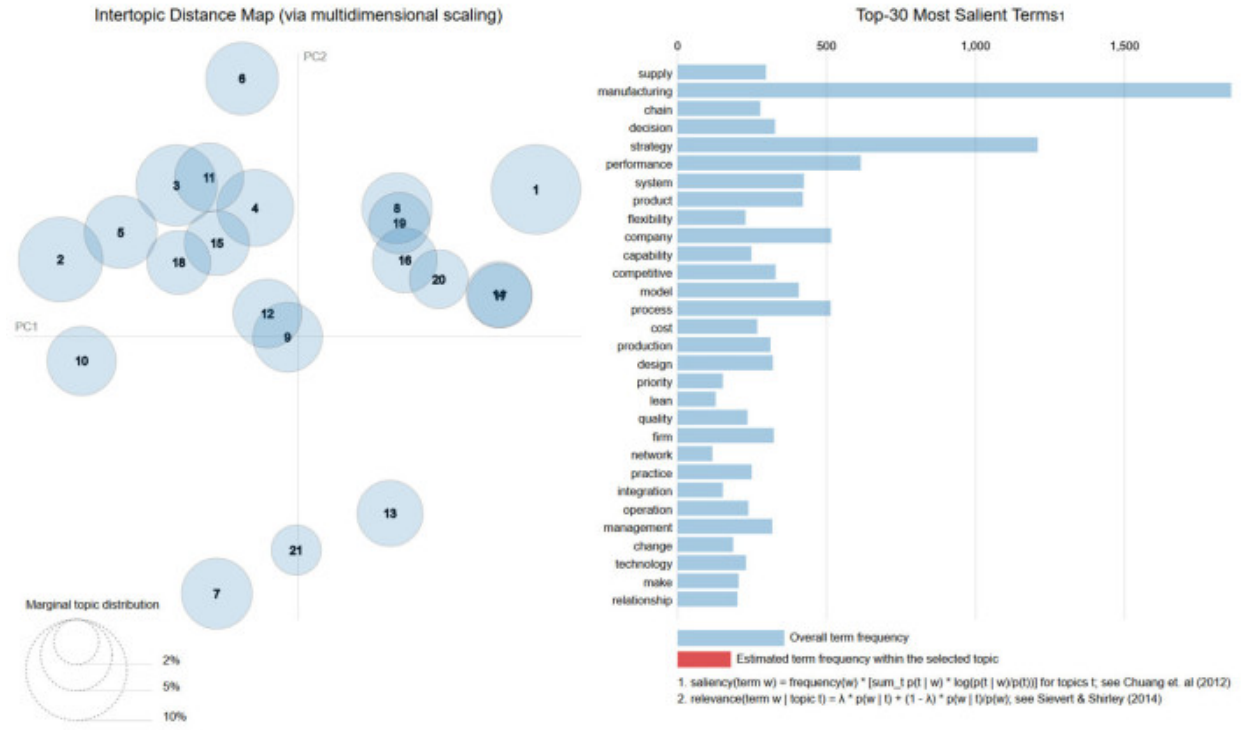

Fig. 8. Intertopic distance map and the list of Top-30 most salient terms for Manufacturing Strategy literature

