Contributions to Management Science

Mantas Vilkas · Jurga Duobienė ·
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Organizational Models for Industry 4.0

Lean, Agile and Service-Oriented Organizations

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Contributions to Management Science

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Chapter 1
Organizational Models for Industry 4.0

Abstract In this introductory chapter, we invite readers to look at the mundane manufacturing sector through the lens of neo-institutional theory. The global manufacturing field is being reshuffled due to emerging digital technologies and connectivity. Companies mimic digitally transformed ones. Countries and regions introduce Industry 4.0 policies to avoid deindustrialization and direct resources for manufacturing companies that adopt digital technologies. "Digitalization" becomes expected. It grants legitimacy, increased demand, talents, and other vital resources. In this chapter, we propose that digital innovations enable the introduction of new service-oriented business models and contribute to the advancement of the capabilities on which companies compete. These two trends—the emergence of new service-oriented firms in relation to more established lean and agile firms and the effects of digital innovations on the performance of organizations—are at the front and center of the book. We ground the research gaps and provide a theoretical–empirical framework. We introduce the effective empirical sample of 500 firms, which was collected as part of a European manufacturing survey. Finally, we argue that studying lean, agile, and service-oriented organizations in relation to each other could result in a more nuanced understanding of companies' strategies and behavior in the context of Industry 4.0.

1.1 Introduction

The extent of the digital transformation of manufacturing firms is an area of profound interest for the research community and policymakers. Approximately one hundred countries contribute to 98% of world manufacturing value added (WEF 2018). Traditionally strong industrialized countries lose their share of global manufacturing value added. The first industrial disruption appeared with the rise of emerging countries. The joint share of Western Europe, North America, and Japan's manufacturing footprint decreased from 80% to 60% of global manufacturing value added from 1991 until 2011. The trend continued further in favor of Asia and Central and Eastern Europe. Recently, China leads global output with 25% of manufacturing

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global value added, while the USA and Japan follow, contributing with 16% and 9%, respectively (OECD 2022).

The shift from manufacturing to service economies was initially accepted with enthusiasm. However, global product markets are a locus of innovation and the most critical factor of the current account balance. In industrialized countries, manufacturing accounts for up to 25% of added value, generates under 70% of all the private investment into R&D, and constitutes up to 70% of all export (Roland Berger strategy consultants 2014). Manufacturing and services are highly interdependent: 40% of jobs in the European manufacturing sector are service related (Pilat and Wölfl 2005). Even more, when plants are moved offshore, the high value-added sectors such as product design, marketing, and sales tend to follow. Manufacturing is vital to ensure a balanced labor market and the skills pyramid. Deindustrialization causes a mismatch of supply and demand in the labor market and polarizes society. Deindustrialization processes are threatening employment stability and, therefore, social cohesion (Kollmeyer 2009). Eventually, the manufacturing sector continued to generate taxes and provide employment during the COVID-19 pandemics, which froze service industries initially (Michie 2020).

The last 10 years have witnessed the emergence of a number of radically new technologies in manufacturing. Many observers believe that these new technologies will lead to a disruptive change in the manufacturing sector in the coming years (Brynjolfsson and McAfee 2014; Ford 2015; Manyika et al. 2012; Schlaepfer et al. 2015). At the heart of the changes lie ubiquitous digital technologies and connectivity. A multidimensional and broad concept of digital transformation defines the overall effect of digital technologies and connectivity on an organization. The ongoing digital transformation has the potential to reshuffle the manufacturing field. The current situation is seen as a turning point if one looks at a global manufacturing field as a contested arena.

The ongoing digital transformation is multifaced encompassing dynamics within and among industrial, public, and finance domains, potentially contributing to a transformation of economies (Bodrožić and Adler 2018). In the global manufacturing field, digital innovations enable the introduction of new service-oriented business models and contribute to the advancement of the capabilities on which companies compete (Evangelista et al. 2014; Iansiti and Lakhani 2014; Manyika et al. 2012; Schlaepfer et al. 2015). While embracing digital transformation, manufacturing companies shift their value proposition away from providing products to proposing new efficiencies through advanced analytics and algorithms based on the data generated by these products (Iansiti and Lakhani 2014). Such a change in business models and the emergence of servitization strategies results in additional functionalities, faster maintenance, higher reliability, and decreased exploitation costs for product owners (Luoto et al. 2017; Lightfoot et al. 2013; Baines et al. 2009). Digital transformation also creates affordances that increase organizations' capabilities on which they compete. Configurations of organizational and technological innovations enable particular affordances, such as decision support systems, intelligent process automation, simulation/synthetic representation, and real-time monitoring of manufacturing processes (Zammuto et al. 2007, Orlikowski and

Scott 2008). Such affordances contribute to quality, fast delivery, flexibility, innovation, and cost-effectiveness competitive performance. These two trends—the emergence of new service-based firms in relation to more established *lean* and *agile* firms and the effects of digital innovations on the performance of organizations—are at the front and center of the book.

The digitalization of manufacturing is a significant area of research. Despite collective efforts, the vast areas are still under-researched due to the extent of the transformation underway. First, the characteristics of *service-oriented* organizational forms and their compatibility with familiar organizational forms, such as lean and agile, received scant attention in scholarly literature. There is broad agreement that digital technologies facilitate the service innovation of manufacturing organizations (Baines et al. 2013; Lightfoot et al. 2013). However, the evaluation of the extent of the compatibility between the emerging service-oriented organizational forms and lean and agile organizations is still under-researched. Such a comparison is essential for several reasons. It would allow deducing the extent of the overlap among the goals, the means, and the resulting capabilities of these organizational forms. It would also shed light on whether lean is a precursor to an agile and whether an agile is a precursor of a service-oriented organization.

Second, the research on lean, agile, and service-oriented organizations is extensive but fragmented. This book empirically assesses the prevalence of lean, agile, and service-oriented organizations using a representative sample of manufacturing firms in an industrialized country. In addition, it allows zooming in and revealing whether adopting lean methods, digital manufacturing innovations, product, customer support, and result-oriented services vary with size, industry, product complexity, lot size, type of design process, and type of manufacturing process of organizations. Such knowledge allows understanding of how competitive orientations, practices, and performance dimensions associated with lean, agile, and service-oriented organizations are dispersed.

Third, adopting lean, agile, and service-oriented goals and organizational practices drives specific operational performance and contributes to increased financial performance. However, measuring the effects of digital innovations and servitization strategies on firms' performance showed mixed results. The productivity paradox (Brynjolfsson 1993; Van Ark 2016), digitalization paradox (Gebauer et al. 2020), and servitization paradox (Brax et al. 2021) are proposed to explain these mixed results. This book seeks to reveal how and which lean practices, digital manufacturing innovations, and services contribute to the leanness-related quality and costs performance, agility-related fast delivery, flexibility and innovation performance, and service-oriented capabilities of high service performance and digitalization. Further, we address if competitive performance dimensions associated with the lean, agile, and service-oriented organizational forms contribute to financial performance in isolation and jointly. This evidence allows hypothesizing whether possessing performance dimensions associated with a single organizational form (e.g., agile) or possessing performance dimensions associated with several forms (e.g., lean and agile) is more financially rewarding.

In summary, the aims of the book are summarized below:

– To characterize lean, agile, and service-oriented manufacturing firms in relation to each other.
– To empirically assess how competitive orientations, practices, and performance dimensions associated with lean, agile, and service-oriented organizations are distributed in a manufacturing field of an industrialized country.
– To empirically assess how lean, agile, and service-oriented practices and performance dimensions contribute to the operational and financial performance of the manufacturing firms.

In order to achieve the aims of the book, we draw on neo-institutional theory to define lean, agile, and service-oriented firms, interpret the extent of the compatibility of these firms and assess the empirical manifestation of these organizations.

1.2 The Theoretical–Empirical Framework

The neo-institutional theory proposes that organizations compete for resources in local and global manufacturing fields. The resources such as production orders and regulatory acknowledgment are granted to organizations that conform to societal expectations, such as "templates of organizing" (DiMaggio and Powell 1991, p. 27). We define a template of organizing as an institutionally relevant arrangement of goals and practices resulting in organizational competencies and differentiating competitive performance constituting an organization's core (Fig. 1.1). Lean, agile, and service-oriented templates of organizing constitute the most prevalent organizing templates in the manufacturing fields.

The goals form an ideational dimension of a template constituted of values and belief systems that direct attention to the particular mode of capturing the value and discriminate whatever action is appropriate. The competitive priorities represent the intentions which performance dimension or pattern of dimensions are essential and will be developed in the future (Boyer and Lewis 2002). Meanwhile, practices are repetitive, recognizable patterns of action that are performed by a group of people (Feldman and Pentland 2003). The competencies refer to the organizational expertise, such as a bundle of the employees' skills, system integration, or specific production technologies that contribute to the competitive performance of an organization (Hallgren et al. 2011). The differentiating competitive performance dimensions are the ability to compete on the particular performance dimensions relative to the primary competitors in the target markets (Schroeder et al. 2011). The adherence

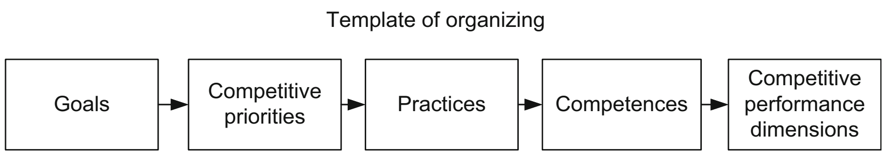

Fig. 1.1 The theoretical framework of templates of organizing

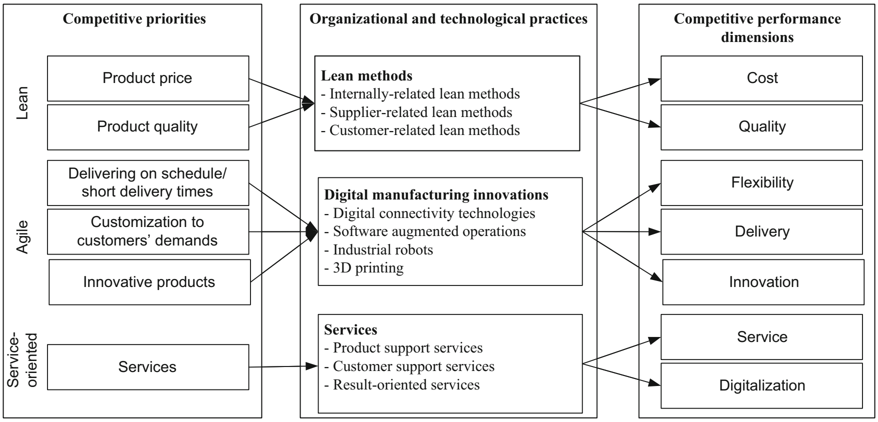

Fig. 1.2 Empirical characterization of lean, agile, and service-oriented templates

to templates of organizing is beneficial. Further, adherence to institutionally relevant templates results in increased organizations' legitimacy in the eyes of stakeholders. Legitimacy leads to increased symbolic performance, which is followed by various resources such as venture capital, more talented employees, or additional orders. Further, the company's operational performance increases if template-related goals and practices fit an organization's technical core. In summary, adherence to templates of organizing increases the possibility of survival.

Drawing on the theoretical framework of templates of organizing, we characterize lean, agile, and service-oriented templates in terms of goals, competitive priorities, practices, competencies, and performance dimensions. We concentrate on the template-related competitive priorities, organizational and technological practices, and performance dimensions (Fig. 1.2).

Following the neo-institutional framework, we empirically reveal the diffusion of lean, agile, and service-oriented template-related competitive priorities, organizational and technological practices, and performance dimensions. We also empirically assess the impact of technological and organizational practices on template-related performance dimensions. Finally, we reveal whether template-related performance dimensions are associated with superior financial performance. The unique empirical dataset of 500 manufacturing companies facilitates the empirical tests.

1.3 Empirical Data and Methods

The data for this study was collected as part of the *2018–2019 European Manufacturing Survey* (EMS 2022). EMS is an international network of research institutions collecting data in their respective countries. A standardized questionnaire is used for data collection. The questionnaire was prepared in English and later translated into the respective languages of each country. Each participating country conducted pretests of the questionnaire.

