5-11-2023

TOWARDS DOMAIN-SPECIFIC KNOWLEDGE ON DIGITAL TRANSFORMATION - THE CASE OF THE FURNITURE INDUSTRY

Simon Zeiher
Sheffield Hallam University, simon.zeiher@student.shu.ac.uk

Alexander Richter
Victoria University of Wellington, alex.richter@wgtn.ac.nz

David Wagner
Munich Business School, david.wagner@munich-business-school.de

TOWARDS DOMAIN-SPECIFIC KNOWLEDGE ON DIGITAL TRANSFORMATION - THE CASE OF THE FURNITURE INDUSTRY

Research Paper

Simon Zeiher, Sheffield Hallam University, United Kingdom, simon.zeiher@student.shu.ac.uk

Alexander Richter, Victoria University of Wellington¸ New Zealand, alex.richter@wgtn.ac.nz

David Wagner, Munich Business School, Germany, david.wagner@munich-business-school.de

Abstract

An abundance of individual cases have explored and explained the Digital Transformation and, ultimately, proven its capability to create new value propositions. Moreover, various meta-studies have provided us with classifications and frameworks to synthesize existing knowledge on the topic. Yet, there is a lack of studies integrating industry-specific knowledge and providing orientation in the context of the relevant value-creation processes. Following a systematic literature search on Digital Transformation in the furniture industry, we analyse insights from 85 papers and suggest a theory-driven framework consisting of 5 focal areas: sources of disruption, strategic responses, value creation transformation, technical application, and obstacles to the implementation. Based on the framework, we structure and elaborate on the existing body of research and identify avenues for further research.

Keywords: Digital Transformation, Theory Development, Industry Applications, Domain-Specificity, Furniture Industry.

1 Introduction

Digital Transformation (DT) has been a major driver of change in business and society over the past decade. It has enabled organizations to become more agile (Tortora *et al.*, 2021; Vial, 2019), created new opportunities to engage with customers (Barni *et al.*, 2017, 2019; Verhoef *et al.*, 2021), and enabled the creation of new value propositions (Wang *et al.*, 2017). Studies have identified sources of disruption, strategic organizational responses, and the resulting transformation of the value creation process (Vial, 2019), captured the contextual conditions and mechanisms to create innovation (Hanelt *et al.*, 2021) and growth strategies (Verhoef *et al.*, 2021) or more broadly suggested classifications, like strategy, operation, and industry (Zhu *et al.*, 2021), to provide a synthesis of existing studies.

Comprehensive and high-level overviews are beneficial to describe the change of conditions in which organizations are embedded and the strategic changes to the structure, strategy, and value creation process across industries. Domain-specific studies, on the other side, can help to refine the postulated changes and clarify their applications to a specific context (Vial, 2019; Zhu *et al.*, 2021). While the mechanisms of DT on a high level are researched quite well, industry-specific aspects of DT are often scarce and require in-depth analysis (Hanelt *et al.*, 2021). Without this contextualization, it remains cumbersome to derive meaningful managerial implications, obstructing the uptake of important research findings by industry practitioners.

Against this backdrop, in this study, we provide a comprehensive domain-specific framework of the furniture industry. The furniture industry, i.e., the network of organizations developing, designing, selling, and producing wooden furniture to either B2B or B2C customers and their immediate supply chain connections, has been the target of several empirical and conceptual studies, as the investment costs for testing innovative ideas and business models are relatively low, compared to high-tech industries. As such, the furniture industry can be seen as an example of an industry with low obstacles to implementing DT. However, despite this and to the best of our knowledge, no review takes stock of current knowledge in the furniture industry, and no domain-specific framework is available.

Hence, this systematic literature review aims to

(1) identify and analyze contemporary research streams and collect the developed frameworks and theories, thus, illustrating the current state of research in the furniture industry,

(2) synthesize it to construct a comprehensive domain-specific framework, and

(3) identify the gaps in the body of literature regarding the furniture industry and scope avenues for further research.

The resulting domain-specific framework on DT in the furniture industry responds to calls for developing theories of DT (Markus and Rowe, 2021). It provides academics and industry professionals with orientation regarding the sources of disruption, strategic responses, value creation transformation, technical application, and implementation obstacles. Whereas existing research primarily contributes studies on a macro level (e.g., Vial, 2019) or micro level (e.g., Baiyere *et al.*, 2020; Dremel *et al.*, 2017), our framework is situated on a meso-level and will hopefully inspire academic works developing further domain-specific frameworks of DT.

In Section 2, we introduce the methodology applied in our study. We follow the 5-step process by Wolfswinkel *et al.* (2013), who suggest using grounded theory as a method for rigorously reviewing literature. Sections 3-5 are named according to steps 2-4 of this process, as illustrated in figure 1. We then split step 5 into three sections (6: framework construction, 7: reintegration and 8: research avenue identification), to acknowledge them as three separate key outcomes of our study. We close with a conclusion (Section 9).

2 Methodological Framework and Structure of this Paper

In order to ensure a comprehensive selection and a rigorous analysis of the available body of literature on DT in the furniture industry, we carried out a systematic literature review. The systematic approach aims to identify all relevant literature on a topic and ensures that no crucial knowledge or understanding is missed (Danson and Arshad, 2014; Tranfield *et al.*, 2003). We followed the approach of Wolfswinkel *et al.* (2013), who suggest a 5-step process, as illustrated in Figure 1 and further outlined below.

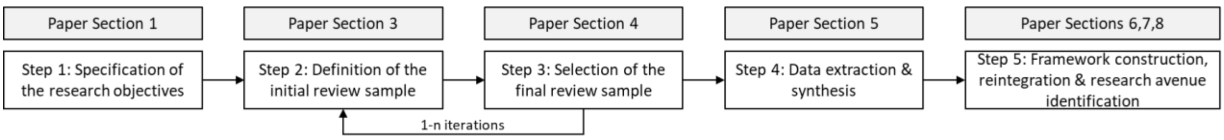

Figure 1. 5-step process for a systematic literature review, based on Wolfswinkel et al. (2013).

After defining the background and the three research objectives (step 1, see the introduction of this paper), we selected an initial review sample by querying various databases for the keyword of "digital transformation" (see Section 3 of this paper). As defined by step 3 of the process, we analyzed the initial sample to extract relevant keywords for selecting a final sample, which is then limited to only results from the furniture industry (see Section 4). We further refined the final sample in an iterative process by filtering doubles, removing irrelevant contributions based on full-text analysis, and conducting a backward and forward citation analysis to identify further relevant literature not captured by the initial query.

In step 4, the final sample of 85 articles was extracted and synthesized using open coding and axial coding (Glaser and Strauss, 2010; Wolfswinkel *et al.*, 2013). Open coding describes the process of identifying, labeling, and building a set of concepts supported by the review sample. When reviewing the studies in the process of open coding, we asked ourselves what each of the studies can contribute to enriching our understanding of DT in the furniture industry.

Each article underwent this process at least once to capture relevant key points for open coding. In an iterative process, through axial coding, the concepts were labeled and relabeled to create categories and subcategories and capture the interrelations between them. In step 5, we used selective coding (Glaser and Strauss, 2010; Wolfswinkel *et al.*, 2013) to connect the relations between the main categories. This allowed us to theorize and conceptualize a new model capturing and describing the findings of this review: a comprehensive framework to identify the gaps in the current body of literature on DT in the furniture industry and to evaluate possible research avenues for further research undertakings.

As the first step (specification of the research objectives) was addressed in the introduction, we continue with step two of the 5-step process in the next section.

3 Definition of Initial Review Sample

The initial sample can be used to extract relevant keywords to ensure that no pertinent research stream or topic is missed (Danson and Arshad, 2014; Wolfswinkel *et al.*, 2013). Therefore, our initial search queries were very broad and capture only the keyword "Digital Transformation" in either title, keywords, or abstract of an article. The search result is limited to English journal articles and proceeding papers published after 2010. Although some sources recommend screening books and conference papers as well (Hart, 2018), other sources claim that only journal articles are considered an acceptable source for literature reviews (Al-Tabbaa *et al.*, 2019; Webster and Watson, 2002; Wolfswinkel *et al.*, 2013). Research shows that proceeding papers also suffice the required quality since they undergo the peer-review process (González-Albo and Bordons, 2011). We have decided to add proceeding papers since proceeding papers often pre-date publications and are a good indicator of knowledge in an unexplored or nascent field. The subject areas exclude results from medical research and other unrelated fields. We conducted our search in three databases and found 3.993 articles in SCOPUS, 2.550 articles in the Web Of Science, and 2.063 articles in EBSCO. Two articles have been retracted and are therefore removed from the selection. Subsequently, all duplicate articles from the three databases were merged, leaving a total number of 5.380 unique articles.

Figure 2 illustrates the result of an analysis in VOSviewer, a bibliometric illustrator/analysis tool, to extract relevant keywords. The analysis considers all keywords with a minimum of 50 occurrences and reveals 4 clusters with a total of 93 different keywords. The total link strength of each keyword, calculated by VOSviewer, indicates the number of publications in which two keywords appear together in the body of literature. A thesaurus file has been used to account for different spellings and pluralization of all keywords (digitalisation/digitalization, SME/SMEs, etc.).