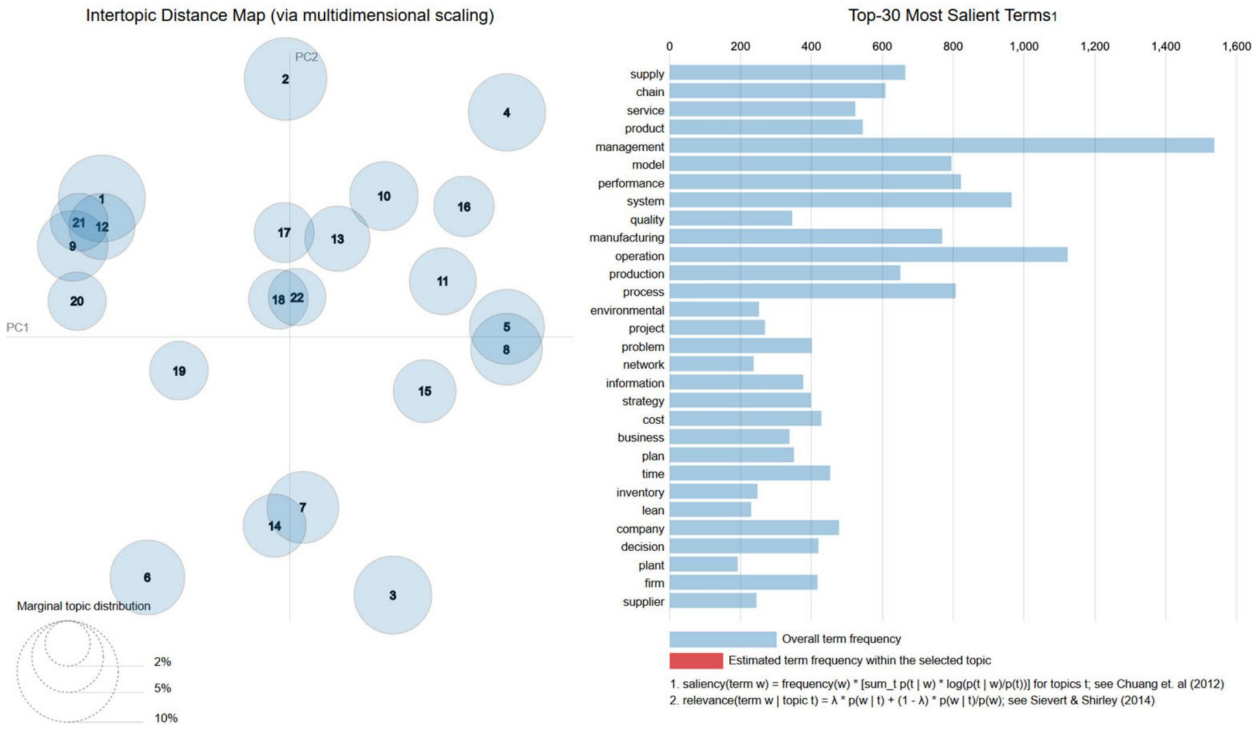

Fig. 9. Intertopic distance map and the list of Top-30 most salient terms for Operation Management literature

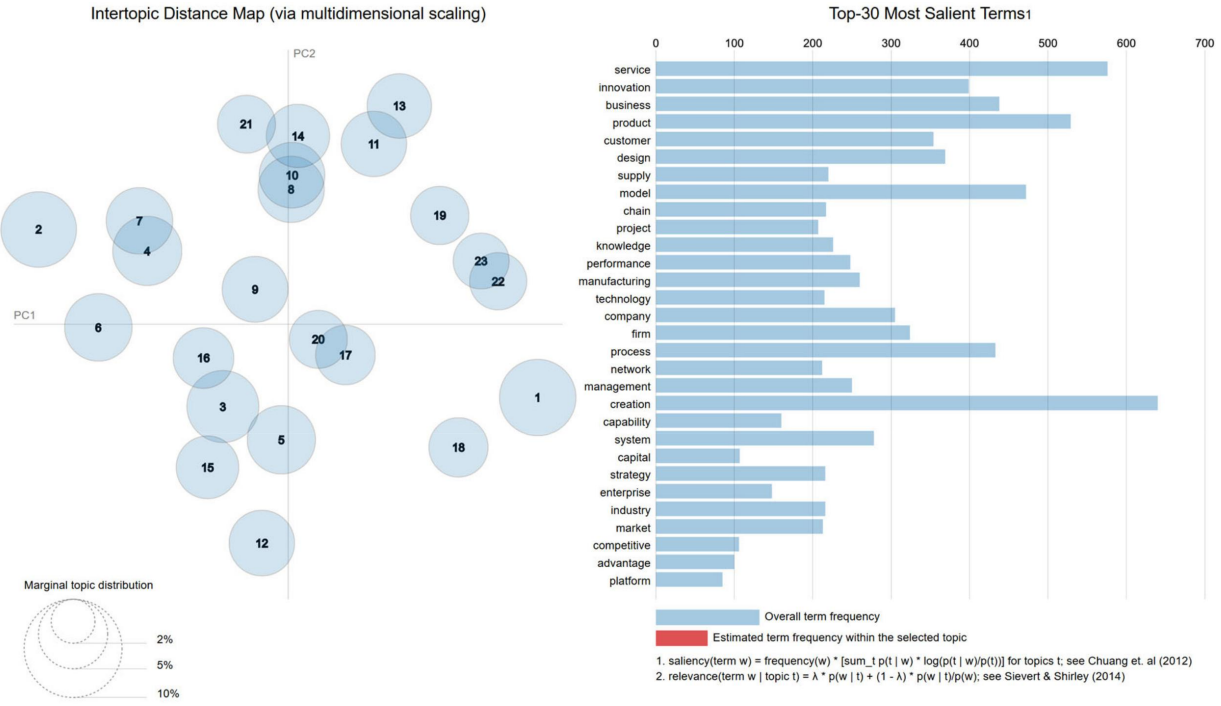

Fig. 10. Intertopic distance map and the list of Top-30 most salient terms for Value Creation literature