The data was collected on individual manufacturing sites because each manufacturing site in a business unit may exhibit unique competitive performance (Boyer and Lewis 2002; Schroeder et al. 2011). The data from Lithuania was used for this research in order to minimize the effects of country differences. The importance of the manufacturing sector (NACE sector C) is relatively robust in Lithuania, constituting 18.4% of added value (Eurostat 2020). The manufacturing sector is thoroughly integrated with the international economy as 65% of all the manufacturing output is exported (Eurostat 2020).

The sampling frame consisted of 6122 manufacturing sites covering all the manufacturing sub-sectors and represents the total population of manufacturing sites in the country. The questionnaire respondents were technical managers or production managers in manufacturing sites with more than 200 employees, as well as general managers, technical managers, and production managers in manufacturing sites with fewer than 200 employees. A telephone survey was used to collect the data. The stratified random sampling procedure was employed. Strata were defined in terms of four country regions and five size-based classes of organizations (2–19, 20–49, 50–99, 100–249, more than 250 employees). A total of 2330 manufacturing sites were contacted. The effective sample is 500 manufacturing sites, which constitutes a 21.5% response rate. The effective sample adequately represents the five size classes, the regions of the country, and the manufacturing sub-sectors (Table 1.1).

In the next paragraph, we discuss the methods used to identify lean, agile empirically, and service-oriented templates of organizing, profile each template, and evaluate the compatibility of the templates.

The book is based on multiple methods employed to achieve the objectives of each chapter. The following methods were used:

– In the second chapter, CFA, gap statistics, and k-means clustering are employed to determine the prevalence of the organizations adhering to lean, agile, and service-oriented templates in relation to each other.
– In the third chapter, CFA and partial least squares-based structural equation modeling are used to determine which lean practices, digital manufacturing innovations, and services contribute to the leanness-related quality and cost-effectiveness performance dimensions.
– In the fourth chapter, CFA and partial least squares-based structural equation modeling are selected to determine which digital manufacturing innovations, lean practices, and services contribute to agility-related flexibility, fast delivery, and innovation performance dimensions.
– In the fifth chapter, the research is based on CFA and partial least squares-based structural equation modeling to determine which product support, customer support, result-oriented services, digital manufacturing innovations, and lean practices contribute to the service-related competitive performance of services and digitalization.

Table 1.1 Sample characteristics

Sector:	$N = 500$	%
Engineering	125	25.0
Food	64	12.8
Textile	70	14.0
Wood and paper	156	31.2
Chemicals and chemistry	11	2.2
Other	74	14.8
Employees:	$N = 500$	%
Up to 19	300	60.0
20–49	108	21.6
50–99	44	8.8
100–249	34	6.8
250+	14	2.8
Product development:	$N = 487$	%
According to the customers' specification	242	48.4
As a standardized basic program incorporating customer-specific options	88	17.6
For a standard program, from which the customer can choose options	142	28.4
Does not exist in this factory	15	3.0
Manufacturing:	$N = 496$	%
Upon receipt of a customer's order, i.e., made-to-order	389	77.8
Final assembly of the product is carried out upon receipt of a customer's order, i.e., assemble-to-order [based on stock-orientated prefabrication]	19	3.8
To stock (before a customer's order)	85	17.0
Does not exist in this factory	3	0.6
Product complexity:	$N = 485$	%
Simple products	83	16.6
Products of medium complexity	288	57.6
Complex products	114	22.8
Batch or lot size:	$N = 494$	%
Single unit production	119	23.8
Small or medium batch/lot	299	59.8
Large batch/lot	76	15.2
Age of organization, years:	$N = 473$	%
1–5	77	16.3
6–10	82	17.3
11–20	130	27.5
21–30	180	38.1
More than 30	4	0.8
Respondent occupation at the branch:	$N = 500$	%
Head/director	334	66.8
Technical manager, technical director, head of the production	162	32.4
Head of a branch	4	0.8

– In the sixth chapter, our investigation is grounded on CFA and multiple other methods to reveal if the balancing of leanness and agility performance dimensions contributes to fit and increases the financial performance of organizations. Following Venkatraman (1989), the performance-enhancing fit was tested while using the *Fit as matching* and *Fit as profile deviation* approaches.
– In the seventh chapter, the research employs CFA and binary logistic regression to determine which organizational variables are predictive if an organization is denoted by one competitive performance dimension or several performance dimensions.
– Finally, in summary, we provide the results of multivariate linear regression revealing if the performance dimensions associated with lean, agile, and service-oriented templates are associated with the companies' financial performance measures.

1.4 The Structure of the Book

Each chapter contributes to a more profound investigation of new forms of organizing based on services and the effects of innovative manufacturing technologies and services on competitive performance.

In the second chapter, we concentrate on the three ideal types of manufacturing templates of organizing: lean, agile, and service-oriented templates. We seek to characterize lean, agile, and service-oriented organizing templates and determine their compatibility. After characterizing the templates, we seek to empirically identify organizations adhering to lean, agile and service-oriented templates in relation to each other.

In the third chapter, we aim to elaborate the lean template by determining empirically:

– The extent of companies that compete on product price and product quality competitive priorities.
– The diffusion of lean methods, leanness-related costs, and quality performance dimensions.
– Whether the lean methods are contingent on the size, industry, product complexity, lot size, the type of the design process, and the type of the manufacturing process of organizations.
– Which lean practices, digital manufacturing innovations, and services contribute to the leanness-related quality and cost performance dimensions.

In the fourth chapter, we seek to contribute to the enhancement of knowledge on the agile template by determining:

– The extent of companies that compete on innovative products, customization to customers' demands, and delivering on schedule/short delivery times competitive priorities.

– The diffusion of digital manufacturing innovations and agility-related flexibility, fast delivery, and innovation performance dimensions.
– Whether digital manufacturing innovations are contingent on the size, industry, product complexity, lot size, the type of the design process, and the type of the manufacturing process of organizations.
– Which digital manufacturing innovations, lean methods, and services contribute to agility-related flexibility, fast delivery, and innovation performance dimensions.

In the fifth chapter, we intend to provide empirical evidence on the emerging Service-oriented template by determining:

– The extent of companies that compete on service competitive priority.
– The diffusion of product support, customer support, and result-oriented services, servitization-related performance dimensions of services and digitalization.
– Whether product support, customer support, result-oriented services, and servitization-related performance dimensions are contingent on the size, industry, product complexity, lot size, the type of the design process, and the type of the manufacturing process of organizations.
– Which services, digital manufacturing innovations, and lean methods contribute to servitization-related performance dimensions of services and digitalization.

In the sixth chapter, we aim to resolve the contradiction inherent in pursuing leanness or agility. From the perspective of the neo-institutional theory, leanness and agility are incompatible. From the perspective of ambidexterity, leanness and agility are necessarily required for a business to prosper. Given this contradiction, we aim to reveal if balancing leanness and agility-related performance dimensions contribute to the performance-enhancing fit and increase the financial performance of organizations.

In the seventh chapter, we delve further into the contradictions of the development of performance dimensions, such as quality, cost, delivery, flexibility, and innovation. We wonder whether organizations are capable of developing more than one competitive performance dimension and, if so, how many of them. In this chapter, we seek to reveal whichever organizational and technological innovations contribute to increasing the number of competitive performance dimensions.

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Chapter 2
Lean, Agile, and Service-Oriented Performers: The Characteristics and Compatibility of Templates of Organizing

Abstract Lean, agile, and service-oriented templates of organizing constitute manufacturing companies' most popular organizational forms. Despite their prevalence, these organizational forms are rarely analyzed in relation to each other. Even more, few have aimed to determine whether organizations adhering to these templates occur with any degree of regularity among the manufacturing firms. In this chapter, we conceptually compare lean, agile, and service-oriented templates to assess their compatibility. Further, we use a representative sample of 500 manufacturing companies to empirically identify companies adhering to the templates in relation to each other. The systematic review reveals the low compatibility of templates. Despite some overlap among practices, the templates are characterized by unique goals, the rationale of capturing the value, and resulting performance capabilities. The cluster analysis allows for identifying lean, agile, and service-oriented performers in relation to each other according to their performance dimensions. The results imply that it is easier to switch from the lean to the agile template and from the agile to the service-oriented template than from the lean to the service-oriented template. However, the study discourages the sequential approach toward the lean, agile, and service-oriented templates and treats these organizational forms as paradigmatically different.

2.1 Introduction

The global manufacturing field is abundant with templates of organizing. The most common templates of the organizing or manufacturing paradigms (Narasimhan et al. 2006) of manufacturing organizations are lean (Womack et al. 1990; Shah and Ward 2007) and agile (Gunasekaran 1999; Yusuf and Aspinwall 1999) templates. These templates constitute consistent prescriptions in terms of goals, supporting practices, and outcomes. The existence of templates has been supported by empirical research (Narasimhan et al. 2006; Hallgren and Olhager 2009; Qamar and Hall 2018).

The recent advances in digital technologies have shuffled the global field of production (Brynjolfsson and McAfee 2014; Ford 2015). The trends provide fertile grounds for the emergence of new templates of organizing. There is broad agreement

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that digital technologies facilitate the service innovation of manufacturing organizations (Baines and Lightfoot 2013; Iansiti and Lakhani 2014, Lightfoot et al. 2013). The research on servitization, i.e., combining products and services, has recently been increasing (Baines and Lightfoot 2013; Lightfoot et al. 2013). Practice-oriented literature reports the emergence of business models based on data collected from products (Allmendinger and Lombreglia 2005; Iansiti and Lakhani 2014; Porter and Heppelmann 2014). The business press focuses on such companies as Rolls-Royce and General Electric (e.g., Biba 2017), which increase their share of the revenue from services, thus making these companies new role models of manufacturing. Such a trend allows hypothesizing that a new template of service-oriented manufacturing organizations emerges. The drivers, contexts, and outcomes of such organizational forms have already been well researched (e.g., Baines and Lightfoot 2013; Lightfoot et al. 2013). However, the evaluation of the extent of the compatibility between the emerging template of service-oriented firms and the prevalent templates of lean and agile production is still under-researched. However, such a comparison is essential. It would allow deducing the extent of the overlap among the goals, the means, and the resulting capabilities of the templates. It would also suggest if the lean template is a precursor to the agile template and whether the agile template is a precursor of the service-oriented template. In this chapter, we aim to achieve several objectives. We seek to characterize the lean, agile, and service-oriented templates of organizing and to determine their compatibility. After characterizing the templates, we seek to empirically identify the prevalence of organizations adhering to the lean, agile, and service-oriented templates in relation to each other.

The literature review and cluster analysis constitute the main methods of the study. A literature review of the existing theory and research is conducted (LePine and King 2010). The recent advances and ideas on the lean, agile, and service-oriented organizational forms are reviewed and extended. The *neo-institutional* theory is used to evaluate the compatibility of the lean, agile, and service-oriented templates of organizing. The neo-institutional theory drew our attention due to explaining how organizations cope with sociocultural expectations (Meyer and Rowan 1977; DiMaggio and Powell 1983). Later research showed that the fields, which resemble the operating environment of organizations, are characterized by multiple and often conflicting prescriptions that have to be comprehended and responded to maximize the possibility of survival (Friedland and Alford 1991; Greenwood et al. 2011). Theoretical tools have been developed to understand the compatibility of institutional prescriptions (Goodrick and Salancik 1996; Pache and Santos 2010; Greenwood et al. 2011). This approach is used to comprehend the level of compatibility of the lean, agile, and service-oriented templates, which constitute the most prevalent templates of organizing in the global manufacturing field.

The chapter is organized as follows. First, the concept of a *template of organizing* is defined. Later on, the lean, agile, and service-oriented templates of organizing are defined in relation to each other. Then, the level of compatibility of the lean, agile, and service-oriented organizing templates are grounded by using the *neo-institutional* perspective. Further, the empirical results of the research on whether organizations adhering to the strategies of lean, agile, and service-oriented templates occur with any degree of regularity among manufacturing firms are provided. Finally, the implications of the study are discussed.