Cluster 1 in red has 28 items. The keyword with the strongest total link strength of 1994 is "Industry 4.0". The keyword "furniture industry" (344) already emerges in this cluster with 66 occurrences. This indicates that the furniture industry plays an important role in the application research of DT and that "Industry 4.0" is an important concept regarding DT in the furniture industry. Where industry 4.0 focuses on technological possibilities, DT comprises the business-focused approach concerning the business model (Wessel *et al.*, 2021).

Cluster 2 in green has 27 items. This cluster is grouped around the main keyword, "Digital Transformation," with a total link strength of 7260. This cluster has various connections to the other clusters since it contains the main search phrase and does not show any emerging internal structure. It is more a collection of keywords that appear in the context of DT but are unrelated to any of the thematic clusters.

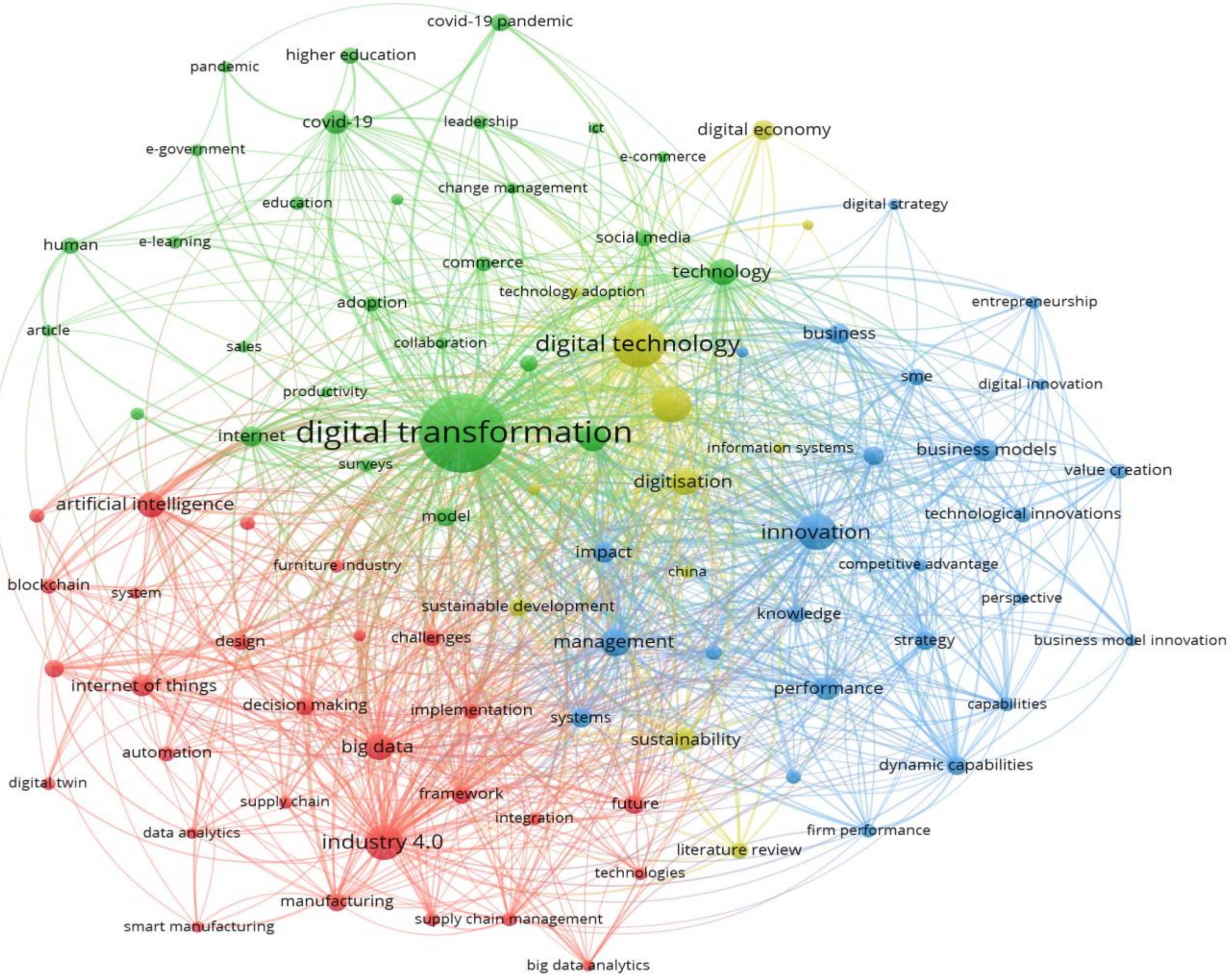

Figure 2. Keyword network visualization on the initial sample

Cluster 3 in blue has 25 items. The main keyword of this cluster is "innovation," with a total link strength of 2358. This cluster is grouped around the themes of innovation and business management. This cluster indicates a range of management and organizational research on the impact of DT.

Cluster 4 in yellow has 14 items: The main keyword of this cluster is "digital technology," with a total link strength of 2884. No concrete theme emerges from this cluster, which is also indicated by the positioning of the single keywords in figure 2.

The main point of this keyword analysis is to extract keywords for the search query for a final sample. Due to the amount of 5.380 articles, no content analysis has been conducted at this point, which means the insights should not be overestimated. But it reveals three conclusions for further investigation:

1. The two big thematic clusters emerging are (1) technical concepts grouped around the keyword of industry 4.0 and (2) a cluster around strategy/business management / organizational research concerning the impact of DT on organizations. This conclusion is further supported by existing literature (Hanelt *et al.*, 2021; Vial, 2019).
2. The furniture industry emerges as a keyword, showing sufficient material available for further analysis.
3. Technical concepts, such as "industry 4.0", "big data," "internet of things," etc., should be included in the search query to capture all relevant research streams.

4 Selection of the Final Sample

We then used the keywords found in step 2 and further refined them in an iterative process to select the final sample for analysis (step 3). This process included a) filtering doubles, b) excluding items based on title and abstract, c) excluding further items based on full-text analysis and d) conducting a backward and forward citation search to identify new relevant articles (Hart, 2018; Webster and Watson, 2002). If new articles were added to the sample, the refining process was repeated until it reached the appropriate breadth and depth, rigor, and consistency and also matched the required brevity to synthesize a consistent and comprehensive framework (Wolfswinkel *et al.*, 2013).

The search query for the final sample includes seven keywords, namely "digital transformation", "industry 4.0", "smart manufacturing", "digitalization", "big data" "internet of things" and "furniture". The queries are constructed in a way that at least one of the first six keywords and the keyword "furniture" have to be included in the result. The databases were queried in title, abstract, and keywords. The queries were adjusted for different spellings and abbreviations. The search results are limited to peer-reviewed journal articles and proceeding articles. Trade Journals and other non-scholarly sources were excluded.

The search reveals 92 articles from SCOPUS, 30 articles from EBSCO, and 131 articles from Web of Science. After merging all duplicates, 173 unique items remain for the first iteration of the final sample. In the first step, all articles are reviewed based on title and abstract. Items meeting one or more criteria for exclusion are removed from the sample. Three criteria for exclusion have been defined:

- Languages other than English.
- Missing connection to DT based on the keywords found in the keyword analysis.
- Missing connection to the furniture industry.

After applying the three criteria, 78 articles remained in the sample for full-text analysis. After full-text analysis, we excluded 14 articles that we considered not relevant for the next step. For instance, we excluded articles on smart furniture and street furniture. During backward citation analysis, all relevant literature providing groundwork and overarching frameworks is identified and added to the sample. For this step, the three criteria for the exclusion of an item remain in place, but the third criterion, the connection to the furniture industry, does not have to be explicit in the text. Some frameworks exerted an influence on the furniture industry through their application. Those publications are considered in the sample since they connect to the application in the furniture industry, even if it's not explicitly stated in the text. The backward citation reveals an additional 18 items containing theoretical frameworks or guidelines for application. The last step of the iteration, the forward citation analysis, reveals another 7 items. After multiple iterations, the number of items for the final sample consists of 85 papers. Since some articles cover multiple topics, Appendix A provides a full overview of the 85 papers identified and their categorization.

5 Data Extraction & Synthesis

This section represents step 4 of the 5-step process. Figure 3 provides an overview of the focal areas emerging from open coding and their categorization as a result of axial coding in 5 groups. Each of the groupings is described in detail in the following sections. The largest sub-category, Cost/Quality Improvement Concepts, which was studied in 39 papers, is depicted in more detail. Appendix B lists all frameworks developed in the final sample with a short description of their purpose. The numbers in figure 3 do not add up to 85, since various articles cover more than one topic and appear more than once. The same applies to the full list of articles in appendix A.

Sources of Disruption		**Strategic Response**		**Value Creation Transformation**		**Technical Applications**		**Obstacles to Implementation**	
Changing consumer behavior and expectations	7	Business Strategy Adjustment	6	Value Propositions	12	Neural Networks	6	Lack of Skilled Workers	9
Disruption of the competitive landscape	10	BSO Engagement	5	Value Networks	4	Digital Twin	4	Lack of BSO Support	2
				Agility and ambidexterity	3	Big Data	3	Unflexible Product Portfolio	1
				Cost / Quality improvements	39	Robotics / Automation	2	Cost of Change	1
						Additive Manufacturing	1		

Cost / Quality Improvement Concepts	
General Efficiency Improvments	13
Lean Management	5
Machine & environmental monitoring	8
Forecasting	2
Panel Dividing	4
Drilling	4
Packing	1
Extralogistics	2

Figure 3. Focal areas of DT in the furniture industry (*and their appearance count in literature)*

5.1 Sources of Disruption

Our analysis shows that two sources have fueled the DT of the furniture industry:

1) A change in consumer expectations and behavior. This change in demand is part of a contemporary global trend, where consumers expect (1) the fast delivery of (2) highly personalized goods which have to (3) meet additional social criteria, such as sustainability (Ding *et al.*, 2021; Dragomir and Bodi, 2020; Xiong *et al.*, 2018). At the same time, customers expect to engage in bidirectional communication with manufacturers through digital channels and expect instant and personalized replies (Stasiak-Betlejewska, 2020).