its intra-links displayed in Figure 11, and (2) the inter-links connecting MM with other IBM components. Finally, the results of these steps are conveyed in the relational framework displayed in Figure 12, which addresses the knowledge gap behind this analysis.

1. Manufacturing model characterization and intra-links

The characterization of MM is the result of highlighted patterns in the MS and OM research areas. Table 2 presents the categories and the themes proposed for MM and Figure 11 show how these themes are linked.

The following sub-sections detail the two categories identified, production strategy and operations, and the intra-links.

Production strategy

Observing the overview of the research areas that were examined, production strategy was identified first within the OM domain. Particularly, topic 12 (see Table 2) appears to be related to the definition of a firm's competitive priorities. Words such as alignment, business, competitive, and strategy provide more details for this topic. The firm should define competitive priorities in manufacturing that are aligned with their business strategy and in such a way as to sustain the firm's competitive advantage. Therefore, competitive priorities can be considered part of the strategic decisions to be made in manufacturing.

The MS research area discusses in greater detail the competitive priorities theme that emerged in the OM domain. Topics 8 and 9 identify the widely accepted set of manufacturing capabilities that define the manufacturing goals a company focuses on. Quality, delivery, cost efficiency, and flexibility emerge as such manufacturing goals. Other key words in topic 8 such as cumulative, model, capabilities, and trade-off allow for a more detailed description of the competitive priorities theme. These key words highlight different theories that have been outlined to develop manufacturers'competitive priorities, i.e., the trade-off theory in which superior performances are reached on one dimension overshadowing others, and a cumulative capabilities model, which entails a mutually reinforced competitive priorities selection.

Topics 15 and 18 complement the production strategy category. These topics are associated with words that highlight the theme of manufacturing strategic options. This theme is characterized by key words such as lean, waste, improvement, agile, strategy, responsiveness, and flexibility. From these terms, two alternative strategy options emerge: lean manufacturing (topic 15), more focused on minimizing inefficiency in the operations following the philosophy of continuous improvements, and agile manufacturing (topic