2.2 Neo-Institutional Theory and Templates of Organizing

Early institutional theorists (Meyer and Rowan 1977) suggested that the survival of organizations depends not only on organizational efficiency, as it had been universally acknowledged previously. According to scholars, survival also depends on organizational conformity to societal expectations, such as rationalized myths (Meyer and Rowan 1977), logics (Thornton et al. 2012), and "templates of organizing" (DiMaggio and Powell 1991, p. 27). The conformity to externally derived templates of organizing provides legitimacy for organizations. The legitimacy of an organization contributes to its symbolic performance, i.e., to the extent to which organizations generate positive social evaluations (Deephouse and Suchman 2008). The positive social evaluations are followed by resources that increase the probability of the survival of the organizations.

Mayer and Rowan were the first to use the concept of *template of organizing* (Dimaggio and Powell 1991, p. 27) in their article. Greenwood and Hinings (1993) used the concepts of archetypes and templates interchangeably and argued that they are "ideal types that organizations might adhere to more or less; they denote a set of systems and structures that reflect underlying beliefs and values" (1993, p. 1025). The templates of organizing are constituted of symbolic, material elements, and resulting competitive performance dimensions. The symbolic, ideational dimension is constituted of goals and values that are pursued by organizations adopting the template. The material dimension denotes the structures and practices that support goals and values. Finally, competitive performance dimensions are organizational abilities to achieve and sustain high levels of performance relative to competitors as the result of adopting the goals and values and implementing the supporting practices. The elements of the template are inescapably intertwined and constitute each other. *We propose that a template of organizing is an institutionally relevant arrangement of goals and practices resulting in organizational competencies and differentiating competitive performance dimensions constituting the core of an organization* (Fig. 2.1).

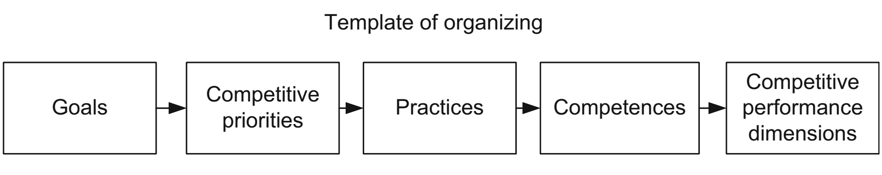

Fig. 2.1 Elements of template of organizing

The goals form an ideational dimension of a template constituted of values and belief systems that direct attention to the particular mode of capturing the value and discriminate whatever action is appropriate. The strategic priorities represent the intentions whose performance dimension or pattern of dimensions are essential and will be developed in the future (Boyer and Lewis 2002). Meanwhile, practices are repetitive, recognizable patterns of action that are performed by a group of people (Feldman and Pentland 2003). The competencies refer to the organizational expertise, such as a bundle of the employees' skills, system integration, or specific production technologies that create competitive capabilities (Hallgren et al. 2011). The differentiating competitive performance dimensions are the ability to compete on the particular performance dimensions relative to the primary competitors in the target markets (Schroeder et al. 2011; Vilkas et al. 2021).

Adherence to the prevalent organizing templates provides legitimacy for the organization's actions. Legitimacy is "a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions" (Suchman 1995, p. 574). The legitimacy of organizations contributes to their symbolic performance, which is contrasted with the substantive operational performance. Symbolic performance is the extent to which organizations generate positive social evaluations (Deephouse and Suchman 2008). Operational performance is based on technical and organizational proficiency. For example, operational performance may be treated as the extent of the manufacturing competencies, such as quality, cost-effectiveness, flexibility, and cost. Finally, substantive performance is the extent to which organizations generate accounting-based profits or increase their overall market value (Meyer and Rowan 1977). Adherence to templates of organizing increases the symbolic performance. The positive social evaluations are followed by resources that increase the substantive performance and the probability of survival of the organizations.

Adherence to the templates considered rational by state agencies, investors, and clients may still decrease the technical efficiency. Let us consider a successful organization that adheres to a template seeking to increase its symbolic performance. The goals, prescribed practices, and the resulting competitive capabilities may be at odds with the realized operations strategy pursued by the company. In this case, the operational performance may suffer because of the increased complexity and conflicting prescriptions. Organizations tend to decouple their technical core from the prescriptions of the template in such situations. For example, research shows that the decision to adopt the *ISO 9000* series standards is driven by efforts to satisfy the state's expectations and clients possessing high bargaining power (Guler et al. 2002; Vilkas and Vaitkevicius 2013). This leads to the buffering of activities from the prescriptions of the requirements of the standards. Organizations create such structures as formal manuals, procedures, and artificial records that employees do not use. These formal structures are continuously maintained for the purposes of certification rituals. The process of certification is compared to a process of acquiring the "organizational degree," including such activities as "role preparation, procrastination, short-term focus and cheating" (Boiral 2012, p. 633).

The diffusion and distribution of institutionally derived templates of organizing occur through normative, coercive, and mimetic pressures on an organization. Coercive pressures are the conformist pressures on a focal organization emanating from other organizations upon which it depends for critical resources or from institutions upholding the cultural expectations of the society in which it functions (DiMaggio and Powell 1983). Mimetic pressures urge the focal organization to model itself after other organizations in its organizational field when faced with uncertainty over goals, technologies, and means-ends relationships. (DiMaggio and Powell 1983). Finally, normative pressures on the focal organization are the pressures to comply with the norms collectively issued by the other occupants of its organizational field in their struggle to define the conditions and methods of their work (DiMaggio and Powell 1983). These pressures result in convergence on the appropriate templates of organizing, resulting in assimilation or isomorphism of organizations.

The neo-institutional theory provides a helpful lens to analyze the institutional complexity of fields and organizational responses to the tensions that institutional plurality creates. In the next section, the most common templates of the global manufacturing field are characterized.

2.3 Templates of Organizing in the Manufacturing Field

Manufacturing organizations participate in their respective organizational fields. The organizational field is defined as "key suppliers, resource and product consumers, regulatory agencies and other organizations that produce similar products and services" (DiMaggio and Powell 1983, p. 148). The automotive field consists of manufacturing organizations, suppliers, consumers, regulatory agencies, consulting organizations, and other interested parties that somehow contribute to these organizations. Fields may be characterized by different levels of maturity and institutional pluralism (Greenwood et al. 2011). High institutional pluralism is characterized by an abundance of templates of organizing, possibly prescribing conflicting goals and practices. Manufacturing is a diverse field of activities. The global production field is constituted of local and global fields based on the type of production. There are global fields of consumer equipment, such as motor vehicles or computers, and local fields of food products.

The most common template of the twentieth century was the *Mass production template*. The Mass production template was based on the works of Frederick Taylor. The template's final characteristics emerged after the scientific management principles were elaborated by industrialists such as Andrew Carnegie, Henry Ford, and Isaac Singer (Hayes et al. 2004). The Mass production template is based on the goal to provide goods and services at prices low enough so that nearly everyone can afford them (Pine 1993). The template was constituted of a coherent set of practices allowing organizations to achieve low costs of production and offer products at low prices to the customer. The core practices prescribed the manufacturing of standardized products constituted of interchangeable parts of products, the usage of specialized production machines, the functional division of the production process, and machine-paced assembly processes (Pine 1993). These practices were complemented with a division of labor and specialization principles, hierarchical organization with professional managers, and vertical integration (Pine 1993). The concept of economies of scale served as an explanatory mechanism explaining how low costs leading to low prices may be achieved. The key features of the template were low-cost, consistent quality, standardized goods, and services with long lifecycles matched with stable demand in large homogeneous markets (Pine 1993). The goal and practices of the Mass production template diverged heavily from the practices of the then-popular template of *Craft production.*

In this research, we concentrate on the agile, lean, and service-oriented templates of manufacturing organizations. These templates do not constitute the exhaustive list of templates available for organizations in their fields. Other templates may constitute *TQM,* the *Learning Organization,* the *High-performance organization,* etc. The agile, lean, and emerging service-oriented templates are universal and available in many manufacturing fields. These templates have recently been treated as desirable ones by stakeholders of manufacturing companies. In the next section, the templates are characterized by the prescribed goals and practices and resulting competitive capabilities.

2.3.1 Lean Template of Organizing

The predecessor of the contemporary lean template is Just-in-time or the Toyota production system, which was designed in the 1980s by Toyota (Schonberger 2007). The Toyota production system results from the experiments with the production practices led by Taichi Ohno (Shah and Ward 2007). The worldwide diffusion of the lean template began in the 1990s when seminal books by Monden (1983). Ohno and Bodek (1988) and Womack et al. (1990) published on the Toyota production system. The books provided a compelling explanation of the template's elements and suggested using *lean* as a synonym for a coherent set of values and practices pioneered by Toyota (Hallgren and Olhager 2009).

The Role Model of the Lean Template There is no better example of *lean* than Toyota. Toyota is still a role model for companies adhering to the lean template. Knowledge-intensive organizations (Staats et al. 2011), hospitals (Bohmer 2010), and public management institutions (Radnor and Walley 2008) tend to model themselves on Toyota. The company still attracts the interest of scholars studying how efficiency and flexibility are achieved simultaneously (e.g., Adler et al. 2009).

Womack et al. (1990) provide a detailed description of Toyota's practices contrasting them with the practices of the Mass production template. The design of the Toyota production system reflected the context of the Japanese car market in the 1950s, which demanded a wide range of cars. The market was characterized by the limited availability of capital and workforce. Toyota's production system was characterized by reliability, speed, and flexibility, while the car producers adhering to the mass production template emphasized volume and cost (Hayes et al. 2004). Mass production-oriented producers achieved low costs through economies of scale. Toyota practiced careful analysis of the value stream and removal of non-value adding activities and other types of waste, such as unnecessary transportation, excess inventory, unnecessary motion, waiting times, overproduction, overprocessing, and defects to lower costs. Toyota's employees were broadly trained. The equipment was multipurpose instead of high specialization and extensive usage of specialized machines promoted by the Mass production template. The production in small batches, ideally in batches of one, was practiced. The production processes were tightly integrated; hence the production was pulled by the downstream workstations. Inventory and overproduction were treated as waste. The costly stops of assembly lines were practiced in the case of even minor problems. Even the split of production batches reflecting the mix of car dealers' sales (i.e., heijunka) was practiced. Finally, long-term relationships with suppliers instead of vertical integration were practiced. Such practices contrasted heavily with the typical car production company adhering to the Mass production template. Toyota achieved higher conformance quality, reliability, and a variety of cars at a lower cost level (Womack et al. 1990). The effects implied that a viable alternative for the Mass production template emerged.

The Goal of the Lean Template The lean template "provides a way to do more and more with less and less—less human effort, less equipment, less time, and less space—while coming closer and closer to providing customers with exactly what they want" (Womack and Jones 2003, p. 15). The lean template directs attention to defining the value from the perspective of the ultimate customer. It is discouraged to take the engineering view toward the definition of value (Womack and Jones 1996). From this perspective, there is the "maximum value" proposition for a set of customers, and an organization has to discover it. Womack and Jones argue that "lean thinking must start with a conscious attempt to precisely define value in terms of specific products with specific capabilities offered at specific prices through dialogue with customers" (2003, p. 15).

On the other hand, the producer creates value. Value has to be provided while using as few resources as possible by eliminating various types of waste, such as transportation, inventory, motion, waiting, overprocessing, overproduction, and defects (Womack and Jones 1996; Shah and Ward 2007). The elimination of waste results in increases in productivity of production, contributing to the low cost of production (Schmenner and Swink 1998). In summary, the goal of the lean template is to provide customers with goods and services that satisfy customer requirements in a low-cost manner by eliminating waste.