2) A change in the competitive landscape through companies who have already successfully established a strategic response. Companies implementing strategies suitable to fulfill emerging demands will exert pressure on their competitors (Warner and Wäger, 2019). While DT changes the strategy and the means by which organizations operate, the rules of competition remain in place (Porter and Heppelmann, 2014). Research indicates that the implementation of Industry 4.0-related technologies is capable of enhancing a firm's competitiveness (Ferreira *et al.*, 2022; Singh *et al.*, 2021).

5.2 Strategic Responses

The strategic response to the opportunities and threats of DT can be classified into two concepts. The first is an adaptation of the business strategy and the business model (Kiel *et al.*, 2017; Rachinger *et al.*, 2019). Given the above-mentioned disruptions, to respond adequately, companies strive to develop the digital capabilities (Matarazzo *et al.*, 2021) and dynamic capabilities (Elia *et al.*, 2021) necessary. For the furniture industry, the adaption of the business strategy has two directions: either through e-commerce into export markets (Elia *et al.*, 2021; Gao *et al.*, 2022; Zulfikar *et al.*, 2018) or through product personalization into domestic markets (Wang, He, *et al.*, 2017; Xiong *et al.*, 2018). Contemporary events, such as the COVID-19 pandemic, as well as the trade war between the USA and China, exert an impact on the availability of options for a company to choose from. As the amount of specific research about personalization and the lack of research on e-commerce in appendix B shows, contemporary events push research toward a product personalization research avenue. A radical concept to engage in domestic personalization is Urban Manufacturing, where a small but highly adaptable factory is embedded into the urban surroundings, with the capabilities to connect designers, customers, and manufacturing technology in a highly dynamic collaborative network which allows fast fulfillment of demands (Barni *et al.*, 2017, 2019). The more traditional approach is to transform an existing company, utilize information technology (IT) to streamline existing processes, and gain a competitive advantage through efficiency gains (Arnold *et al.*, 2016; Szopa and Cyplik, 2020).

The second strategic response concerns business support organizations (BSOs). While many frameworks focus on the viable actions a company can take in response to disruption (Compare the findings in (Verhoef *et al.*, 2021; Vial, 2019; Zhu *et al.*, 2021)), many companies in the furniture industry are too small to develop the capabilities necessary for DT by themselves. They would simply accept "environmental determinants" (Hanelt *et al.*, 2021, p. 1165) to provide the contextual conditions for DT. One determinant is the availability of a skilled workforce to design, implement and operate key enabling IT, such as CAD/CAM technology, robotics or artificial intelligence (Romero Gázquez *et al.*, 2021). BSOs play a vital role as knowledge gatekeepers, knowledge brokers and to facilitate knowledge diffusion (Dyba and De Marchi, 2022). The required skill sets comprise both higher education (Abidin *et al.*, 2021) and vocational training in woodworking technologies, including the operation of robots (Bueno-Delgado *et al.*, 2017).

5.3 Value Creation Transformation

What sets DT apart from IT-enabled organizational transformation is the redefinition of value creation (Wessel *et al.*, 2021). Changes in the business strategy often trigger changes in the (1) value creation or (2) delivery process, or (3) a mechanism that allows a company to capture a higher share of the generated value. Studies on the transformation of these three mechanisms make up a large part of the final sample (52 out of 85 papers).

The first concept of this category comprises research about creating additional value through the usage of digital technologies compared to a traditional business model (Rachinger *et al.*, 2019). This starts with a better design for standardized articles by including customer feedback early in the development process (Dragomir and Bodi, 2020) to manufacturing fully customized or personalized designs (Jimeno-Morenilla *et al.*, 2021). It also includes a shift from B2B business models to B2C models, taking at least one player out of the value chain to capture a higher share of the created value for the manufacturer (Matarazzo *et al.*, 2021). This leads to a process transformation towards higher servitization which is a "dynamic process in which enterprises transform the value chain from a manufacturing center to a service center to meet customer demand, realize added value, and gain a competitive advantage" ((Song *et al.*, 2022) p. 1) which also correlates with the higher overall productivity of the sector (Song *et al.*, 2022).

One way to reach a higher level of servitization is the usage of IT at the point-of-sale (POS), for example, exploratory or immersive virtual reality applications for room planning (Prabhakaran *et al.*, 2021, 2022). Other possibilities include design software, either operated by a designer or by the end customer, to fully customize the furniture in question (Rodriguez-Conde and Campos, 2020). Design rules in the software limit the customization to a point where efficient manufacturing can be guaranteed, or brand style can be enforced (Compare for limitation to Chinese Ming-style designs (Peng and Du, 2021)). This creation of a "product-service ecosystem" ((Zhou *et al.*, 2013) p. 1064) requires a holistic solution to enable the data exchange between POS and the shop floor (Zhang and Shi, 2022). Another possibility to raise the level of servitization is the manufacturing of smart products, which fulfill additional functions compared to traditional furniture (Popescu *et al.*, 2017). Besides changing the value creation, another adjustment of the business model is the change in the value creation network. Agents within the network are connected through IT to exchange information. A possible integration concept is the horizontal connection of various manufacturing sites in a manufacturing network (Barni *et al.*, 2019; Jimeno-Morenilla *et al.*, 2021). The implementation of digitalized value networks naturally requires a high level of integration for each of the involved agents (Szopa and Cyplik, 2020). The other dimension of integration is vertical integration along the value chain in a digitalized supply chain. A digital supply chain harbors various advantages over a traditional implementation. Its design is multidimensional, and the purpose is not only to manage logistics activities but to satisfy real demands based on customer needs (Garay-Rondero *et al.*, 2020). In both implementations, the connection to the customer has to be kept via various channels to funnel the customer's needs into the value network (Iglesias-Pradas *et al.*, 2021).

Other than the information exchange with the customer, a crucial success factor for a successful business model transformation is the capability of a company to react and adapt to unforeseen events. This capability can be described as agility and ambidexterity (Gregory *et al.*, 2015; Vial, 2019) or agility and adaptability (Bhatti *et al.*, 2022). Engaging in an iterating adapting process to 'stay ahead' can be a viable business model and requires the building of dynamic capabilities to create customer value (Matarazzo *et al.*, 2021; Tortora *et al.*, 2021).

5.4 Subcategory: Cost / Quality Improvements

Nearly half of the analyzed articles, 37 out of 85, focus on how IT is used to enable quality improvements or raise the efficiency of existing processes - which is in line with reviews of other domains (Maroufkhani *et al.*, 2022). It can be subdivided further, as shown in figure 3.

The first subcategory (general efficiency or quality improvements) covers a wide range of propositions to raise the efficiency of various processes or provide value through the collection and provision of information. One proposition is the usage of simulation technology such as software-based process evaluation (Bambura *et al.*, 2020; Medini *et al.*, 2021) and the usage of digital twins, collecting real-time data and enabling a continuous improvement process (Barni *et al.*, 2018). Another frequent proposition is to raise the level of automation, which is considered a key enabling factor for mass customization (Jasińska and Szala, 2021), for instance through hybrid human-robot collaborations to make processes more efficient and create a better working environment (Colim *et al.*, 2021). The data gathered from such collaboration can be used further for data-mining-based analysis (Oliveira *et al.*, 2019). Automation technology can also be used to stabilize process quality during the execution of machining processes, such as the cutting of panels (Jimeno-Morenilla *et al.*, 2021) and the sorting of parts, which is prone to mistakes by human operators (Kocsi and Oláh, 2017). The automation of production processes requires an identifiable workpiece, for example through RFID technology. The advantages are that in contrast to paper-based information transfer (such as a label on a part) the information can be updated in real-time (Zhong *et al.*, 2013). It is also possible to ensure an uninterrupted information flow from the POS to the shop floor. Solutions range from general ERP systems such as SAP to industry-specific solutions such as BaaN. Research highlights the necessity of industry-specific functions to match the needs of a product suitable for a highly customized product and to enable proactive decision-making (Gludovatz and Bacsardi, 2016). Other areas for efficiency or quality improvements are CAD/CAM solutions (Ratnasingam *et al.*, 2021), big data analysis to support decisions in the design process (Tsang *et al.*, 2022) and the development of frameworks to support decision-making (Dalalah *et al.*, 2022).