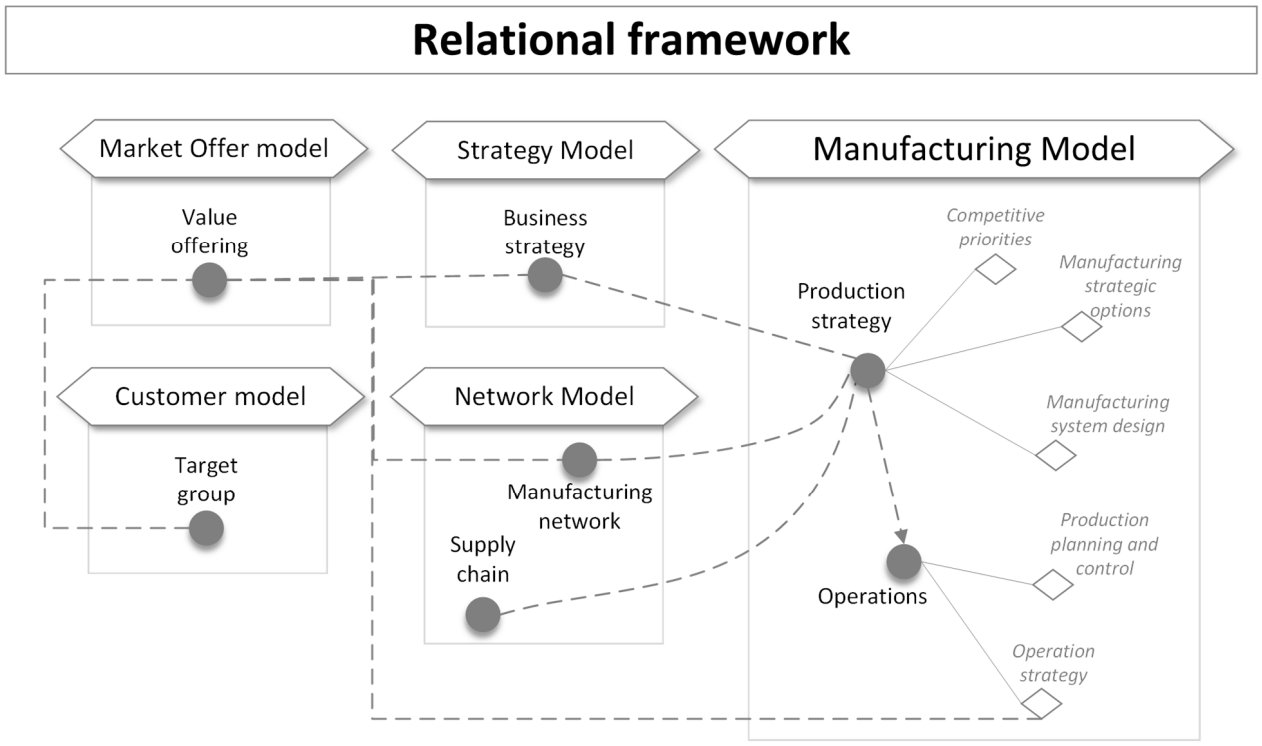

Fig. 12. Relational framework summarizing the characterization of MM, the description of Market Offer model, Strategy model, Customer model and Network model, as well as the linkages among the BM's elements involved

18), which is more focused on responsiveness affecting the flexibility of the processes. Topic 5 presents the theme of manufacturing system design. Specifically, flexible manufacturing system (FMS) seems to emerge as a common class of manufacturing systems. Advanced manufacturing technology (AMT) seems to be another predominant trend in the manufacturing system.

Summarizing, the production strategy category encloses the themes of competitive priorities, manufacturing strategic options, and manufacturing system design.

Operations

The OM research area discloses the two main themes identified: operation strategy and production planning and control. Few additional insights are found in the MS field. Operation strategy is the theme addressed in topics 2, 15, 16, and 18 (see Table 2). Topic 2 addresses the lean manufacturing strategy. The concept of lean should be used as a leading strategy in the production operations aiming at continuous improvement. Topic 16 relates to quality management, serving from quality planning and control to quality improvements. The quality level of finished products/services is set according to customers' expected level of quality in order to fulfil the customers'requirements. The theme of service operations is introduced by topic 18. Keywords such as technology, RFID, customer, digital, and delivery geared the discussion towards how digital technologies impact service operations (e.g., enhance service delivery to the customer). Lastly, topic 15 addresses aspects related to maintenance policies. Words such as assets, repairing, monitoring, and reliability stress that the monitoring and repairing the companies'assets involved in production processes is paramount in order to satisfy a certain level of reliability.

The production planning and control theme is found in both MS (topics 7, 13) and OM (topics 3, 5, 7, 8, 14) research areas.

A decision support system that aids the decision-making process in production planning and control is the inferred theme in topic 8. Topic 7 (MS) stresses that the development of tools and methods is paramount to strategic decision-making processes. More specifically, simulation models highlighted in topic 8 will be used to improve and assist the decision-making process. Keywords such as information, system, and strategy point out that an information system strategy is necessary to support the decision-making process, as clearly identified by topics 5 and

Table 1
Main themes identified for Operation management, Manufacturing strategy and Value creation research areas. The numbers in parenthesis refer to the topics included in the different themes

Operation Management (OM)	Manufacturing Strategy (MS)	Value creation (VC)
Performance (1, 13)	Competitive priorities (8, 9)	Value Offering (6, 7, 8, 10, 11, 21)
Competitive priorities (12)	Manufacturing system design (5, 19, 20)	Value creation strategy (9, 14, 19)
Production planning and control (3, 5, 8, 7, 14)	Manufacturing strategic options (6, 15, 18)	Sustainability (4)
Operations strategy (2, 15, 16, 18)	Manufacturing network (14, 17)	Network (13, 18)
Manufacturing network (9, 21)	Performance (1, 4)	Performance (1, 15)
Sustainability (19)	Production planning and control (7, 13)	Other (12, 16, 17, 20, 22, 23)
Other (4, 6, 10, 11, 17, 20, 22)	Sustainability (21)	
	Other (10, 11, 12, 16, 23)	