Proposition 1.1 *Organizations that adhere to lean template differentiate on the product quality and low product price competitive priority; they attribute primary importance to the fast/on-schedule delivery competitive priority and assign secondary importance to innovative products, product customization, and service competitive priorities.*

Table 2.1 Practices constituting the lean template

Practice	Description
Customer involvement	Extensive focus on a firm's customers and their needs through the understanding of the lifecycle of products and services from the perspective of customers (Shah and Ward 2007)
Continuous flow	Mechanisms that enable and ease the continuous flow of products through the application of value stream mapping, changed spatial arrangements of production steps, customer or product-oriented lines/cells in the factory, 5S, visual management, practices of standard work
Pull (also a part of the agile template)	Methods that facilitate just-in-time production include Kanban cards which serve as a signal to start or stop production (Shah and Ward 2007)
Setup time reduction (also a part of the agile template)	Means to process downtime between product changeovers (Shah and Ward 2007)
Statistical process control	Ensuring that each process shall supply defect-free units to the subsequent processes (Shah and Ward 2007)
Employee involvement/multifunctional employees (also a part of the agile template)	Ensuring the employees' role in problem solving, and their cross-functional character (Shah and Ward 2007)
Total preventive maintenance	Methods to address equipment downtime through total productive maintenance and thus achieve a high level of equipment availability (Shah and Ward 2007)
Supplier feedback	Provision of regular feedback to the suppliers about their performance (Shah and Ward 2007)
JIT delivery by suppliers	Ensuring that suppliers deliver the correct quantity at the right time in the right place (Shah and Ward 2007)
Supplier development	Development of the suppliers so they can be more involved in the production process of the focal firm (Shah and Ward 2007)

The Practices Constituting the Lean Template Organizations implement customer-related, internally related, and supplier-related practices to provide goods that satisfy customers at a low cost (Shah and Ward 2007) (Table 2.1). Customers' requirements along the product lifecycle are monitored, translated into product characteristics, and customer feedback is collected.

Organizations adopt internally related practices facilitating continuous flow, pull of production, setup time reduction, statistical process control, total preventive maintenance, and employee involvement (Shah and Ward 2007). The speed of the flow of materials through the organization is an essential characteristic of the lean template and is achieved through creating customer or product-oriented lines or cells in the factory instead of task-structured shop floors, standardization of routine tasks, and visual redesign of facilities and workplaces. Products are grouped into product families with similar processing requirements. The layout and equipment are restructured into easily replicable lines or cells responsible for the production of product families in order to eliminate physical obstacles to the flow of materials and to increase volume flexibility (Wemmerlöv and Hyer 1989). The routine activities are analyzed and standardized, contributing to the development of mechanical skills and savings of cognitive resources (Staats et al. 2011; Cohen and Bacdayan 1994). The production facilities and workplaces are visually and ergonomically redesigned. The redesigned facilities and workplaces contain environmental cues that increase the flow of materials, easy access to the necessary information, and indicate emerging problems (Parry and Turner 2006; Bilalis et al. 2002). Preventive maintenance of equipment and efforts to decrease setup and changeover times ensure the high availability of production equipment (Shah and Ward 2007). Statistical process control techniques allow for estimating the performance characteristics of the production processes and their drivers.

Furthermore, companies adopting lean templates execute production in small batches or even batches equal to one item while trying to reflect the demand pattern for products. Production is pulled by the downstream workstations, decreasing the work-in-process inventory. Integrating processes with supplies constitutes an important template practice (Shah and Ward 2007). The long-term relationships with suppliers, exchange of information on quality and delivery performance, suppliers-managed inventory, and delivery of materials directly to manufacturing helps to achieve the flow of materials and information and decrease the inventory size.

Finally, the template advocates the extensive involvement of employees in the continuous improvement of processes. The expertise of different organizational roles is exploited during group problem solving—sessions of value stream mapping and Kaizen (Womack and Jones 1996). These sessions are intended to identify various types of waste. Hypothesis-driven problem solving is promoted to eliminate waste and other identified problems (Staats et al. 2011).

Proposition 1.2 *Organizations that adhere to the lean template are characterized by extensive use of practices of customer involvement, continuous flow, pull, setup time reduction, statistical process control, employee involvement, multifunctional teams/machines, total productive/preventive maintenance, supplier feedback, JIT delivery by suppliers, and supplier development.*

The Competencies Associated with the Lean Template An organization that adheres to the lean template "utilizes less in terms of all inputs to create the same outputs like those created by traditional mass production system while contributing increased varieties for the end customer" (Womack and Jones 1996). Narasimhan et al. (2006) suggest that "production is lean if it is accomplished with minimal waste due to unneeded operations, inefficient operations, or excessive buffering in operations" (2006, p. 443).

By combining the insights of Naylor et al. (1999) and Shah and Ward (2007), we submit a proposal that the adoption of the lean template allows the development of these competencies: customer-defined value, elimination of waste, low variability of demand, processing time and supply, integrated supply chain, and lead time compression. The customer-defined value competence is the ability to prioritize customers' needs during the new product development process. Eliminating waste is the ability to continuously use everyone's knowledge and insights to eliminate value non-adding activities and other types of waste through the entire supply chain. Low variability of demand, processing time, and supply is the ability to stabilize the variability of demand, processing time, and supply at low levels. The integrated supply chain's capability is mobilizing all the members of the supply chain to ease the flow of information, resources, and goods (Naylor et al. 1999). Lead time compression is the ability to respond quickly to a customer's order (Naylor et al. 1999). The analysis of the lean template allows for raising the following propositions:

Proposition 1.3 *Organizations that adhere to the lean template excel at customer-defined value, elimination of waste, low variability of demand, processing time and supply, integrated supply chain, and lead time compression competencies.*

Differentiating Competitive Performance of the Lean Template Multiple benefits of the adoption of the template exist. Naylor et al. (1999) propose that cost performance differentiates the lean template adopting companies from the adopters of other approaches. Narasimhan et al. (2006) empirically identified the lean template adopting companies in relation to the agile template adopted companies and found that the lean organizations exhibit higher cost-effectiveness compared to the agile organizations. The theory of swift and even flow (Schmenner and Swink 1998) explains how the lean template adopters achieve superiority in cost performance. The theory proposes that the productivity of any process increases with the speed by which materials flow through the system, and it falls with increases in variability associated with the flow, whether it may be variability of supply, demand, or processing time (Schmenner and Swink 1998, p. 102). Most of the lean practices are deliberately oriented to increase the flow of materials through the production system via the reorganized layout, standardization of routine tasks, visual transparency of facilities and workplaces, and continuous elimination of waste. Furthermore, customer-related practices reduce demand variability caused by inaccurate information and product quality problems. Supplier-related practices decrease the supply variability caused by delayed, defected deliveries and inadequate information flows. Internally related practices directly contest the variability of the processing time, such as the production time spent in various process steps and the defectiveness of parts. As productivity increases, the cost of production decreases. In line with this reasoning, we propose cost performance as the differentiating performance capability of the lean template adopters.

Proposition 1.4 *Organizations that adhere to the lean template are superior in cost performance compared to those that adhere to agile and service-oriented templates.*

2.3.2 Agile Template of Organizing

Agile manufacturing was proposed in 1991 as a way of competition in the face of fragmentation of consumers' preferences and the increasing speed of changing these preferences (Yusuf and Aspinwall 1999). In such a context, the ability to follow the ever-changing preferences was identified as a way to dominate the emerging world order. Gunasekaran (1998, p. 1223) proposes that agility is "the capability to survive and prosper in a competitive environment of continuous and unpredictable change by reacting quickly and effectively to the changing markets while being driven by customer-designed products and services."

The Role Model of the Agile Template Let us consider Dell, a company that was the agile template's role model for a long time. The company started its operations in 1984. It was ranked among the world's five largest computer companies, and by 1995, Dell's value proposition was based on customizable PCs. Dell allowed its customers to assemble their computer system while adjusting its specifications, for instance, to monitor the memory size, hard disk size, processor speed, and other peripherals. The primary benefit of such an approach was that customers could maximize the preferred components and minimize the components that were non-essential for them. When an order was placed, Dell processed the order through financial and configuration evaluations of the ordered system. Configurational evaluation checked the technical feasibility of the ordered computer system. In most cases, Dell could produce the custom system and deliver it to the customer within 3–5 days (Fugate and Mentzer 2004). Even more, Dell achieved 9.9% lower production costs compared to Compaq and 27% lower costs compared to Gateway, which was one of the top producers of PCs in 1990 (Dignan 2002). Dell was an example of a manufacturer that could customize its products on a mass scale while simultaneously achieving low production costs.

The Goal of the Agile Template The agile template emphasizes "the successful exploration of competitive bases (speed, flexibility, innovation proactivity, quality, and profitability) through the integration of reconfigurable resources and best practices in a knowledge-rich environment to provide customer-driven products and services in a fast-changing market environment" (Yusuf and Aspinwall 1999, p. 37). The agile template draws attention to continued adherence to the ever-changing preferences of customers. It also directs attention to the possibility of satisfying the preferences of each customer regarding the product. In summary, *the goal of the agile template is to provide customers with goods with enough variety and customization that nearly everyone finds exactly what they want (*Pine 1993*).* Following the rationale of the template, the companies that adhere to the agile template choose flexibility and innovation as differentiating competitive priorities. The quality, delivery, services, and cost are primary priorities for the adopters of the template.

Proposition 2.1 *Organizations that adhere to the agile template differentiate on product customization, innovative products, and/or on schedule/ fast delivery* *competitive priorities; they attribute primary importance to product quality, services, and product price competitive priorities.*

The Practices Constituting the Agile Template The practices constituting the agile template are directed to enabling organizations to provide customers with goods featuring enough variety and customization so that nearly everyone finds exactly what they want. Scholars propose differentiating between external and internal agility (Da Silveira et al. 2001). Internal agility is the ability to respond quickly to the market, customer demands for new products and product features. External agility is a broader concept related to how proactivity with regard to market trends is achieved.

The practices of mass customization depend on the level of customization of the products pursued by the company. There are at least six levels of customization named after the stage where customization is performed: design customization, fabrication customization, assembly customization, sale customization, packaging and distribution customization, and usage customization (Da Silveira et al. 2001). Design level customization is the most sophisticated version of customization involving customized design and manufacturing of the products. It is proposed that advanced manufacturing technologies, design-product platforms, supply chain coordination, design for manufacturing, modular product design, concurrent engineering, rapid prototyping, pull of production, employee involvement/multifunctional employees, and setup time reduction are associated with the agile template and help to achieve design level customization (see Table 2.2).

Design level customization requires effective capture of customer preferences and internal and external organizational practices enabling fast design and manufacturing. Mass customization is a challenge for organizations but may also pose a challenge for the customers. An opportunity to customize the product may become a burden if it is not managed effectively. Customers tend to experience the "paradox of choice": too many choices reduce customer value instead of increasing it (Desmeules 2002). Organizations develop IT-enabled spaces for choice navigation and solution development to decrease customer choice burden (Salvador et al. 2009). Various techniques, such as customer intelligence, assortment matching, fast trial-and-error learning, innovation toolkits, and virtual concept testing are employed to translate customer preferences into custom product design (Salvador et al. 2009).

Furthermore, customized orders should be designed and manufactured in fast fashion at acceptable costs. Organizations employ various design techniques to make design processes faster and more cost-effective. These techniques include computer-aided design, rapid prototyping, concurrent engineering, design for manufacturing, and modular product design. Advanced manufacturing technology, such as enterprise resource planning systems (ERP), flexible automation, and connected equipment, is essential to manage customization on a mass scale at relatively low costs. As production processes change, companies use multifunctional employees and equipment. On top of that, companies have to be able to produce in small batches or batches equal to one. Methods of the pull of production and setup time reduction are relevant to agility-seeking companies and those that use the lean template.