The second subcategory is the combination of lean management and industry 4.0. Lean management aims to reduce everything that does not create customer value (Ōno, 1988; Santos *et al.*, 2021), whereas Industry 4.0 aims to implement a business model of customization, to transfer the information about what customer value actually is into the shop floor (Santos *et al.*, 2021). Research identifies the lack of a pull system as one major obstacle to the implementation of industry 4.0 (Ingaldi *et al.*, 2021). This obstacle can be overcome by IT (Kolberg *et al.*, 2017; Rosienkiewicz *et al.*, 2018). A different approach is to adjust existing methods, such as value-stream mapping, which is traditionally used in mass production lines, where the products are known, and therefore the parameters for production can be determined. In a customized production, this approach is not possible. The solution is to utilize IT to collect data for further calculation and analysis. This improves the usability of value-stream mapping in a context of high customization (Wang, He, *et al.*, 2021).

The third subcategory contains articles about monitoring both machine and environmental parameters to collect data, for example to calculate direct and indirect costs of production (Koncz and Gludovatz, 2021). Since the whole production is treated as one interconnected system, it is possible to add sensors to measure environmental parameters and combine the data (van den Broek *et al.*, 2020; Son *et al.*, 2019). By separating machinery, data collection, and data usage, cyber-physical systems also allow for enhancing the functionality of the machinery. Intelligent spindle systems in CNC machinery enable the system to collect process parameters and derive actions through big-data analysis and artificial intelligence (Bachim *et al.*, 2020; Lee *et al.*, 2018; Liu *et al.*, 2019; Qin *et al.*, 2021). Additionally, the connection of the cyber-physical system with the internet allows it to preemptively react to situations and lower transaction costs by remote access (Lee *et al.*, 2014).

The fourth subcategory, termed 'forecasting,' utilizes order data to fuel demand forecasting by neural networks. While demand forecasting is nothing new, IT enables a new level of prediction quality by including seasonal effects through a vast amount of data (Bibaud-Alves *et al.*, 2019; Ensafi *et al.*, 2022).

The next four subcategories comprise the production process as illustrated in Figure 4, with intralogistical processes in dark grey and machining processes in light grey. The process steps for cabinet furniture range from the handling of raw boards, the dividing, edge banding, and drilling of panels to, finally, the sorting and packing of the article. These subcategories, emerging from open coding and axial coding, match the categorization found in the literature - except for the edge banding process step - to a great extent (Jasińska and Szala, 2021). Articles in this sample cover the topics of panel dividing, CNC processing, packing, and extralogistics. Research on the edge banding and other intralogistical processes are not represented in the final sample.

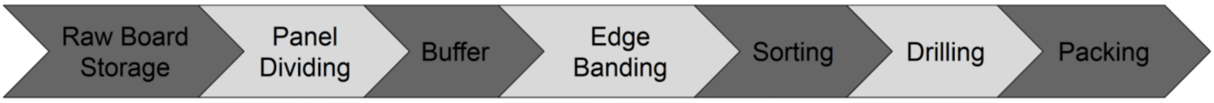

Figure 4. The process steps of furniture production, adjusted from (Jasińska and Szala, 2021)

The first machining process step is the dividing of panels from raw boards, either through cutting or nesting. The cutting patterns are generated by optimization software and need to yield a maximum of material usage while keeping within certain restrictions, such as the amount of simultaneously open parts, the number of head cuts and rotations, and machine restrictions like independent moving pushers. This optimization process is a derivative of the two-dimensional cutting stock problem (Oliveira *et al.*, 2016). Cloud computing, to access higher calculation power, as well as the availability of extensive order data yields significant improvements. One way to improve material usage is to apply an iterative optimization process over the order pool and tune the selection parameters (Ding *et al.*, 2021). Other improvements include the interconnection of machinery to spread the cutting over multiple machines (Farag *et al.*, 2020). The drilling process step is covered by similar concepts. The basic goal is to produce drilling patterns with a given complexity with a minimal number of spindle configurations and drilling head movements. The usage of software to optimize multi-spindle configurations is, again, nothing new (Klene *et al.*, 2001). What changes is the IT behind the calculation, such as AI-powered systems (Lee *et al.*, 2018) and the integration into a comprehensive cyber-physical framework (Liu *et al.*, 2019). This includes capturing real-time parameters to gain higher quality (Liu *et al.*, 2019) and an automatic quality check after the drilling process (Augustauskas *et al.*, 2021). The last process step in the manufacturing facility is the packing of parts. Since customized furniture has variable dimensions, the final package varies in dimensions and weight as well. The calculation of the packing layers is also a derivative of the cutting stock problem. Efficient utilization of packing space can increase the quality of packing as well as reduce the amount of packing material (Wang, Zhu, *et al.*, 2021).

Following the process steps of furniture production is extralogistics. The delivery route typically serves multiple customers with each less-than-truck-load of goods (Malladi and Sowlati, 2017). With the availability of mobile internet, the possibility of optimizing the delivery process has increased. One focus is to include the estimated assembly time necessary to install furniture in the overall route planning process (Luo *et al.*, 2021).

To summarize the category of cost and quality improvements: The literature in the subcategories can be distinguished into two research streams. One research stream is more abstract, focussing on methodology and how to improve processes through lean management and overarching concepts. The second research stream focuses on specific process improvements through the usage of digital technology.

5.5 Technical Applications

The next category to cluster the body of literature is the technical application of IT within a specific use case. In contrast to the previous chapter, this category emphasizes new use cases which were not applicable without IT. Existing studies have analyzed the following five technologies.

Neural networks and artificial intelligence allow for the execution of tasks too complex to be programmed in a traditional algorithm by utilizing large amounts of datasets. Neural networks have proven to reach a higher prediction quality than traditional systems (Ensafi *et al.*, 2022; Rosienkiewicz *et al.*, 2018), although the limited data available to train the model can lead to overfitting and a loss in predictive power. Since time series forecasting inherently relies on past data, the amount of available past data is fixed, and the further back the data is collected, the less meaningful it is (Bibaud-Alves *et al.*, 2019). Neural networks can also be used for quality control through image processing (Augustauskas *et al.*, 2021) or in smart control units to exercise complex control tasks (Lee *et al.*, 2018). The fourth area of application is data conversion, besides traditional data mapping. Research has been undertaken to apply a deep-learning-based neural network to map point clouds to corresponding CAD models. This technology has the potential to support order creation by translating design drawings into CAD files for production (Hu *et al.*, 2022).

Next, digital twins can either depict the furniture itself and be used for design and construction (Hu *et al.*, 2022), or they can depict the manufacturing environment. It can be used to boost process efficiency based on simulation (Yan *et al.*, 2021) or to create a sustainability report comprising all data collected from the digital twin of the production system (Barni *et al.*, 2018).

Another technical application, big data, is often a prerequisite for other technologies, especially to train neural networks. The usage of collected data to extrapolate results is again nothing new (Klene *et al.*, 2001). However, big data concepts allow the application of results in new areas, such as product development (Tsang *et al.*, 2022) or machine monitoring and maintenance activities based on big data analytics (Lee *et al.*, 2014).

The fourth technology is robotics and automation. Two related use cases mentioned in the analyzed studies are the support of human operators to improve working conditions (Colim *et al.*, 2021) and quality improvement or cost reduction by replacing the human operator entirely (Kocsi and Oláh, 2017).

The fifth technology is additive manufacturing. Nevertheless, the claimed importance of the topic does not reflect in the literature thus far, as the study also shows that wood is a difficult material for additive manufacturing technology (Murmura and Bravi, 2018).

5.6 Obstacles to the Implementation of DT

The last main category is the evaluation of obstacles to the implementation of DT. Two topics can be identified. First, the lack of skilled workers and second the lack of organizational capabilities. The lack of skilled workers as an obstacle is mentioned in four publications (Ingaldi *et al.*, 2021; Murmura and Bravi, 2018; Ratnasingam *et al.*, 2020, 2021; Resetar et al., 2017), two publications research the topic specifically (Pagano *et al.*, 2021; Romero Gázquez *et al.*, 2021) and three articles develop solutions to create and distribute the necessary skills and knowledge (Abidin *et al.*, 2021; Bueno-Delgado *et al.*, 2017; Romero-Gazquez *et al.*, 2022).

The lack of organizational capabilities can be classified into three fields (Ingaldi *et al.*, 2021). The first is the product portfolio, which does not allow the utilization of the promises of digitalization in terms of personalization. The second obstacle is the cost of change, especially the investment in automation technology. The third obstacle is human resistance to organizational change. Additionally, the lack of knowledge within the organizations can be seen as a root cause of obstacles to digitalization. This emphasizes the role of BSOs in solving this problem structurally (Dyba and De Marchi, 2022).

6 Framework Construction

As the last step of the 5-step process, the emerging concepts and their categories are connected into a framework to illustrate the findings of this literature review (figure 4). The framework connects the categories identified in the body of literature through selective coding. The dotted lines depict contemporary global trends. The solid lines illustrate the mechanisms of DT within organizations (Vial, 2019).