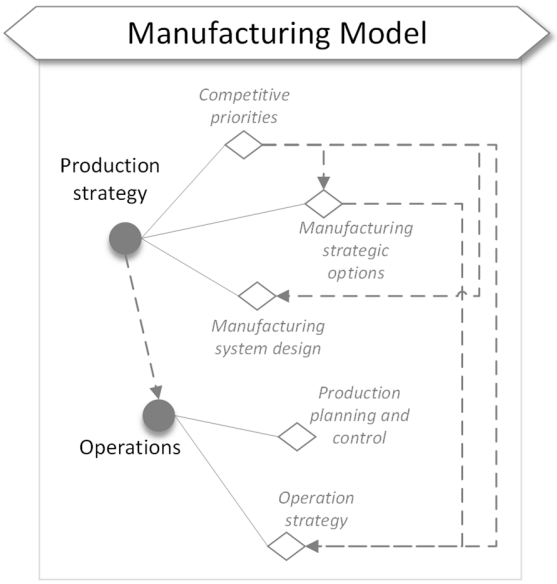

Fig. 11. Intra-links in the Manufacturing model

8. Furthermore, topics 3, 7, and 14 (OM) refer to the problem of production scheduling. In detail, topic 3 is characterized by keywords such as rules, scheduling, algorithm. These terms relate to the definition of scheduling rules and exploiting scheduling algorithms that support finding solutions to scheduling problems. Topics 7 and 14 specify scheduling in the particular application of job and batch production system. Additionally, topic 7 identifies material requirements planning (MRP) as a tool for production and capacity planning and control. Among other functions, MRP will facilitate the planning of manufacturing activities, ensuring that the input materials are available for production activities.

Summarizing, the operation category encloses the themes of operation strategy and production planning and control.

2. Intra-links in the manufacturing model

Figure 11 shows the relations identified among the categories and themes in the MM.

The map of links was identified by analysing topic proximity in the intertopic distance map of MS and OM datasets. Firstly, the links identified among the themes of the categories will be explained. Secondly, the connection between the two categories of MM will be introduced.

The links identified among the production strategy and operations'themes are the following. The competitive priorities theme defines goals to be pursued in manufacturing in terms of quality, delivery, cost, and flexibility, affecting manufacturing system options and manufacturing systems design. Therefore, manufac-

Table 2
Categories and themes characterizing the MM and related dataset and topic number. A detailed description of the themes is available in Appendix 1, 2, and 3

Category	Themes	Dataset	Topic number
Production Strategy	Competitive priorities	OM	12
		MS	8, 9
	Manufacturing strategic options	MS	15, 18
	Manufacturing system design	MS	5, 19, 20
Operations	Operation strategy	OM	2, 15, 16, 18
	Production planning and control	OM	3, 5, 7, 8, 14
		MS	7, 13

turing strategic options and manufacturing systems design should be implemented according to the competitive priorities.

The categorization made in this work highlights lean manufacturing and agile manufacturing as manufacturing system options. A company chooses among these two options according to the competitive priorities defined. If cost and delivery is the focus, the successful implementation of lean manufacturing philosophy leads to a positive effect on manufacturing in terms of reducing cost and time. If flexibility is required in the company's production activities, a strategic choice favouring agile manufacturing will enhance flexible capabilities. As for the manufacturing systems design theme, a flexible manufacturing system is one of the options identified. The decision of introducing such a production system will have impacts on shop floor flexibility performances.

It has been identified that the manufacturing strategic options theme influences the operations strategy.

In particular, choices made in manufacturing strategic options are inherited by the operation strategy aiming at implementing production operations accordingly, e.g., lean or agile.

The operation strategy should also reflect the competitive priorities defined by the production strategy. In detail, the quality management identified in operation strategy should delineate quality policies according to the quality goals defined in the competitive priorities.

3. Inter-links among the BM's components

The topic model analysis highlights themes such as "supply chain management" and "manufacturing network" that were semantically connected to other components of the IBM. These topics are associated with the corresponding IBM sub-models based on the description given by Weking et al., (2020), as shown in Table 3.