Table 2.2 Practices constituting the agile template

Material practices	
Advanced manufacturing technologies (also a part of the service-oriented template)	Forefront production techniques, such as enterprise resource planning systems (ERP), flexible automation, connected equipment, and barcodes or RFID marked materials
Design-product platforms	The hardware and software infrastructure which enables customers to design their products
Supply chain coordination	The integration of members of the supply chain coordinates the flow of information and the selection of the decoupling point (Naylor et al. 1999)
Rapid prototyping	Embraces arrangement of technologies for the production of accurate models of products or their parts directly from CAD models in a fast manner with little need for human intervention (Pham and Gault 1998)
Concurrent engineering	The organization of the product development process from a sequential, 'over the wall' process to a concurrent process where marketing, product engineering, process engineering, manufacturing planning, and sourcing activities overlap (Koufteros et al. 2001)
Design for manufacturing	The application of the manufacturing technology at the early stage of design (Hallgren and Olhager 2009)
Modular product design	An approach to designing a variety of products while using the same modules of components called "platforms" (Jose and Tollenaere 2005)
Pull of production (also a part of the lean template)	Methods that facilitate just-in-time production, including Kanban cards, which serve as a signal to start or stop production (Shah and Ward 2007)
Employee involvement (also a part of the lean template)	Ensuring employees' role in problem solving, and their cross-functional character (Shah and Ward 2007)
Setup reduction (also a part of the lean template)	Means to process downtime between product changeovers (Shah and Ward 2007)

Continuous change dictates the necessity of employee involvement to capture the benefits of improvement.

The coordination of the supply chain constitutes the central practice of the agile template (Fugate and Mentzer 2004; Naylor et al. 1999; Fogliatto et al. 2012). Effective demand information management, internal collaboration of the supply chain participants, and the ability to leverage business partners are essential practices constituting the template (Fugate and Mentzer 2004). Demand information management constitutes activities that are intended to shape demand beneficially. For example, Dell used to adjust promotions to decrease the demand for products containing elements that were running low (Fugate and Mentzer 2004). The demand information tends to be passed as soon as possible to all the participants of the supply chain, thus allowing them to adjust their manufacturing schedules (Fugate and Mentzer 2004). The essential practices assuring coordination of the supply chain constitute sharing capacity, cost, and inventory level information among the supply chain members. The centrally managed inventory or centralized ordering decisions are also employed. Integrating processes with the business partners enables increased responsiveness and decreases the costs of the supply chain.

Proposition 2.2 *Organizations that adhere to the agile template could be differentiated by extensive use of practices of advanced manufacturing technologies, design-product platforms, supply chain coordination, rapid prototyping, concurrent engineering, design for manufacturing, and modular product design.*

The Competencies Associated with the Agile Template By combining the findings of Naylor et al. (1999) and Salvador et al. (2009), we could suggest that adherence to the agile template leads to the development of the solution space for choice navigation, integrated supply chain, lead time compression, rapid reconfiguration, and robust process design competencies. Solution space development for choice navigation, similar to Naylor et al. (1999) use of market knowledge capability, allows customers to identify their solutions while minimizing the complexity of choice (Salvador et al. 2009). The integrated supply chain capability is a mobilization of all the members of the supply chain in order to ease the flow of information, resources, and goods (Naylor et al. 1999). Lead time compression is the ability to respond quickly to a customer's order (Naylor et al. 1999). Rapid reconfiguration competence is the ability to introduce new products into the manufacturing and low changeover times among the product mix (Naylor et al. 1999). Finally, robust process design is the ability to reuse and recombine the existing organizational and supply chain resources to fulfill differentiated and ever-changing customer requirements (Naylor et al. 1999; Salvador et al. 2009).

Proposition 2.3 *Organizations that adhere to the agile template excel at solution space development for choice navigation, integrated supply chain, lead time compression, rapid reconfiguration, and robust process design competencies.*

Differentiating the Competitive Performance of the Agile Template Adopters The conceptual and empirical findings on competitive performance dimensions associated with the adoption of the agile template are mixed. Part of the overviewed scholars proposes that the agile template performers differentiate by flexibility performance (e.g., Naylor et al. 1999; Elkins et al. 2004; Hallgren and Olhager 2009). In contrast, other scholars report a broader range of differentiating performance dimensions (e.g., Sharifi and Zhang 2001; Brown and Bessant 2003; Narasimhan et al. 2006).

Naylor et al. (1999) argue that flexibility distinguishes between the adopters of the agile template versus those of the lean template. In this view, agility is the ability "to survive and prosper in a competitive environment of continuous and unpredictable change by reacting quickly and effectively to changing markets driven by customer-designed products and services" (Gunasekaran 1998, p. 1223).

Hallgren and Olhager (2009) empirically confirm that agile companies excel at high customization, efficient variety handling, and new product agility capabilities.

Brown and Bessant (2003) propose that an agile organization is expected to excel at proactive and reactive flexibility, delivery speed, design quality, and cost-efficiency. Sharifi and Zhang (2001) state that agile organizations exhibit high performance in terms of product introduction speed, stable unit cost, changeover flexibility, and delivery speed. Narasimhan et al. (2006) found that the companies that adhere to the agile template have superior flexibility, quality, and delivery performance compared to those that adhere to the lean template.

Zhang and Sharifi (2007) reconcile both views by proposing that different types of agile performers, such as responsive, quick, and proactive, seem to exist. Responsive performers excel at the new product development and customization of products. Quick performers are superior in terms of order delivery speed. Finally, proactive performers excel at new product development and fast order delivery performance. Taking into account that the flexibility performance dimension is attributed to organizations that adopt the agile template while in either camp, it is suggested that the flexibility performance differentiates among the agile template adopters.

Proposition 2.4 *Organizations that adhere to the agile template are superior in flexibility competitive performance if compared to organizations that adhere to the lean and service-oriented templates.*

2.3.3 Service-Oriented Template

The intertwining of trends of the increase of computational power, mobile Internet, sensor technology, and data science provide fertile grounds for the emergence of new templates in the global manufacturing field. In general, there is broad agreement that digital technologies facilitate the service innovation of manufacturing organizations (Ardolino et al. 2018).

The Role Model of the Service-Oriented Template Let us consider *Rolls-Royce* and *General Electric* (GE) *Aviation* which constitute the role models of service-oriented templates. The companies used to sell jet engines with major repair services for airline operators. One engine typically costs around $12–35 million. An engine is used for about 25 years. Approximately every 5 years, the engine needs major repairs, which could last about 50 days. Such a model resulted in high costs for airline operators. The investment in the engine constituted high fixed costs. The maintenance was technically challenging and could last long, as the engine consists of about 10,000 parts. The costs of maintenance activities began rising. The expensive maintenance functions still did not guarantee short repair times. The extended downtime of the engines was costly as planes would stand on the ground at the time. Roll-Royce and GE Aviation responded, proposing operators pay for the jet engines' performance and maintenance of the engines. Instead of purchasing the engines, the customers were offered to pay for the hours the aircraft spent in the air (Smith 2013). In addition, the company offered to conduct preventive maintenance activities, which were provided by the engineers based in the global network of maintenance centers.

The nature of the contracts directed the jet engine producers toward minimizing the risk that any unscheduled maintenance may be required (Girotra and Netessine 2011). They came up with a technology-enabled solution of a "digital twin" of the engine. The companies ran software models of each engine based on the specific characteristics of each engine, variables of the context in which it was used, and the relevant data was streamed in real-time by over 100 sensors placed in the engine (Biba 2017). The technology enabled the producers to provide additional services. The real-time monitoring of engine performance became beneficial in unexpected events occurring during flights, such as lightning strikes. Predictive maintenance allowed predicting unscheduled maintenance events. The companies also provided consultations on fuel-saving options for airline operators. Finally, this approach extended the engine's lifetime and provided valuable feedback for engine designers.

The Goal of the Service-Oriented Template Digital technologies enable the expansion of business models of manufacturing organizations from transactional (sell parts and repairs) to contractual (shared risk and reduction of the total cost of ownership) and expanded customer outcomes (use of data and analytics to provide decision support services (Iansiti and Lakhani 2014). The contractual relationships are also called "performance-based contracts" (Kim et al. 2007) or "outcome-based contracts" (Ng et al. 2009). Within this contract, the manufacturer "takes over the risks and responsibilities of performing activities previously handled in-house by their customer" (Davies 2004, p. 732). The expanded customer outcomes constitute new efficiencies, such as the ability to monitor the product status and condition, control and personalize product functioning, optimize and enhance the product/ process performance, and provide self-operating/autonomous products (Porter and Heppelmann 2014). In summary, *the goal of the service-oriented template is to provide a customer with value by delivering new efficiencies and other benefits through advanced analytics and algorithms based on the data generated by produced products* (Iansiti and Lakhani 2014). Following the goal of the template, the organizations that adopt the service-oriented template choose services as a differentiating competitive priority. Competitive priorities of quality, flexibility, and innovation are considered of primary importance. Finally, competitive priorities related to delivery and cost constitute priorities of secondary importance.

Proposition 3.1 *Organizations that adhere to the service-oriented template differentiate on the service competitive priority, attribute primary importance to product quality, innovative products, product customization competitive priorities, and give secondary importance to the product price and on schedule/fast delivery competitive priorities.*

The Practices Constituting the Service-Oriented Template The shift from the industrial producer to the integrated service provider requires substantial changes in the organizational strategy, integrated product-service design, and organizational transformation (Baines et al. 2009). Iansiti and Lakhani (2014) propose that adopting the service-oriented template of organizing requires the development of a service-oriented business model, building software, and outcomes-based sales competencies (Table 2.3).

The service-based models are an integrated set of decisions that allow capturing value from the services provided to customers (e.g., product support, customer support, pay-per-performance, and pay-per-use, renting products). Services supporting products are services that support the usage of the product (e.g., installation and start-up, maintenance, and repair). Services supporting customers are services that support the customer's activities (e.g., design, consulting, and remote monitoring of products' operating status). Result-oriented services are services used to take over a customer's activity completely (e.g., operation of products at the

Table 2.3 Practices constituting the service-oriented template

Description	
Product support services	The services that support the usage of the product (e.g., installation and start-up, maintenance and repair)
Customer support services	The services that support the activities of the customer (e.g., design, consulting, and remote monitoring of operating status)
Result-oriented services	The services that are used to take over activity of a customer completely (e.g., operation of products at customer site for the customer, taking over the management of maintenance activities)
Advanced manufacturing technologies (also a part of the agile template)	Forefront back-end production techniques include enterprise resource planning systems (ERP), flexible automation, connected equipment, barcodes or RFID marked materials, etc.
Digital technologies	Digital platforms—the infrastructure that acts as a hub for collecting and analyzing the data generated by connected products. Product platforms could be proprietary or function as cloud-based software-as-service
	Internet of Things—an inter-networking world in which various objects are embedded with electronic sensors, actuators, or other digital devices so that they can be networked and connected to collect and exchange data (Xia et al. 2012; Zhong et al. 2017)
	Cloud computing—is a general term that refers to delivering computational services through visualized and scalable resources over the Internet (Armbrust et al. 2010; Zhong et al. 2017)
	Data mining—application of algorithms in order to discover patterns in the data or to identify relationships between the set of variables and the target variable (Esmaeilian et al. 2016)

customer site for the customer, taking over the management of maintenance activities).

Developing a service-oriented business model requires answering whether the template is suitable for the relevant company. At the heart of the service-oriented template is the connection between the products and the information system of producers. However, not all the products could be or are worth connecting (Allmendinger and Lombreglia 2005). The service-oriented template is the most prevalent in electromechanical capital goods producers (Smith 2013). The value of the sales of capital goods with a relatively long lifespan constitutes a small portion of the possible revenue from the maintenance and additional services (Wise and Baumgartner 1999). However, recent developments in the sensor technology allowing to embed sensors into textiles or food packaging have increased the applicability of the template with virtually no restrictions.

If the technical feasibility to connect the products exists, and if the value proposition of the networked products makes sense, the necessary IT capabilities have to be developed. The networked products' data must be collected and analyzed, and inferences for services based on the collected data should be made. Such a process requires dealing with a large amount of real-time data. The legacy software systems should be replaced with digital platforms, and new employee skills also have to be developed (Iansiti and Lakhani 2014).

The change in pricing and sales models also poses a challenge. The performance-based pricing may require an individualized understanding of the performance levels of each customer. Taking over customers' functions, such as maintenance, requires thorough comprehension of the risks and costs experienced by the customer. The sales function should combine technical knowledge, analytical knowledge, and the customer's proprietary operational and financial data to develop models for business outcomes (Iansiti and Lakhani 2014).