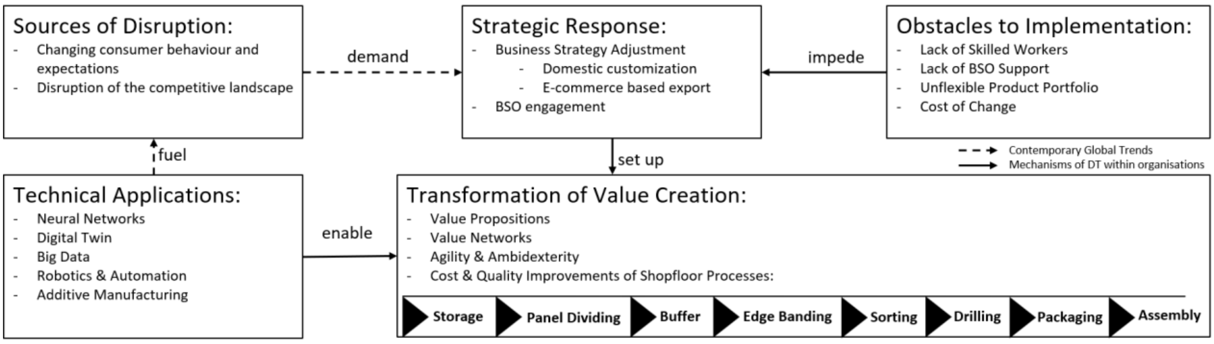

Figure 4. Framework of Digital Transformation in the furniture industry.

As illustrated in Figure 4, the role of digital technology in the furniture industry is twofold. On the one hand, it fuels the disruption and forces organizations to react either to customer expectations (e.g. Liu *et al.*, 2019; Yan *et al.*, 2021) or to competitive pressure (e.g. Bambura *et al.*, 2020; Barni *et al.*, 2018; Lee *et al.*, 2014; Tsang *et al.*, 2022). On the other hand, it enables the transformation of the value chain in new ways (e.g. Ghobakhloo and Fathi, 2019). The sources of disruption demand a strategic response from the affected organizations (Rachinger *et al.*, 2019). Six articles argue for a strategic response to changing consumer demand through personalization (Barni *et al.*, 2019; Luo *et al.*, 2021; Matarazzo *et al.*, 2021; Stasiak-Betlejewska, 2020; Wang *et al.*, 2017; Xiong *et al.*, 2018). Four articles call for adopting digital strategies to achieve a competitive edge (Ding *et al.*, 2021; Ferreira et al., 2022; Gao *et al.*, 2022; Singh *et al.*, 2021). The strategic response is impeded by obstacles, most notably the lack of skilled workers (Abidin *et al.*, 2021; Bueno-Delgado *et al.*, 2017; Murmura & Bravi, 2018; Pagano *et al.*, 2021; Ratnasingam *et al.*, 2020; Resetar *et al.*, 2017; Romero Gázquez *et al.*, 2021; Romero-Gazquez *et al.*, 2022) but also a variety of other reasons (Dyba & De Marchi, 2022).

The organization's strategic response typically involves a transformation of the value-creation process (Rachinger *et al.*, 2019; Wang *et al.*, 2017). This process includes creating value through personalization, a change in the value network through the interconnection of the different involved systems, and cost and quality improvements to ensure competitiveness. The changes in the manufacturing process are holistic in nature and aim to transform the manufacturing process to handle personalized parts efficiently to meet the demand of consumers. Mixing various smaller personalized customer orders into one production batch, instead of mass producing one article, leads to highly variable cutting patterns on the saw, requires highly flexible CNC drilling machines and demands an additional sorting process to distribute parts of one production batch into the final customer order.

7 Reintegration of the Framework into DT Research

By comparing the resulting meso-level framework with existing meta-level frameworks (such as Vial, 2019), we can identify several areas, which deepen our understanding of DT on the meta- and the meso-level.

First, it is worth pointing out that the main components of the meta-level and meso-level models are similar (i.e., technological developments, sources of disruption, strategic responses, obstacles, transformation of the value chain). What is different on the meso-level, compared to the meta-level, is the content, or the sub-components, of each of the boxes in the model. For instance, different technologies will have different impacts on different industries. Strategic responses will differ across industries. The obstacles industry incumbents are facing will be context specific. Most importantly, for value creation to be transformed, in-depth knowledge on value creation processes, or in the manufacturing world, the manufacturing processes, is required.

To give a more specific example, consider the emphasis on skill and individual knowledge of managers and workers. While on a meta-level, organizations have the possibility to develop new capabilities and the roles and skills of employees are acknowledged in this process (Vial, 2019), in practice companies face severe obstacles to educating qualified staff to conduct DT. This problem is particularly pronounced in a variety of SME-related studies (Eller *et al.*, 2020; Soluk & Kammerlander, 2021). Hence, in the meso-level context of the furniture industry, the role of BSOs as knowledge brokers and facilitators for knowledge diffusion is particularly prevalent, making the use of BSO's an important obstacle in the domain.

Second, building on the first point above, applied research concerning process technology is urgently needed, making shifts in industry-specific value creation processes visible. In the context of the furniture industry, for example, the trend towards personalisation of physical goods has an immense impact on the production processes and requires a holistic information flow from consumer demand to the execution of shop-floor processes. Best-practice case studies, illustrating process changes over time (compared to Verhoef et al., 2021), as well as the practical application of new technology, such as neural networks or cloud computing, are necessary to guide practitioners toward a path for improvement. Here lies the real value of translating meta-level models into meso-level, industry-specific models. To sum up, the sub-components of the main components of the model are likely to differ significantly and a conversion from meta- to meso-level is necessary to make these differences explicit.

Ultimately, the comparison with the meta-level also reveals additional gaps in our domain-specific framework. Research about the positive and negative effects of DT and research about structural changes for small and medium-sized enterprises is absent in the body of literature to date (compared to Vial, 2019).

8 A Domain-specific Research Agenda for DT in the Furniture Industry

The constructed framework (Figure 4) reveals a coherent and comprehensive picture of DT in the furniture industry. The reintegration of the framework into meta-level research reveals focal areas and gaps in the state of the art of DT in the furniture industry. Besides the different perspectives between our framework and the meta-level discussion, additional gaps can be identified within the domain of furniture production. Future research can be located in three research avenues: (A) researching the strategic response of organisations, (B) researching transformational processes in the furniture industry over time, and (C) the obstacles impeding DT in the furniture industry.

The strategic response of companies can aim at two business models: (a) e-commerce-based export of mass-produced furniture. This requires information exchange about furniture concepts and ideas and a prototyping process. (b) Domestic personalization strategy, implementing personalized furniture production with a continuous information flow from the POS to the shop floor, including the customer in the information loop. However, the changing global environment has a significant impact on this research avenue. With tightening restrictions in international trade, the focus on personalized products in domestic markets is the more dominant of the two possible research streams, while export-based product personalization is absent within the body of literature, possibly due to the delivery time of personalised furniture delivered to export markets. So far, every article researching practical applications focused on the use case of product personalization (cf. Wang, He, *et al.*, 2017), while the possibility of export-focused e-commerce has been neglected. This lack of research might be caused by the COVID-19 pandemic, which hindered international trade and forced companies to focus on domestic markets.

The second research avenue, the transformational processes over time, arises from the comparison with meta-level frameworks. While various frameworks construct a connection between lean management and industry 4.0 (cf. Ferreira *et al.*, 2022) as well as technical concepts to improve single processes, such as cutting, drilling or quality management (cf. Ding *et al.*, 2021), the literature does not analyse the transformation process itself over time. There is no guiding framework on what exactly has to change within a company to transition from mass production to personalized production. Since the investment costs are identified as an obstacle, companies need a framework for reorganizing existing resources and managing the transition process while the new business model is ramping up. Personalized furniture production requires transparency throughout the process to track the parts. Damaged parts need to be reworked immediately to meet delivery deadlines, and the sorting process to collect all parts of an order is more sophisticated than in mass production.

The third research avenue concerns the research about obstacles to implementing DT and how to overcome them. Even though several obstacles have been identified in the literature, nine articles cover the lack of skilled workers, while only one article covers the other aspects, e.g., the construction of the product portfolio and the required cost of change (Ingaldi *et al.*, 2021). Possible future research could develop frameworks for product development meeting the requirements of product personalisation. Another possibility is to investigate if automation is an integral part of digitalization or if a continuous information flow can be realised without investment into expensive robotics.

9 Conclusion

Ample research explores the DT on a case, i.e., micro level (e.g., Baiyere *et al.*, 2020; Dremel *et al.*, 2017) and on a macro level (e.g., Vial, 2019). In response to calls for more theoretical contributions to understand DT (Markus and Rowe, 2021), we provide a domain-specific, or meso-level, framework of DT in the furniture industry. We discuss the sources of disruption, strategic responses, value creation transformation, technical application, and obstacles to implementing DT in the furniture industry in detail and based on our findings, identify gaps in the existing research and avenues for further research, intended to stimulate further research.

The domain-specific supplements of and deviations from meta-level theory are an essential step towards contextualising DT models and sharpening the theory toolkit (Whetten, 1989). On a managerial level, they further enable managers in the furniture and manufacturing industries to develop new business models and implement new use cases, advancing the DT of the industry. Without understanding the industry-specific processes, managers struggle to derive concrete actions on a strategic and operational level. Beyond the above discussed research gaps and avenues for further research in the furniture industry, we hope that the approach we used will inspire the development of further domain-specific frameworks of DT.

Appendix

Appendix A: *Overview of the coding results:*
https://www.dropbox.com/s/qmhgypscgpj7z6p/Appendix_A.pdf?dl=0

Appendix B: 28 frameworks identified in the final sample:
https://www.dropbox.com/s/aizvme81l27ah0c/Appendix_B.pdf?dl=0

References

Abidin, SZ, Bahari, S.A., Ibrahim, A., Ghazali, A.E.M., Ahmad, M.A., Mujir, M.S., Delgado, M.V.B., *et al.* (2021), "Analysing the malaysian higher education training offer for furniture design and woodworking industry 4.0 as an input towards joint curriculum validation protocol", *Asia Pacific Journal of Educators and Education*, Vol. 36 No. 1, pp. 1–24.