Emerging from the analysis of the three datasets, the network model is mainly characterized by supply chain and manufacturing network categories. Specifically, topics 9 and 14 (MS) clearly delineate the concept of supply chain integration by stressing the importance of collaboration and coordination strategy among partners. In a manufacturing network, the most common decision-making drivers that should be considered are configuration and structure of the network (e.g., specific partners involved), location of production, and definition of the firm's role (topic 17, 21). Keywords associated with topic 18 heighten the theme of knowledge sharing among, e.g., partners and supplier buyer, which is, in turn, beneficial for a successful collaboration and coordination strategy.

Table 3
The categories associated with the IBM's components. For each category, the related dataset and topic number is specified

IBM component	Category	Dataset	Topic number
Network model	Manufacturing network	MS	17
		OM	21
		VC	13, 18, 19
	Supply chain	MS	14
		OM	9
		VC	13, 18, 19
Strategy model	Business strategy	MS	6
Market Offer model	Value offering	VC	6, 7

Topic 13 is characterized by keywords related to value creation networks. The point of view is instead on a system perspective of the creation of value for customers, moving beyond an individual firm's effort. As such, the theme in topic 19 hints at establishing strategic alliances among the networks that aim at the co-development of offerings. These alliances define a firm's boundaries within the value creation network to ensure the competitiveness of the entire system. Summarizing, supply chain and manufacturing network can both be linked to the MM and particularly to the production strategy category.

Leveraging on the cooperative nature of the value creation network, partners within the network contribute with their core capabilities, i.e., what they do best, and outsource to the network what they need support on. A common strategy is therefore required that leads to an efficient and effective system. In terms of an individual firm's manufacturing capabilities, this logic reflects on the boundaries by which a firm develops its competitive priorities.

The category business strategy, classified as part of the strategy model, is found in topic 6 (MS). Keywords such as alignment and fit identify a relational rather than a stand-alone topic. Hence, it can be stated that the inferred theme expresses the relation between business strategy and production strategy. The two strategies should be aligned in order to have internal coherence and improve manufacturing performances.

The value offering category is included in the market offer model. Topic 6 appears to be more design-oriented, with particular focus on keywords such as

tool and method. The theme further stresses the involvement of "humans" in the design process, i.e., the role of the users. The product-service system (PSS) represented in topic 7 is one particular example of a possible value offering. Overall, through the analysis of the VC field, the involvement of customers seems to be a major trend in the design process, therefore the link with the customer model. In greater detail, it is paramount to achieve the right fit between customer requirements and final offering characteristics. Furthermore, one additional element of alignment arises between business strategy and value offering, i.e., the former gives "direction" to the latter when establishing a strategy map. In this regard, topic 9 in the VC dataset highlights keywords such as service and strategy. A strategy map could be more oriented toward a service strategy, and therefore the value offering is aimed at creating value by providing only services or a PSS to the market. These choices can reflect on the operation strategy and, in more detail, on setting service operations. Therefore, the value offering is linked to operation strategy.

Figure 12 displays the inter-links among components.

Discussions and conclusions

The research objective of this paper is of descriptive nature. It presents a relational framework that provides an in-depth characterization of the MM and initial insights into the related BM components, as well as a first map of linkages among elements of a BM. Such characterization and links emerge from the analysis of the available manufacturing literature that is then investigated through the lens of the BM concept. The proposed framework is a holistic, yet static representation of the MM role in an IBM. Future work can be aimed at extending the descriptive value of this study to identify new areas of research: possible approaches include the use of the identified categories and relations to plan structured interviews and case studies focused on identification of current and future trends and pattern of development of the focal domain.

The relational framework builds on the IBM. The authors recognized its limitations in capturing external factors affecting the company and lacks detail in internal factors. Future research effort is recommended to consider in the analysis the impact of external forces such as globalization, competition, labor market, political and legal factors, socio-cultural factors, demographic factors, as well as internal factors such as employee competences, organizational culture, structure.

As its main practical contribution, the relational framework helps designing the and track the impact of MM disruptions on the other related components thanks to the proposed map of links, ensuring alignment and coherence within the BM. In light of this, the framework aims to assists organizations in developing a manufacturing technology portfolio aligned with their strategic goals.

MM characterization and intra links

Each element included in the relational framework is identified by carrying out an analysis from a manufacturing perspective, i.e., strong production and operations focus. In particular, the research areas investigated are the manufacturing strategy, operation management, and value creation. The literature review of these domains provides clear arguments on the reason why it is relevant to investigate these three specific domains.

Regarding the MM internal links, it was found that the production strategy guides the operations that must be developed accordingly. This will ensure intra (internal) component coherence.