Customer support and result-oriented services, digital platforms, the Internet of Things, cloud computing, and data mining are mutually interdependent and constitute a coherent system.

Proposition 3.2 *Organizations that adhere to the service-oriented template provide product support, customer support, and result-oriented services enabled by advanced manufacturing and digital technologies.*

The Competencies Associated with the Service-Oriented Template The review of competencies associated with service-oriented templates of organizing (Iansiti and Lakhani 2014; Ardolino et al. 2018; Lenka et al. 2017) allows to identify four generic competencies stemming from the adoption of the template: intelligence, connect, analytic, and outcomes-based sales capabilities.

Intelligence competence "represents the ability to configure hardware components to sense and capture information with low human intervention" (Lenka et al. 2017, p. 95). It constitutes the ability to upgrade physical products with sensors, processors, network adapters, and software applications. It also enables the collection of operational data about the usage and conditions of the products. The connect competence "denotes the ability to connect digitalized products through wireless communication networks" (Lenka et al. 2017, p. 96). It allows processing data to storage and processing centers which should constitute a company's proprietary product platforms or cloud-based services. The second aspect of competence involves the possibility of simultaneous connections (product-to-product) compared to a singular connection (product-platform), which potentially opens new value creation scenarios. Analytic competence "is the ability to transform the data available at hand into valuable insights and actionable directives for the company" (Lenka et al. 2017, p. 96). Analytic competence constitutes the ability to transform data into predictive insights. It also enables us to get insights into customers' product usage patterns. Finally, following Iansiti and Lakhani (2014), it is proposed that outcome-based sales allow combining technical knowledge, analytical knowledge, and customer's proprietary operational and financial data in order to develop models for business outcomes.

Proposition 3.3 *Organizations that adhere to the service-oriented template excel at intelligence, connect, analytic, and outcomes-based sales competencies.*

Differentiating Competitive Performance Dimensions of the Service-Oriented Template The adherence to the service-oriented template results in a shift from the provision of equipment to the provision of integrated product-service offerings. Such offerings draw heavily on intelligence, connection, analytics (Lenka et al. 2017), and technical competencies. Intelligence competence "represents the ability to configure hardware components to sense and capture information with low human intervention" (Lenka et al. 2017, p. 95). The connect competence "denotes the ability to connect digitalized products through wireless communication networks" (Lenka et al. 2017, p. 96). Finally, analytic competence "is the ability to transform the data available at hand into valuable insights and actionable directives for the company" (Lenka et al. 2017, p. 96). The companies achieve satisfying levels of quality, delivery, cost, and flexibility in competitive performance, but what differentiates the companies from the adopters of other approaches is the ability to generate a share of revenues from services based on products (Kim et al. 2007; Ng et al. 2009; Iansiti and Lakhani 2014). In line with this reasoning, we propose that the service performance dimension distinguishes companies that adopt the service-oriented template.

Proposition 3.4 *Organizations that adhere to the service-oriented template are superior in service competitive performance compared to those that adhere to the agile and lean templates.*

2.4 The Comparison of Lean, Agile, and Service-Oriented Templates

In the previous sections, the lean, agile, and service-oriented templates were characterized in terms of goals, practices, and the resulting capabilities. Analysis of the degree of compatibility of the templates allows answering if the templates command conflicting prescriptions for their potential users.

The degree of incompatibility of the organizing templates could be approached by looking at whether the differences concern goals or means (Pache and Santos 2010; Greenwood et al. 2011). It is also crucial if the degree of specificity of the prescriptions of the templates is equal. Non-specific templates provide higher discretion for action (Goodrick and Salancik 1996; Greenwood et al. 2011). There are highly specific templates, such as templates based on quality, environmental or social responsibility standards, and codes of conduct. For example, the organizations that adhere to the social responsibility template (e.g., SA8000) must implement a high number of the listed best practices of social responsibility. Auditors evaluate their adherence to the best practices twice a year. Nonscheduled audits are also performed. Lean, agile, and service-oriented templates are equally specific. Thus, the level of compatibility of the means and goals becomes the decisive factor. Pache and Santos (2010) suggest that the incompatibility of goals is more critical than the incompatibility of the courses of action. The conflicting goals are more challenging to resolve. The association with the particular goals is more evident and may threaten institutional support.

The goals of the lean, agile, and service-oriented templates differ sharply according to our analysis (see Table 2.4). The lean template promotes the search for the ultimate value proposition for a set of customers and provides value by saving on resources as much as possible. The company captures more value compared to typical manufacturing companies as the value acquired by the customer is relatively high, whereas the costs are comparably low. On the contrary, the agile template draws attention to the fragmentation of the company's customers and their ever-changing preferences. The only solution for this situation is to create a production system capable of mass customization. Only such systems may satisfy each customer's unique preferences, which may change prior to the next purchase. The company captures value by charging high premiums because of its individualized products and services, which are produced while remaining close to the mass production efficiencies. The service-oriented template shifts attention from the products to share the risk and to the reduction of the total cost of ownership of the product, and to deliver new efficiencies and other benefits. It allows capturing value by charging the customer a lower price than the total cost of ownership. The companies benefit from additional high-value-added services based on the analysis of data generated from products.

The goals are supported by contrasting competitive priorities, such as product price and quality within the lean template, product customization, innovative products or fast delivery in the agile template, and services in the service-oriented

Table 2.4 The characteristics of the lean, agile, and service-oriented templates

Dimensions	Lean	Agile	Service-oriented
Goal	Providing customers with goods and services that are characterized by high customer value in a low-cost manner through the elimination of waste (Womack and Jones 1996; Hines et al. 2004)	Providing customers with goods with enough variety and customization that nearly everyone finds exactly what they want (Pine 1993)	Providing customers with value by sharing risk; reducing the total cost of ownership of the product, and delivering new efficiencies and other benefits (Iansiti and Lakhani 2014)
Competitive priorities	– Cost***D – Quality***D – Delivery***, Flexibility**, Innovation** – Services*	– Flexibility***D, Innovation***D – Quality***, Delivery***, Services***, Cost***	– Services***D – Quality***, Flexibility*** – Innovation*** – Cost**, Delivery**
Practices	– Continuous flow – Customer involvement – Statistical process control – Total preventive maintenance – Supplier feedback – JIT delivery by suppliers – Supplier development – *Pull of production* – *Setup time reduction* – *Employee involvement*	– Design-product platforms – Concurrent engineering – Rapid prototyping – Modular product design – Design for manufacturing – Supply chain coordination – *Advanced manufacturing technologies* – *Pull of production* – *Employee empowerment* – *Setup time reduction*	– Product support services – Customer support services – Result-oriented services – Digital technologies – *Advanced manufacturing technologies*
Organizational competencies	– Customer-defined value – Integrated supply chain – Lead time compression – Waste elimination – Low variability of demand, processing time, and supply	– Solution space development for choice navigation – Integrated supply chain – Lead time compression – Rapid reconfiguration – Robust process design	– Intelligence – Connect – Analytic – Outcomes-based sales
Competitive performance dimensions[a]	– Cost***D – Quality	– Flexibility***D – Innovation – Fast delivery	Services***D

* Arbitrary importance; ** Secondary importance; *** Primary importance; ***D Differentiator
[a] The differentiating competitive performance dimension is identified because others tend to overlap (e.g., quality could be important in adhering to all templates; innovation could be important in adhering to service-oriented templates)

template. There is also some overlap among competing priorities. For example, the competitive priority of quality is of primary importance in all the templates. However, the concept of quality is denoted by many dimensions, for example, conformance and design quality. Conformance quality became the order qualifier in most sectors. Meanwhile, the approach to the design quality is different in each template, as illustrated by the discussion of the goals of the templates. From the perspective of the lean template, high design quality means a product defined from a customer's perspective. From the perspective of the agile template, high design quality is achieved via custom-designed and manufactured products. Finally, from the perspective of the service-oriented template, it means sharing the risk reduction of the total cost of the customer using a product.

The comparison of the practices constituting the templates allows for identifying some overlap. The lean and agile templates are constituted of, in part, overlapping practices. Pull of production, employee involvement, and setup time reduction make up an important part of the lean and agile templates. Advanced manufacturing technologies are a means of service-oriented and agile templates. Other practices constitute nonoverlapping means of achieving goals prescribed by the template. The resulting competencies of the agile and lean templates overlap in part as well. Both templates result in integrated supply chain and lead time compression competencies. Other competencies associated with each template are substantially different. Finally, the resulting competitive performance dimensions, such as cost-effectiveness, flexibility, and services, distinguish the templates from each other.

In summary, we argue that the templates promote different goals and direct action to fundamentally different customer value creation aspects. They are incompatible in terms of goals and result in competing priorities. There is an overlap of activities associated with the lean and agile templates and the agile and service-oriented templates. The lean and agile templates result in two similar performance dimensions. Despite that, we propose that the templates exhibit incompatibility as their goals differ substantially. The templates are conflicting, and the emergence of the service-oriented template increases the institutional complexity of the global manufacturing field.

In this chapter, we have characterized the lean, agile, and service-oriented templates of organizing. The following sections of our research describe an empirical study to determine whether organizations adhering to the lean, agile, and service-oriented templates occur with any degree of regularity among manufacturing firms.

2.5 The Manifestation of Lean, Agile, and Service-Oriented Templates of Organizing Among Manufacturing Firms

2.5.1 Hypotheses, Measures, and Methods

In this chapter, by using a representative sample of 500 manufacturing companies in a single country, we seek to determine whether organizations adhering to lean, agile, and service-oriented templates occur with any degree of regularity among manufacturing firms. The empirical identification of organizations adopting templates of organizing may be made in various ways. The organizations adhering to this template may be identified by empirically associating them with a goal, competitive priorities, practices, capabilities, differentiating competitive performance dimension, or all of these elements related to their template. In this study, organizations adopting a template are empirically identified by the differentiating competitive performance dimension. It is assumed that the organizations that adhere to the lean, agile, and service-oriented templates are superior in terms of cost, flexibility, and service performance. Cluster analysis draws on the four variables which are considered theoretically relevant for identifying distinct clusters of manufacturing plants based on their competitive performance reflected through cost, flexibility, services, and digitalization capabilities. Consequently, we propose three hypotheses for empirical identification of companies adhering to different templates of organizing in relation to each other:

H1. Organizations that adhere to the lean template are superior in cost performance compared with organizations that adhere to agile and service-oriented templates.
H2. Organizations that adhere to the agile template are superior in flexibility performance compared to organizations that adhere to lean and service-oriented templates.
H3. Organizations that adhere to the service-oriented template are superior in service performance compared to organizations that adhere to agile and lean templates.

The selection of the competitive performance measures was based on an extensive review of scholarly literature. Several approaches to the operationalization of performance dimensions are available (Narasimhan et al. 2006; Grossler and Grubner 2006; Schroeder et al. 2011; Narasimhan and Schoenherr 2013; Singh et al. 2015). We used the operationalization proposed by Schroeder et al. (2011) for the measurement of quality and flexibility performance. Measures of service and digitalization performance complemented the scales of costs and flexibility.

The measurement of the digitalization of production systems continues to emerge. To identify dimensions of digitalization, we reviewed the literature on digital capabilities (Lenka et al. 2017; Ardolino et al. 2018; Srinivasan and Swink 2018) and frameworks and maturity models (Mittal et al. 2018) of the digitization of manufacturing organizations. The following four key components of the digitalization of production systems were identified from the literature: digitizing production data, connecting equipment and devices, collecting and analyzing production data, and automating processes. These dimensions were used for the measurement of the extent and breadth of the digitalization of a production system.

By measuring service performance, we intended to measure the organizational performance related to the provision of services. After reviewing the literature on empirical measurement of services (Egger et al. 2011; Gebauer et al. 2011; Martín-Peña et al. 2020; Sousa and da Silveira 2017; Visnjic et al. 2016), the following four key components of the service performance were used: product support services, online product support service, advanced service provision models, and data-driven services. These dimensions served as the measurement of the service performance. The respondents were asked to indicate how well their factory performed compared to its competition within their industry along the different performance dimensions. A five-point scale was used for assessment where *1* indicates the poor/low end of the industry, *3* refers to the average, and *5* stands for the superior level. This approach allows standardizing the results with respect to industry (Hallgren et al. 2011). The scales of measurement of competitive performance dimensions are listed in Annex 2.1.