Al-Tabbaa, O., Ankrah, S. and Zahoor, N. (2019), *Systematic Literature Review in Management and Business Studies: A Case Study on University–Industry Collaboration*, SAGE Publications Ltd, 1 Oliver's Yard, 55 City Road, London EC1Y 1SP United Kingdom, available at:https://doi.org/10.4135/9781526467263.

Arnold, C., Kiel, D. and Voigt, K.-I. (2016), "How the industrial internet of things changes business models in different manufacturing industries", *International Journal of Innovation Management*, Vol. 20 No. 08, p. 1640015.

Augustauskas, R., Lipnickas, A. and Surgailis, T. (2021), "Segmentation of drilled holes in texture wooden furniture panels using deep neural network", *Sensors*, Vol. 21 No. 11, available at:https://doi.org/10.3390/s21113633.

Bachim, T., Martens, M.L., Digiesi, S., Favero Trindade, D. and Ricci, B. (2020), "Improving predictive maintenance benefits from online monitoring of spindles: Case Study in woodworking machine tool", Vol. 20 No. 4, pp. 7–34.

Baiyere, A., Salmela, H. and Tapanainen, T. (2020), "Digital transformation and the new logics of business process management", *European Journal of Information Systems*, Vol. 29 No. 3, pp. 238–259.

Bambura, R., Sujova, E. and Cierna, H. (2020), "Utilizing Computer Simulation to Optimize Furniture Production System", *BioResources*, Vol. 15 No. 3, pp. 6752–6765.

Barni, A., Carpanzano, E., Landolfi, G. and Pedrazzoli, P. (2019), "Urban Manufacturing of Sustainable Customer-Oriented Products", in Monostori, L., Majstorovic, V., Hu, S. and Djurdjanovic, D. (Eds.), *Proceedings Of The 4th International Conference On The Industry 4.0 Model For Advanced Manufacturing (Amp 2019)*, presented at the The 4th International Conference On The Industry 4.0 Model For Advanced Manufacturing (Amp 2019), pp. 128–141.

Barni, A., Corti, D., Pedrazzoli, P., Rovere, D. and Lucisano, G. (2017), "Mini-factories for Close-to-customer Manufacturing of Customized Furniture: From Concept to Real Demo", *Procedia Manufacturing*, Vol. 11, pp. 854–862.

Barni, A., Fontana, A., Menato, S., Sorlini, M. and Canetta, L. (2018), "Exploiting the Digital Twin in the Assessment and Optimization of Sustainability Performances", in JardimGoncalves, R., Mendonca, J., Jotsov, V., Marques, M., Martins, J. and Bierwolf, R. (Eds.), *Proceedings Of The 9th International Conference On Intelligent Systems (Is)*, presented at the 2018 9th International Conference On Intelligent Systems (Is), pp. 706–713.

Bhatti, S.H., Hussain, WMHW, Khan, J., Sultan, S. and Ferraris, A. (2022), "Exploring data-driven innovation: What's missing in the relationship between big data analytics capabilities and supply chain innovation?", *Annals of Operations Research*, Springer, available at:https://doi.org/10.1007/s10479-022-04772-7.

Bibaud-Alves, J., Thomas, P. and El Haouzi, H. (2019), "Demand Forecasting using Artificial Neuronal Networks and Time Series: Application to a French Furniture Manufacturer Case Study", in Merelo, J., Garibaldi, J., Barranco, A., Madani, K. and Warwick, K. (Eds.), *Universite de Lorraine*, presented at the Ijcci: Proceedings Of The 11th International Joint Conference On Computational Intelligence, pp. 502–507.

van den Broek, J., Klein Cerrejon, D., Pratsinis, S.E. and Güntner, A.T. (2020), "Selective formaldehyde detection at ppb in indoor air with a portable sensor", *Journal of Hazardous Materials*, Vol. 399, available at:https://doi.org/10.1016/j.jhazmat.2020.123052.

Bueno-Delgado, M., Romero-Gazquez, J., Pavon-Marino, P., Melero-Munoz, F. and Canavate-Cruzado, G. (2017), "In4wood: developing an online and free training course to adapt the curricula of workers and managers of wood and furniture sector to the skills required by industry 4.0", in Chova, L., Martinez, A. and Torres, I. (Eds.), *Universidad Politecnica de Cartagena*, presented at

the 9th International Conference On Education And New Learning Technologies (Edulearn17), pp. 536–543.
Colim, A., Faria, C., Cunha, J., Oliveira, J., Sousa, N. and Rocha, L.A. (2021), “Physical ergonomic improvement and safe design of an assembly workstation through collaborative robotics”, *Safety*, Vol. 7 No. 1, available at:https://doi.org/10.3390/safety7010014.
Dalalah, D., Khan, S.A., Al-Ashram, Y., Albeetar, S., Ali, Y.A. and Alkhouli, E. (2022), “An integrated framework for the assessment of environmental sustainability in wood supply chains”, *Environmental Technology and Innovation*, Vol. 27, available at:https://doi.org/10.1016/j.eti.2022.102429.
Danson, M. and Arshad, N. (2014), “The Literature Review”, *Research Methods for Business & Management: A Guide to Writing Your Dissertation*, Goodfellow Publ, Oxford.
Ding, J., Wang, M., Zeng, X., Qu, W. and Vassiliadis, VS (2021), “Mass personalization strategy under Industrial Internet of Things: A case study on furniture production”, *Advanced Engineering Informatics*, Vol. 50, available at:https://doi.org/10.1016/j.aei.2021.101439.
Dragomir, D. and Bodi, S. (2020), “Increasing design process robustness in the case of durable consumer goods”, *Acta Technica Napocensis Series-Applied Mathematics Mechanics and Engineering*, Vol. 63 No. 2, pp. 169–174.
Dremel, C., Herterich, M., Wulf, J., Waizmann, J. and Brenner, W. (2017), “How AUDI AG Established Big Data Analytics in Its Digital Transformation”, *MIS Quarterly Executive*, Vol. 16 No. 2, pp. 81–100.
Dyba, W. and De Marchi, V. (2022), “On the road to Industry 4.0 in manufacturing clusters: the role of business support organisations”, *Competitiveness Review*, available at:https://doi.org/10.1108/CR-09-2021-0126.
Eller, R., Alford, P., Kallmünzer, A., & Peters, M. (2020). Antecedents, consequences, and challenges of small and medium-sized enterprise digitalization. Journal of Business Research, 112, 119–127. https://doi.org/10.1016/j.jbusres.2020.03.004
Elia, S., Giuffrida, M., Mariani, M.M. and Bresciani, S. (2021), “Resources and digital export: An RBV perspective on the role of digital technologies and capabilities in cross-border e-commerce”, *Journal of Business Research*, Vol. 132, pp. 158–169.
Ensafi, Y., Amin, S.H., Zhang, G. and Shah, B. (2022), “Time-series forecasting of seasonal items sales using machine learning – A comparative analysis”, *International Journal of Information Management Data Insights*, Vol. 2 No. 1, available at:https://doi.org/10.1016/j.jjimei.2022.100058.
Farag, M., Aboosaeedan, E. and Leong, E.N.K. (2020), “NanoPC ARM-based panel saw machine with industrial internet of things”, *International Journal of Mechanical Engineering and Robotics Research*, Vol. 9 No. 1, pp. 143–147.
Ferreira, W.D.P., Armellini, F., Santa-Eulalia, L.A.D. and Thomasset-Laperrière, V. (2022), “Extending the lean value stream mapping to the context of Industry 4.0: An agent-based technology approach”, *Journal of Manufacturing Systems*, Vol. 63, pp. 1–14.
Gao, F., Lin, C. and Zhai, H. (2022), “Digital Transformation, Corporate Innovation, and International Strategy: Empirical Evidence from Listed Companies in China”, *Sustainability (Switzerland)*, MDPI, Vol. 14 No. 13, available at:https://doi.org/10.3390/su14138137.
Garay-Rondero, C.L., Martinez-Flores, J.L., Smith, N.R., Caballero Morales, S.O. and Aldrette-Malacara, A. (2020), “Digital supply chain model in Industry 4.0”, *Journal of Manufacturing Technology Management*, Emerald Group Holdings Ltd., Vol. 31 No. 5, pp. 887–933.
Ghobakhloo, M. and Fathi, M. (2020), "Corporate survival in Industry 4.0 era: the enabling role of lean-digitized manufacturing", Journal of Manufacturing Technology Management, Vol. 31 No. 1, pp. 1-30. https://doi.org/10.1108/JMTM-11-2018-0417
Glaser, B.G. and Strauss, A.L. (2010), *The Discovery of Grounded Theory: Strategies for Qualitative Research*, 5. paperback print., Aldine Transaction, New Brunswick.
Gludovatz, A. and Bacsardi, L. (2016), “Production Related IT Solutions in the Operation of Factories”, in Szakal, A. (Ed.), *Proceedings Of The 17th Ieee International Symposium On Computational Intelligence And Informatics (Cinti 2016)*, presented at the 2016 17th Ieee International Symposium On Computational Intelligence And Informatics (Cinti 2016), pp. 187–