Components and links characterization

In the analysis, the emerged themes are associated with the IBM's components reflecting major concerns discussed within manufacturing literature. For instance, the analysis highlights production strategy (competitive priorities, manufacturing system), operations strategy (production planning and control), supply chain, and manufacturing network. The relational framework contributes by translating these manufacturing themes into a BM context. Consequently, the BM's components reflect major concerns discussed within manufacturing literature.

The identification of the themes allows the characterization of five IBM's components, in particular, the customer model, market offer model, strategy model, and network model. The relational framework provides a vertical characterization of five IBM's components: MM, customer model, market offer model, strategy model and network model. Additionally, the framework is enriched with relationships between these components. The links give insight into the dependency between the connected components: these links aid to trace the impact of a change in one of the components on the other connected elements. The key strength observed within the relational framework concerns ensuring intra (internal) component coherence and inter (external) element coherence. The

linkages within the MM and among BM's blocks will ensure equilibrium in the entire BM in case of disruption. As such, inter component coherence can be achieved. Nevertheless, the relational framework embraces internal and external element coherence, limited to five of the BM's components.

The links displayed in the relational framework represent a connection between only two components. This means that a link does not have a specific orientation: the components cannot be labelled as antecedent or posterior of a change. Further investigations will be needed to specify the nature of each single link.

The presented analysis was carried out from a manufacturing perspective. More links are expected to emerge by approaching the issue from other research fields. Hence, a multi-field study may contribute to discover new links that would present a more complete map of links as well as a more comprehensive characterization of other BM elements.

Topic model analysis

The initial dataset which the topic model is based on was limited to WoS due to the scope of this study. Analytical tools such as the ones used here gives increasingly accurate results the larger is the dataset. While the chosen dataset has proven effective is addressing the research objectives of this work, future works could benefit from including other prestigious indexing entities to increase the dataset.

The topic modelling that allows the characterization of MM and the other BM's components encompass themes labelled as "Performance", "Others", and "Sustainability", which the authors decided to omit from the relational framework. Regarding "Others" and "Sustainability", they include themes referring to external factors such as organization theory, energy efficiency strategy, and sustainable logistic, which impact the BM as a whole. The authors decided to exclude these from the relational framework, as these factors would go beyond the scope of the present work.

Appendix 1

Table 4
The main themes of Manufacturing strategy dataset

Theme	Topic #	Label	Description
Competitive priorities	8	Development of competitive priorities	The most discussed competitive priorities: Quality, cost, delivery, flexibility. Cumulative capabilities model (also called sand-cone which also underline the link between operation capabilities) and trade-off theory
	9	Development of competitive capabilities	Development of competitive capabilities to gain sustainable operational competitiveness and keep competitive advantage
Manufacturing system design	5	Manufacturing system design	Flexible manufacturing system (FMS) Advanced manufacturing technology (AMT)
	19	Change management	Changes in manufacturing, more specifically changes in manufacturing practices. Strategy and organization changes could occur.
	20	Manufacturing flexibility	Implementing a strategic and manufacturing flexibility would help coping with environmental uncertainties
Manufacturing strategic option	15	Lean manufacturing	Lean manufacturing implementation will lead to waste improvement
	18	Agile manufacturing strategy	An agile manufacturing strategy can be implemented to improve companies'responsiveness. This will lead to improve companies'flexibility
	6	Strategy fit	There should be alignment/fit between the business strategy and the manufacturing strategy in order to improve manufacturing performances

The "Performance" themes are identified in all three datasets (MS, OM, and VC). The words in "Performance" relates mostly to the positive, direct or indirect impact of different factors on the firm and manufacturing performances. The aspect of performance assessment emerges. In particular, it is clearly associated with the performance measurement system (PMS), which supports the decision-making process of an organization. Each enterprise selects the most appropriate KPIs to reflect operation performance and assess whether specific manufacturing goals are met. Performances may, therefore, be considered as an output of the MM.