We performed the confirmatory factor analysis model by using *R* package *lavaan* with listwise deletion of the missing values. The characteristics of the measurement model and competitive performance dimensions scale are reported in Table 2.5.

Cluster analysis was used to identify groups of organizations exhibiting a degree of regularity according to cost, flexibility, services, and digitalization performance dimensions. The hierarchical K-means clustering method was used. A one-way ANOVA test was conducted to check whether the differences in means are significant. Furthermore, the pairs of clusters were compared along each performance dimension by using the Bonferroni post hoc test (0.05 level).

2.5.2 Lean, Agile, and Service-Oriented Organizations

The hierarchical K-means clustering procedure for the saved factor scores of the four constructs was used. Before implementing cluster analysis, the saved factor scores were standardized with mean *0* and standard deviation *1*. The gap statistics revealed that the optimal number of clusters is 3, as theoretically expected.

Three clusters, one of which stands out in terms of higher flexibility (i.e., agile), another has a higher score for services (i.e., service-oriented), and the third cluster is the most similar to lean performers (i.e., lean), were obtained (Table 2.6). The "service-oriented" cluster is the largest, with 41 objects, which translates into a relative cluster size of 39.4%. The "lean" cluster consists of 35 objects (33.7%). The "agile" cluster is the smallest in size (26.9%) and includes 28 objects.

Next, the centroids of the clustering variables were computed. Figure 2.2 presents the visualization of differences across the clusters. The comparison of variables means across the three clusters revealed that manufacturing plants in the second service-oriented cluster feature a high score on the services-related performance

Table 2.5 The measurement model of cost, flexibility, digitalization, and service competitive performance

Construct	Item	AVE	CR	Reliability (alpha)	Loading*	Mean	SD
Cost	Unit cost	0.916	0.970	0.970	0.935	3.15	0.62
	Manufacturing overhead cost				0.988	3.17	0.61
Flexibility	Ability to adjust production volumes	0.871	0.964	0.965	0.955	3.79	0.74
	Ability to respond to changes in the delivery requirement				0.977	3.82	0.73
	Ability to customize products				0.876	3.83	0.79
	Ability to produce a range of products				0.931	3.74	0.80
Digitalization	Digitalization of the production data	0.979	0.995	0.995	0.995	2.57	1.11
	Connection of the production system elements				0.990	2.57	1.11
	Autonomous production data collection and analysis				0.991	2.55	1.09
	Automation of production processes				0.982	2.58	1.11
Service	Regular products support services	0.905	0.974	0.974	0.887	2.08	1.29
	Online product support services				0.968	1.98	1.20
	Advanced service provision models				0.977	1.91	1.12
	Data-driven services				0.985	1.94	1.18

P value of all loadings $p < 0.001$

Table 2.6 Hierarchical K-means cluster centers with complete cases ($N = 104$)

Cluster number	Title	Costs	Flexibility	Digitalization	Service	*N*	% of the sample
1	Agile	−0.024	0.375	0.793	−0.919	28	26.92
2	Service-oriented	0.064	−0.188	0.525	1.291	41	39.42
3	Lean	−0.055	−0.080	−1.250	−0.777	35	33.65

dimension, as evidenced by the average value of 1.291, which is well above the overall sample mean. Thus, the most significant difference between service-oriented organizations and the two other groups is manifested in the service performance dimension. Organizations in the service-oriented cluster also outperform others for

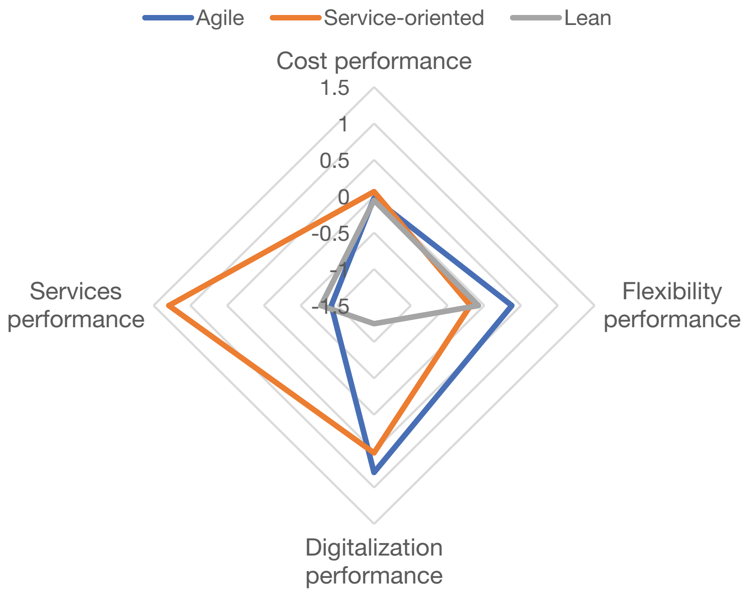

Fig. 2.2 Mean differences in competitive performance dimensions of lean, agile, and service-oriented performers (Vilkas et al. 2021)

costs (mean score of 0.064). However, the average cost performance differs only slightly. The mean score for the flexibility dimension of the service-oriented organizations is the lowest among the three identified clusters. These results are in line with our theoretical prediction.

Manufacturing organizations in the agile cluster stand out from the others in terms of their flexibility (0.375) and digitalization (0.7931) operational capabilities. Considering the flexibility performance outcomes, the average score of agile organizations is above the overall mean of the sample (0.375) and is much higher than that of service-oriented (−0.188) and Lean (−0.08) organizations. Agile performers also exhibit strong capabilities along the dimension of digitalization. However, the mean score of digitalization (0.793) is only slightly distinct from the service-oriented group (0.525) within this domain. Agile performers lag in-service performance (−0.919), and this underperformance is comparable to that of the lean performers (−0.777). These results support the assumption that agile organizations demonstrate their superiority in flexibility performance.

The organizations that fall into the lean cluster do not possess obvious competitive advantages. They are relatively comparable with service and agile organizations in the cost performance capability. Contrary to expectations, the mean score for the cost performance in the lean cluster is slightly below the average (−0.055) and is the lowest among the three clusters. Similarly, no notable differences in the mean scores are detected concerning the performance outcomes of services when compared with organizations from the agile cluster. Both clusters are characterized by relatively poor service performance. In the same way, lean and service-oriented organizations do not show significant differences in flexibility performance.

To sum up, empirical evidence supports the existence of the three distinct clusters. Consistent with the theoretical propositions, service-oriented organizations excel to a great extent in the performance dimension of services compared with the organizations adhering to the lean and agile templates. Similarly, in line with the expectation, the most advanced capabilities of agile performers are centered on the flexibility dimension. Agile organizations outperform service-oriented organizations with regard to digitalization. However, the relative magnitude of the difference is small (see Fig. 2.2). Contrary to expectations, lean organizations were not found to be exceptional performers along the cost performance dimension. Moreover, lean organizations do not appear to exceed the other two groups in all the remaining performance outcomes.

A one-way ANOVA test was conducted to check whether the differences in means are statistically significant. It was revealed that flexibility ($F(2{,}101) = 6.08$, $p = 0.03$), digitalization ($F(2{,}101) = 100.38$, $p < 0.001$), services ($F(2{,}101) = 272.95$, $p < 0.001$) factor score means differ statistically significantly among the clusters. As it was expected, the costs ($F(2{,}101) = 0.43$, $p = 0.65$) factor score means do not differ significantly among the clusters. Further, the pairs of clusters were compared along each performance dimension using the Bonferroni post hoc test (0.05 level). The analysis showed that service-oriented organizations differ statistically significantly along the services performance dimension compared to lean and agile organizations. We found that agile organizations exhibit statistically significantly different flexibility performance compared to lean and service-oriented organizations. There was no statistically significant difference regarding the cost performance dimension among all the types of organizations. The test revealed that agile and service-oriented organizations are characterized by statistically significantly different digitalization performance compared to lean organizations. The cluster analysis results and differences in factor score means of competitive performance dimensions of identified clusters allow for confirming the H1 and H3 hypotheses but reject the H2 hypothesis.

2.6 The Compatibility of Lean, Agile, and Service-Oriented Templates

In response to the recent advances in digital innovations, the study aims to elaborate on manufacturing organizations' typologies and determine whether organizations adhering to the lean, agile, and service-oriented templates occur with any degree of regularity among manufacturing firms. The study contributes to the efforts to typify manufacturing firms by extending the typologies of manufacturing organizations in several ways. First, the research invokes the concept of a template of organizing to characterize coherent manufacturing approaches. Second, the study provides empirical support for organizations that adhere to the service-oriented template in relation to those that adhere to the lean and agile templates. Third, it allows characterizing the templates in relation to the capability of digitalization.

Narasimhan et al. (2006) suggest that the manufacturing approaches could be discussed as manufacturing paradigms or competitive performance dimensions. The manufacturing paradigms are characterized by practices, whereas performance outcomes characterize the performance dimensions. We propose to invoke the concept of a template of organizing (Meyer and Rowan 1991; Greenwood and Hinings 1993) to characterize coherent manufacturing approaches. We define a template of organizing as *an institutionally relevant arrangement of goals, practices, and resulting competitive performance dimensions constituting an organization's core.* Such an approach integrates goals, practices, and competitive performance dimensions instead of separating them. It emphasizes that goals, practices, and competitive performance dimensions are mutually interdependent and constitute a coherent system. The templates provide coherent prescriptions consisting of goals, means, and outcomes. Such an approach is consistent with various ways of empirical research of templates of organizing. Association with goals, practices, and competitive performance dimensions specific to the templates allows us to identify organizations adhering to the templates empirically.

Contrary to the dominating manufacturing typology, which consists of lean and agile templates (Naylor et al. 1999; Narasimhan et al. 2006), we propose to complement the typology with the type of service-oriented organization. It was hypothesized that the organizations adhering to the service-oriented, agile, and lean templates are superior, along with the services, flexibility, and cost performance dimensions. The clustering of organizations according to cost, flexibility, service, and digitalization performance dimensions allowed distinguishing three clusters and three types of companies: service-oriented performers, agile performers, and the organizations that resemble lean performers. In line with the prediction, we found that service performers exhibit considerably superior performance along the service dimension compared to the lean and agile performers. The results indicate that service-oriented performers are far ahead in developing service capabilities compared to other companies. As it was hypothesized, our data provide empirical evidence supporting the assumption that agile performers are superior along with the flexibility competitive performance dimension compared to the organizations that adhere to the lean and service-oriented templates. Contrary to our hypothesis, the organizations occupying the third cluster are not superior along the cost-competitive performance dimension to those adhering to the agile or service-oriented templates. There could be several explanations for these empirical findings. First, it may be suggested that leanness or the focus on cost competitiveness becomes the industry standard, the organizational orientation that is mandatory to ensure survival in the highly competitive global market. The lean template became widespread among manufacturing organizations in the 1990s and is the oldest of the three.

The study allows characterizing the templates in relation to the digitalization performance. The digitalization performance capability empirically measures the extent of the digitalization of the internal production system of an organization. The results reveal that the organizations resembling lean performers lag substantially regarding the extent of digitalization performance compared to the agile and service-oriented performers. These results are in line with the research which argues that the lean template is based on the critical values over the usage of IT technology (Ohno and Bodek 1988; Maguire 2016). IT technology may result in over-automation, improper problem analysis, failure to consider the total cost of ownership in IT investment decisions, and reinforcing silos, among other factors from the perspective of the lean template (Orzen and Bell 2016). Empirical results show that the agile performers outpace service-oriented performers in the digitalization performance, with a mean score of 0.793–0.525. Conceptually, the proponents of both templates (e.g., Yusuf and Aspinwall 1999; Iansiti and Lakhani 2014) argue for the utilization of advanced manufacturing technologies and ICT. The results indicate that the flexibility of production systems and integrated service and product offerings heavily draws on digital innovations. The correlations of digitalization and cost (0.228*), digitalization and flexibility (0.150**), digitalization and services (0.433**) indicate the strongest association among digitalization and services performance dimensions.