191.
González-Albo, B. and Bordons, M. (2011), "Articles vs. proceedings papers: Do they differ in research relevance and impact? A case study in the Library and Information Science field", *Journal of Informetrics*, Vol. 5 No. 3, pp. 369–381.
Gregory, R.W., Keil, M., Muntermann, J. and Mähring, M. (2015), "Paradoxes and the Nature of Ambidexterity in IT Transformation Programs", *Information Systems Research*, Vol. 26 No. 1, pp. 57–80.
Hanelt, A., Bohnsack, R., Marz, D. and Antunes Marante, C. (2021), "A Systematic Review of the Literature on Digital Transformation: Insights and Implications for Strategy and Organizational Change", *Journal of Management Studies*, Vol. 58 No. 5, pp. 1159–1197.
Hart, C. (2018), *Doing a Literature Review: Releasing the Research Imagination*, 2nd edition., SAGE Publications Inc, Thousand Oaks, CA.
Hu, S., Polette, A. and Pernot, J.-P. (2022), "SMA-Net: Deep learning-based identification and fitting of CAD models from point clouds", *Engineering with Computers*, available at:https://doi.org/10.1007/s00366-022-01648-z.
Iglesias-Pradas, S., Acquila-Natale, E. and Del-Río-Carazo, L. (2021), "Omnichannel retailing: a tale of three sectors", *Economic Research-Ekonomska Istrazivanja*, available at:https://doi.org/10.1080/1331677X.2021.1991825.
Ingaldi, M., Knop, K., Jagusiak-Kocik, M. and Ulewicz, R. (2021), "Industry 4.0 in the furniture industry - the problematic aspect in implementation", in Jost, M. (Ed.), *Technical University Czestochowa*, presented at the Woodema 2021: The Response Of The Forest-Based Sector To Changes In The Global Economy, pp. 207–212.
Jasińska, K. and Szala, Ł. (2021), "Potential directions for improving production processes in industry 4.0 conditions based on a polish furniture enterprise – a case study.", *Potencjalne Kierunki Doskonalenia Procesów Produkcji w Warunkach Industry 4.0 Na Przykładzie Polskiego Przedsiębiorstwa Meblarskiego – Case Study.*, Vol. 2 No. 60, pp. 27–46.
Jimeno-Morenilla, A., Azariadis, P., Molina-Carmona, R., Kyratzi, S. and Moulianitis, V. (2021), "Technology enablers for the implementation of Industry 4.0 to traditional manufacturing sectors: A review", *Computers in Industry*, Vol. 125, available at:https://doi.org/10.1016/j.compind.2020.103390.
Kiel, D., Arnold, C. and Voigt, K.-I. (2017), "The influence of the Industrial Internet of Things on business models of established manufacturing companies – A business level perspective", *Technovation*, Vol. 68, pp. 4–19.
Klene, G., Grauel, A., Convey, H. and Hartley, A. (2001), "Data mining and automation of experts decision process applied to machine design for furniture production", in Kurkova, V., Steele, N., Neruda, R. and Karny, M. (Eds.), *University of Paderborn*, presented at the Artificial Neural Nets And Genetic Algorithms, pp. 453–456.
Kocsi, B. and Oláh, J. (2017), "Potential connections of unique manufacturing and industry 4.0.", *Potenzielle Verbindung von Einzelproduktion Mit Dem Industry 4.0-Konzept.*, Vol. 13 No. 4, pp. 389–400.
Kolberg, D., Knobloch, J. and Zühlke, D. (2017), "Towards a lean automation interface for workstations", *International Journal of Production Research*, Vol. 55 No. 10, pp. 2845–2856.
Koncz, A. and Gludovatz, A. (2021), "Calculation of indirect electricity consumption in product manufacturing", *International Journal of Energy Production and Management*, Vol. 6 No. 3, pp. 229–244.
Lee, J., Davari, H., Singh, J. and Pandhare, V. (2018), "Industrial Artificial Intelligence for industry 4.0-based manufacturing systems", *Manufacturing Letters*, Vol. 18, pp. 20–23.
Lee, J., Kao, H.-A. and Yang, S. (2014), "Service Innovation and Smart Analytics for Industry 4.0 and Big Data Environment", *Procedia CIRP*, Vol. 16, pp. 3–8.
Liu, B., Zhang, Y., Zhang, G. and Zheng, P. (2019), "Edge-cloud orchestration driven industrial smart product-service systems solution design based on CPS and IIoT", *Advanced Engineering Informatics*, Vol. 42, p. 100984.
Luo, H., Tian, S. and Kong, XTR (2021), "Physical Internet-enabled customised furniture delivery in

the metropolitan areas: digitalisation, optimisation and case study", *International Journal of Production Research,* Vol. 59 No. 7, pp. 2193–2217.

Malladi, K. and Sowlati, T. (2017), "Optimization of operational level transportation planning in forestry: a review", *International Journal Of Forest Engineering,* Vol. 28 No. 3, pp. 198–210.

Markus, M.L. and Rowe, F. (2021), "Guest Editorial: Theories of Digital Transformation: A Progress Report", *Journal of the Association for Information Systems,* Vol. 22 No. 2, pp. 273–280.

Maroufkhani, P., Desouza, KC, Perrons, RK and Iranmanesh, M. (2022), "Digital transformation in the resource and energy sectors: A systematic review", *Resources Policy,* Elsevier Ltd, Vol. 76, available at:https://doi.org/10.1016/j.resourpol.2022.102622.

Matarazzo, M., Penco, L., Profumo, G. and Quaglia, R. (2021), "Digital transformation and customer value creation in Made in Italy SMEs: A dynamic capabilities perspective", *Journal of Business Research,* Vol. 123, pp. 642–656.

Medini, K., Romero, D. and Wuest, T. (2021), "Developing a multi-agent system to support multi-variant production ramp-up management", *Smart and Sustainable Manufacturing Systems,* Vol. 5 No. 1, pp. 129–147.

Murmura, F. and Bravi, L. (2018), "Additive manufacturing in the wood-furniture sector: Sustainability of the technology, benefits and limitations of adoption", *Journal of Manufacturing Technology Management,* Vol. 29 No. 2, pp. 350–371.

Oliveira, M., Bettoni, A., Coscia, E. and Torvatn, H. (2019), "Applying Co-creation Principles to Requirement Elicitation in Manufacturing", in Stephanidis, C. (Ed.), *SINTEF,* Vol. 11786, presented at the Hci International 2019 - Late Breaking Papers, Hcii 2019, pp. 54–61.

Oliveira, O., Gamboa, D. and Fernandes, P. (2016), "An Information System for the Furniture Industry to Optimize the Cutting Process and the Waste Generated", *Procedia Computer Science,* Vol. 100, pp. 711–716.

Ōno, T. (1988), *Toyota Production System: Beyond Large-Scale Production,* Productivity Press, Cambridge, Mass.

Pagano, A., Carloni, E., Galvani, S. and Bocconcelli, R. (2021), "The dissemination mechanisms of Industry 4.0 knowledge in traditional industrial districts:evidence from Italy", *Competitiveness Review,* Vol. 31 No. 1, pp. 27–53.

Peng, Z. and Du, Y. (2021), "Computer Digital Technology-Based Educational Platform for Protection and Activation Design of Ming Furniture", *Wireless Communications and Mobile Computing,* Vol. 2021, available at:https://doi.org/10.1155/2021/3000011.

Popescu, D., Dragomir, M., Popescu, S. and Neamtu, C. (2017), "From smart products to smart manufacturing in emerging economies: challenges and insights from the furniture industry", in Fertsch, M., Stachowiak, A., Mrugalska, B., OleskowSzlapka, J., Hadas, L., Cyplik, P. and GolinskaDawson, P. (Eds.), *Technical University of Cluj Napoca,* presented at the 24th International Conference On Production Research (Icpr), pp. 93–97.

Porter, M.E. and Heppelmann, J.E. (2014), "How Smart, Connected Products Are Transforming Competition", *Harvard Business Review (Reprint),* 1 November, Vol. 1 No. November 2014, pp. 1–23.

Prabhakaran, A., Mahamadu, A.-M., Mahdjoubi, L., Booth, C. and Aigbavboa, C. (2022), "Virtual reality utility and usefulness in the furniture, fixture and equipment sector: a validation of interactive and distributed immersion", *Smart and Sustainable Built Environment,* available at:https://doi.org/10.1108/SASBE-02-2022-0038.

Prabhakaran, A., Mahamadu, A.-M., Mahdjoubi, L., Manu, P., Che Ibrahim, C.K.I. and Aigbavboa, C.O. (2021), "The effectiveness of interactive virtual reality for furniture, fixture and equipment design communication: an empirical study", *Engineering, Construction and Architectural Management,* Vol. 28 No. 5, pp. 1440–1467.

Qin, H., Wang, H., Zhang, Y. and Lin, L. (2021), "Constructing Digital Twin for Smart Manufacturing", in Shen, W., Barthes, J., Luo, J., Shi, Y. and Zhang, J. (Eds.), *Guangdong Academy of Sciences,* presented at the Proceedings Of The 2021 Ieee 24th International Conference On Computer Supported Cooperative Work In Design (Cscwd), pp. 638–642.

Rachinger, M., Rauter, R., Müller, C., Vorraber, W. and Schirgi, E. (2019), "Digitalization and its influence on business model innovation", *Journal of Manufacturing Technology Management*, Vol. 30 No. 8, pp. 1143–1160.