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Theme	Topic #	Label	Description
Manufacturing network	17	Strategic manufacturing network management	Decision-making drivers when desining a manufacturing network: - define the configuration and structure of the network - identify the production location (where the production should be) - what is the role of each single plant in the networ.
	14	Supply chain integration	Supply chain integration
Performance	1	Firm and manufacturing performance	Authors examined the positive, direct or indirect effect/impact of different factors on firm's manufacturing performances
	4	Production cost and lead time	The company should focus on the reduction of Production cost and lead time
Production planning and control	7	Decision support systems	Decision support system that aids the decision making process. Development of tools and methods for strategic decision making process
	13	Production control	Production, inventory and capacity control
Sustainability	21	Energy consuption	There should be a energy efficiency strategy in order to push the machines involved in the manufacturing process towards optimisation
Other	11	New product development	Product design and innovation product
	10	Modelling	Modelling problems withing manufacturing strategy
	12	Organization theory	Organization theory
	16	SMEs	Small and medium enterprises
	2	Framework and approaches for MS	Manufacturing strategy: frameworks models and approaches
	3	Company manufacturing strategy	Company manufacturing strategy

Appendix 2

Table 5
The main themes of Operation management dataset

Theme	Topic #	Label	Description
Performance	1	Firm performances	Firm performances
	13	Performance measurement system	Performance measurement system for internal firm performance. The use of KPIs to measure and evaluate performances
Competitive priorities	12	Definition of competitive priorities	The definition of competitive priorities should be made within manufacturing strategy. This definition should be aligned with the business strategy to ensure and maintein competitive advantage

Theme	Topic #	Label	Description
Production planning and control	8	Decision support system	Decision support system that aids the decision making process. Simulation system dynamics: simulation model to improve and support decision making process
	5	Information system strategy	There should be an information system strategy to aid the decision support in Operation Management
	3	Scheduling problems	Scheduling problems refers to the definition of rules. These problems are solved with the support of scheduling algoritm. Particular context of job shop scheduling problem.
	14	Production system	Job and batch production system
	7	Planning and control	Production and capacity planning and control: MRP
Operations strategy	2	Lean manufacturing	Lean manufacturing consists of the implementation of a continuous improvements philosophy
	16	Quality management	Quality management
	18	Service	Service delivery to customers. The use of digital technologies such as Industry 4.0 technologies in services will improve service delivery.
	15	Maintenance policies	Maintenance policies for assets repairing and monitoring their reliability
Manufacturing network	9	Supply Chain Management	Contract between supplier and buyer. A firm should formulate collaboration and coordination strategy
	21	Manufacturing network	Plant configuration meaning the firm should define the role of the plants in the network of partners
Sustainability	19	Sustinable logistic	Green and environmental sustainable logistic. Regulation are putting pressure on transportation/logistic emission
Other	4	Organisation theory	Organisation theory
	17	Product development	Product design and product development process
	6	Inventory	Inventory: retailer return policies
	10	Publication	Publications in the field of operation management
	11	Noise	Noise
	20	SMEs	SMEs: response to market and ERP implementation
	22	Health care project	Health care project: service for appointment system to reduce waiting time

Appendix 3

Table 6
The main themes of Value creation dataset

Theme	Topic #	Label	Description
Value offering	6	Design process	Tools and methods for the design process. Define the role of users during the design process. The users are more and more involved in the design process
	10	Customer-product fit	the offering needs to match customer's requirements

Theme	Topic #	Label	Description
Value offering	7	PSS	Product service system and product life cycle
	11	value creation Product-service	Consumer involvement in value creation
	8	Customer oriented Offering	Customer oriented service. Create customer value including customer perspective in the value creation process
	21	Customer value creation	The design process has a customer focus. The design process should conduct a customer value analysis and define co-creation activities. The customer is then integrated in the value creation process
Value creation strategy	9	Strategy map for value creation	Strategy to give "direction" to the process of value creation
	14	Innovation strategy	Innovation strategy
	19	Strategic alliances for co-development	identify the firm position in the network through alliances in value creation
Sustainability	4	Sustainable value creation	Sustainable value creation to boost economic, social and environmental dimensions
Network	13	Value creation network	Value creation network to sustain competitive advantage
	18	Knowledge sharing	Knowledge sharing among enterprises (e.g. partners, supplier-buyer)
Performance	1	Performances	Firm performances
	15	Performance measurement system	Performance measurement system for internal firm performance: use of KPIs to measure/evaluate performances
Other	12	Business models	Business models
	16	Projects	Project: task, team stakeholder
	17	Technology	Technology: digital technologies, tech-based enterprise
	20	Supply chain management	Supply chain management: coordination among the suppy chain
	22	Outsourcing	Outsourcing
	23	Capital	Capital: intangible, allocation of capital, intellectual social investment of capital for innovation.

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