Ratnasingam, J., Ioras, F., Liat, L.C., Ayenkaren, J., Yi, L.Y. and Latib, H.A. (2021), "Digital Technology Application Among Malaysian Valueadded Wood Products Manufacturers", *BioResources*, North Carolina State University, Vol. 16 No. 2, pp. 2876–2890.

Ratnasingam, J., Yi, L.Y., Azim, A.A.A., Halis, R., Liat, L.C., Khoo, A., Daud, MMM, *et al.* (2020), "Assessing the awareness and readiness of the Malaysian furniture industry for Industry 4.0", *BioResources*, Vol. 15 No. 3, pp. 4866–4885.

Resetar, Z., Resetar, N., & Tolusic, M. (2017). Fourth Industrial Revolution and Individualization of Products. In A. Tonkovic (Ed.), University of JJ Strossmayer Osijek (WOS:000445028500023; pp. 248–255).

Rodriguez-Conde, I. and Campos, C. (2020), "Towards customer-centric additive manufacturing: Making human-centered 3d design tools through a handheld-based multi-touch user interface", *Sensors (Switzerland)*, Vol. 20 No. 15, pp. 1–28.

Romero Gázquez, J.L., Bueno Delgado, M.V., Ortega Gras, J.J., Lova, J.G., Gómez Gómez, M.V. and Zbiec, M. (2021), "Lack of skills, knowledge and competences in Higher Education about Industry 4.0 in the manufacturing sector", *RIED-Revista Iberoamericana de Educacion a Distancia*, Vol. 24 No. 1, pp. 285–313.

Romero-Gazquez, J.L., Canavate-Cruzado, G. and Bueno-Delgado, M.-V. (2022), "IN4WOOD: A Successful European Training Action of Industry 4.0 for Academia and Business", *IEEE Transactions on Education*, Vol. 65 No. 2, pp. 200–209.

Rosienkiewicz, M., Kowalski, A., Helman, J. and Zbieć, M. (2018), "Development of lean hybrid furniture production control system based on glenday sieve, artificial neural networks and simulation modeling", *Drvna Industrija*, Vol. 69 No. 2, pp. 163–173.

Santos, B.P., Enrique, D.V., Maciel, V.B.P., Lima, T.M., Charrua-Santos, F. and Walczak, R. (2021), "The synergic relationship between industry 4.0 and lean management: Best practices from the literature", *Management and Production Engineering Review*, Vol. 12 No. 1, pp. 94–107.

Singh, S., Sharma, M. and Dhir, S. (2021), "Modeling the effects of digital transformation in Indian manufacturing industry", *Technology in Society*, Elsevier Ltd, Vol. 67, available at:https://doi.org/10.1016/j.techsoc.2021.101763.

Soluk, J., & Kammerlander, N. (2021). Digital transformation in family-owned Mittelstand firms: A dynamic capabilities perspective. European Journal of Information Systems, 30(6), 676–711. https://doi.org/10.1080/0960085X.2020.1857666

Son, J., Kim, M. and Son, Y. (2019), "IoT Testbed for Dynamic Management of Fine dust in Indoor Environments", in Ramachandran, G. and Ortiz, J. (Eds.), *Electronics & Telecommunications Research Institute - Korea (ETRI)*, presented at the Proceedings Of The 2019 International Conference On Internet Of Things Design And Implementation (Iotdi '19), pp. 277–278.

Song, L., Wang, H., Song, W. and Yang, C. (2022), "Empirical Analysis of Influence of Furniture Manufacturing Servitization on Industry Performance Based on Big Data", *Scientific Programming*, Vol. 2022, available at:https://doi.org/10.1155/2022/7115035.

Stasiak-Betlejewska, R. (2020), "Marketing communication tools and channels for the future industry", in Jelacic, D. (Ed.), *Technical University Czestochowa*, presented at the Sustainability Of Forest-Based Industries In The Global Economy, pp. 83–86.

Szopa, Ł. and Cyplik, P. (2020), "The concept of building a digital transformation model for enterprises from the SME sector", *Logforum*, Poznan School of Logistics, Vol. 16 No. 4, pp. 593–601.

Tortora, D., Chierici, R., Farina Briamonte, M. and Tiscini, R. (2021), "'I digitize so I exist'. Searching for critical capabilities affecting firms' digital innovation", *Journal of Business Research*, Elsevier Inc., Vol. 129, pp. 193–204.

Tranfield, D., Denyer, D. and Smart, P. (2003), "Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review", *British Journal of Management*, Vol. 14 No. 3, pp. 207–222.

Tsang, Y.P., Wu, C.H., Lin, K.-Y., Tse, Y.K., Ho, GTS and Lee, C.K.M. (2022), "Unlocking the

power of big data analytics in new product development: An intelligent product design framework in the furniture industry", *Journal of Manufacturing Systems*, Vol. 62, pp. 777–791.
Verhoef, P.C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Qi Dong, J., Fabian, N. and Haenlein, M. (2021), "Digital transformation: A multidisciplinary reflection and research agenda", *Journal of Business Research*, Vol. 122, pp. 889–901.
Vial, G. (2019), "Understanding digital transformation: A review and a research agenda", *The Journal of Strategic Information Systems*, Vol. 28 No. 2, pp. 118–144.
Wang, G., Zhu, J., Cai, W., Liu, B., Tian, Y. and Meng, F. (2021), "Research on Packaging Optimization in Customized Panel Furniture Enterprises", *Bioresources*, Vol. 16 No. 1, pp. 1186–1206.
Wang, H.-N., He, Q.-Q., Zhang, Z., Peng, T. and Tang, R.-Z. (2021), "Framework of automated value stream mapping for lean production under the Industry 4.0 paradigm", *Journal of Zhejiang University: Science A*, Vol. 22 No. 5, pp. 382–395.
Wang, L., He, J. and Xu, S. (2017), "The Application of Industry 4.0 in Customized Furniture Manufacturing Industry", edited by Zhao, L., Xavior, A., Cai, J. and You, L.*MATEC Web of Conferences*, Vol. 100, p. 03022.
Wang, Y., Ma, H.-S., Yang, J.-H. and Wang, K.-S. (2017), "Industry 4.0: a way from mass customization to mass personalization production", *Advances in Manufacturing*, Vol. 5 No. 4, pp. 311–320.
Warner, K.S.R. and Wäger, M. (2019), "Building dynamic capabilities for digital transformation: An ongoing process of strategic renewal", *Long Range Planning*, Vol. 52 No. 3, pp. 326–349.
Webster, J. and Watson, R.T. (2002), "Analyzing the Past to Prepare for the Future: Writing a Literature Review", *MIS Quarterly*, Vol. 26 No. 2, pp. xiii–xxiii.
Wessel, L., Baiyere, A., Ologeanu-Taddei, R., Cha, J. and Jensen, T. (2021), "Unpacking the Difference Between Digital Transformation and IT-Enabled Organizational Transformation", *Journal Of The Association For Information Systems*, Vol. 22 No. 1, pp. 102–129.
Whetten, D. A. (1989). What Constitutes a Theoretical Contribution? The Academy of Management Review, 14(4), 490–495. https://doi.org/10.2307/258554
Wolfswinkel, J.F., Furtmueller, E. and Wilderom, C.P.M. (2013), "Using grounded theory as a method for rigorously reviewing literature", *European Journal of Information Systems*, Vol. 22 No. 1, pp. 45–55.
Xiong, X., Yuan, Y., Fang, L., Liu, H. and Wu, Z. (2018), "Status and Development Trends of Intelligent Manufacturing in China's Furnishings Industry", *Forest Products Journal*, Vol. 68 No. 3, p. 9.
Yan, D., Liu, Q., Leng, J., Zhang, D., Zhao, R., Zhang, H. and Wei, L. (2021), "Digital Twin-Driven Rapid Customized Design of Board-Type Furniture Production Line", *Journal of Computing and Information Science in Engineering*, Vol. 21 No. 3, available at:https://doi.org/10.1115/1.4050617.
Zhang, J. and Shi, L. (2022), "Optimization of Network Furniture Management System Based on Big Data", *Mathematical Problems in Engineering*, Vol. 2022, available at:https://doi.org/10.1155/2022/9698853.
Zhong, R.Y., Dai, Q.Y., Qu, T., Hu, G.J. and Huang, G.Q. (2013), "RFID-enabled real-time manufacturing execution system for mass-customization production", *Robotics and Computer-Integrated Manufacturing*, Vol. 29 No. 2, pp. 283–292.
Zhou, F., Ji, Y. and Jiao, R.J. (2013), "Affective and cognitive design for mass personalization: status and prospect", *Journal of Intelligent Manufacturing*, Vol. 24 No. 5, pp. 1047–1069.
Zhu, X., Ge, S. and Wang, N. (2021), "Digital transformation: A systematic literature review", *Computers & Industrial Engineering*, Vol. 162, p. 107774.
Zulfikar, M., Ilham, M. and Muslichah, I. (2018), "Digitalization as a Solution to Raise Indonesian Furniture Market: A Study of the Development of Furniture E-Commerce Platform in Jepara, Indonesia", in Soliman, K. (Ed.), *Universitas Islam Indonesia*, presented at the Innovation Management And Education Excellence Through Vision 2020, Vols I -Xi, pp. 4778–4787.