2.7 Summary

In this study, we sought to elaborate the typology of manufacturing organizations by characterizing the service-oriented template of organizing in relation to the lean and agile templates. We also aimed to determine whether organizations adhering to the lean, agile, and service-oriented templates occur with any degree of regularity among the manufacturing firms. The review allowed comparing lean, agile, and service-oriented templates in terms of goals, supporting practices, and the resulting competitive performance dimensions. The results show low compatibility of goals and rationale for capturing the value inscribed in these three templates. However, there is considerable overlap among the practices constituting the templates, especially the lean and agile templates. Adopting the templates affects multiple performance dimensions, such as cost, flexibility, services, quality, and delivery. However, it is possible to differentiate among the organizations adhering to the lean, agile, and service-oriented templates in terms of cost, flexibility, and service performance dimensions, respectively.

We managed to identify the organizations adhering to the templates in relation to each other by clustering manufacturing organizations by cost, flexibility, service, and digitalization performance dimensions. The results allow revisiting the taxonomies of manufacturing organizations. The results imply that it is easier to switch from the lean to the agile template and from the agile to the service-oriented template than from the lean to the service-oriented template. However, the study discourages the sequential approach toward the lean, agile, and service-oriented templates and treats these organizational forms as paradigmatically different.

Annex 2.1 Measurement Scales

Measurement of Operational Performance

Indicate how well your factory performed compared to its competition within your industry along these different performance dimensions, 1—Much worse, 2—Somewhat worse, 3—About the same, 4—Somewhat better, 5—Much better, 6—I don't know.

Cost

– Unit cost
– Manufacturing overhead cost
– Inventory turnover

Flexibility

– Ability to adjust production volumes
– Ability to respond to changes in delivery requirements
– Ability to customize products
– Ability to produce a range of products
– Speed of new product introduction into the plant

Service

– Regular products support services
– Online product support services
– Advanced service provision models
– Data-driven services

Digitalization

– Digitalization of production data
– Connection production system elements
– Autonomous production data collection and analysis
– Automation of production processes

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Chapter 3
Lean Performers

Abstract Lean, agile, and service-oriented templates of organizing constitute manufacturing companies' most popular organizational forms. Companies that adhere to the lean template differentiate on cost and quality competitive priorities, adopt a set of lean methods, and are characterized by superior cost and quality competitive performance. Despite huge attention, representative empirical studies of companies adhering to the lean template are rare. In this chapter, we use a representative sample of 500 manufacturing companies to reveal how lean template-related competitive priorities, methods, and performance capabilities are diffused. We also show whether using lean methods is contingent on internal and external factors and which lean methods contribute to cost and quality performance. The results show that quality competitive priorities and performance capabilities are far more prevalent than cost-related ones. Our findings reveal that manufacturing companies use lean methods extensively. We also discover that adopting the lean methods increases with the company's size. Finally, our models reveal that pull of production, customer or product-oriented lines/cells, and development of suppliers positively contribute to the quality competitive performance. Pull of production positively influence the cost performance. Such findings contribute to a more nuanced understanding of lean template diffusion among manufacturing firms.

3.1 Introduction

In the first chapter, we proposed a typology consisting of the lean, agile, and service-oriented templates of organizing. Each template is an ideal type to which organizations choose to adhere when seeking symbolic and operational performance. We suggested that organizing templates could be described by using a framework constituted of goals, competitive priorities, practices, competencies, and differentiating competitive performance dimensions. We also proposed a system of propositions regarding the lean template:

– The goal of the lean template is to provide customers with goods and services that are characterized by high customer value in a low-cost manner through the elimination of waste (Womack and Jones 1996; Hines et al. 2004).

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– Organizations that adhere to the lean template differentiate on the product quality and low product price competitive priority.
– Organizations that adhere to the lean template are characterized by extensive use of the practices of continuous flow, pull of production, setup time reduction, statistical process control, employee involvement, multifunctional teams/ machines, total preventive maintenance, customer involvement, supplier feedback, Just-in-time delivery by suppliers, and supplier development.
– Organizations that adhere to the lean template excel at customer-defined value, elimination of waste, low variability of demand, processing time and supply, integrated supply chain, and lead time compression competencies.
– Organizations that adhere to the lean template are superior along with the cost performance compared to those that adhere to the agile and service-oriented templates.

This characterization of the lean template serves as the conceptual framework for further studies of the lean template. In this chapter, we aim to conceptually and empirically elaborate on the lean template by determining:

– The extent of companies that compete on product price and product quality competitive priorities.
– The diffusion of the lean methods, leanness-related cost, and quality competitive performance dimensions.
– If the diffusion of lean methods is contingent on size, industry, product complexity, lot size, the type of the design process, and the type of the manufacturing process of organizations.
– Which lean practices, digital manufacturing innovations, and services contribute to the leanness-related quality and cost performance.

The chapter is organized as follows. First, we review definitions of lean production. Secondly, we concentrate on how the lean methods result in the improvement of operational performance and on the challenges of the adoption of the lean template. Further, when using a representative sample of 500 organizations within a country, we shed light on the diffusion of the lean methods and the prevalence of cost and quality performance capabilities. We also contribute by determining if the lean methods are contingent on size, industry, product complexity, lot size, the type of the design process, and the type of the manufacturing process of organizations. Finally, we reveal which lean methods, digital innovations, and services contribute to the quality and cost performance.

Table 3.1 Stages of lean development

	JIT/TPS toolkit stage	Lean management system stage
Focus	JIT techniques, decreasing cost	Increasing value and decreasing costs through the elimination of waste
Key business processes	Production processes	End-to-end processes, supply chains
Industry sectors	Automotive companies	High and low-volume manufacturing companies, public institutions, service organizations
Contributing authors	Ohno and Kumagai (1981), Shingo (1981), Schonberger (1982), Monden (1983)	Womack et al. (1990), Womack and Jones (1996)

3.2 Defining Lean Production

The contemporary lean methods were developed mostly within Toyota in the 1960s (Schonberger 2007). There are two principal phases of the diffusion of lean methods: the Just-in-time/Toyota production system (JIT/TPS) toolkit stage and the lean management systems stage (Schonberger 2007; Hines et al. 2004) (Table 3.1).

The first stage of the lean methods diffusion started in the 1980s after seminal books by Ohno and Kumagai (1981), Shingo (1981), and Schonberger (1982) were published in the USA and Europe. The improvement programs that companies initiated mainly focused on Just-in-time techniques to decrease production costs (Schonberger 2007). A number of techniques were transferred from Japanese companies during the first stage of the lean diffusion: cellular manufacturing, quick setup and change-over, frequent small lot production, and pull/Kanban techniques (Schonberger 2007). Softer practices, such as the quality at the source, supplier partnership, and employee involvement, were also practiced (Schonberger 2007). JIT/TPS techniques were mainly applied to the manufacturing processes and were not diffused outside the shop floor (Hines et al. 2004). The JIT/TPS techniques were mostly popular among automotive companies (Hines et al. 2004).

The books by Womack et al. (1990) and Womack and Jones (1996) initiated the second stage of the diffusion of lean methods—the lean management system stage. The first book, titled "The Machine that Changed the World: The Story of Lean Production," instantly became a bestseller. The massive interest in the book was a surprising outcome for the authors of the book (Holweg 2007). Several reasons contributed to its popularity. The book not only described the new production system but also contrasted its performance against the mass production system, dominating high-volume production companies at that time. The book also provided a more systematic treatment of the wider management systems at Toyota. The JIT/TPS tools were treated as an element of Toyota's management system and were linked to the product development, supplier management, and customer management processes. The book caught the attention of many companies and entire manufacturing industries that had not adopted JIT/TPS techniques during the JIT/TPS toolkit stage (Schonberger 2007).

Table 3.2 Definitions of the lean production system in manufacturing

Womack and Jones (1996)	"Lean thinking is *lean* because it provides a way to do more and more with less and less—less human effort, less equipment, less time, and less space—closer and closer providing customers exactly what they want" (p. 15)
Shah and Ward (2007)	"Lean production is an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability" (p. 10)
Narasimhan et al. (2006)	"Production is *lean* if it is accomplished with minimal waste due to unneeded operations, inefficient operations, or excessive buffering in operations" (p. 443)

The second wave of diffusion of the lean methods started after Womack and Jones published their second book, "Lean Thinking: Banish Waste and Create Wealth in Your Corporation," in 1996. The authors reflected on the lean methods and suggested the following five generic principles of the lean management systems suitable for companies from any industry. The following principles constituted the core of lean: value specification, value stream identification, value flow initiation, pulling value from the customers, and pursuing perfection (Womack and Jones 1996). The five principles were universal enough to catch the attention of companies from various sectors seeking insights into increasing customer value and decreasing operating costs. The lean methods began spreading into service organizations and even public institutions—the objective and scope of the application of techniques of the lean programs transformed substantially. Companies started focusing on increasing customer value and decreasing costs by eliminating waste. Lean tools were applied to supply chains and end-to-end business processes, transcending the company's boundaries. Eventually, early adopters started to enjoy the benefits of adopting lean systems.

The wide acceptance of the book marked the emergence of the universal lean template. Any company could adopt the template. The template was described enough revealing the goals, methods, and resulting performance capabilities. Adoption of the template was associated with increased performance, specifically decreased costs, increased quality, and productivity. At the same time, adopting the lean template was challenging because it was constituted by interrelated and reinforcing values and methods. Partial adoption of the lean template rarely resulted in superior performance. Such characteristics made it desirable to shareholders, venture funds, and quality-conscious public institutions. Even after 30 years of the seminal books by Womack and colleagues, lean is one of the most influential templates of organizing that guides efforts of improvement-conscious companies.

Lean is defined in various ways (for a review, see Bhamu and Sagwan 2014). We draw on three definitions of l*ean* (Table 3.2).

The definitions capture different levels of leanness. Womack and Jones (1996) formulate the lean template's goal: increasing customer value at low costs, which is achieved by decreasing waste. Shah and Ward (2007) define lean production. Their definition provides the framework for explaining how leanness affects operational performance in the production context. Finally, Narasimhan et al. (2006) suggest the definition of leanness as a characteristic of an operating system. These three definitions of leanness are sufficient to guide action, explain how results are achieved, and evaluate the effectiveness of adopting the lean template.

In this chapter, we described the emergence of the lean template. We suggested two major phases of lean methods' diffusion: the JIT/TPS toolkit stage and the lean management systems stage. After reviewing the definitions of lean, we proposed three interrelated definitions of lean, which guide the efforts of organizations, explain how lean methods are interrelated and deliver effects in the production context, and provide the framework for evaluating the leanness of operating systems. In the next chapter, we focus on how the lean template delivers operational improvements in the production contexts.

3.3 The Effects of Lean Production on Operational Performance

Womack and Jones (1996) suggested five universal principles of lean, which constitute a core of the universal lean template. The universal template is then tailored to the characteristics of the sector. Lean templates were conceived for service organizations (Liker and Morgan 2006), knowledge-intensive organizations (Staats et al. 2011; Al-Baik and Miller 2014), hospitals (Spear 2005; LaGanga 2011), and public organizations (Radnor and Walley 2008). The lean template in the manufacturing context is usually called "lean production". Further, we draw on the works of Shah and Ward (2003, 2007), Schmenner and Swink (1998), and Netland and Ferdows (2016), explaining how lean production increase the operational performance of manufacturing companies. First, we explain the effects of lean production while using the theory of the swift and even flow (Schmenner and Swink 1998). Second, we explain how lean production influences an increase in operational performance while using a processual account of lean adoption proposed by Netland and Ferdows (2016).

lean methods affect the operational performance of organizations positively in the following way:

1. Lean production methods contribute to the reduction of demand-related variability, supply-related variability, and the variability of processing time;
2. the decreased variability of supply, demand, and the processing time contributes to the reduction in the waste within production;
3. the reduced waste increases the speed by which materials flow through the production system;
4. the increased flow of materials through the production system results in increased productivity, quality, and reduced costs (Fig. 3.1).

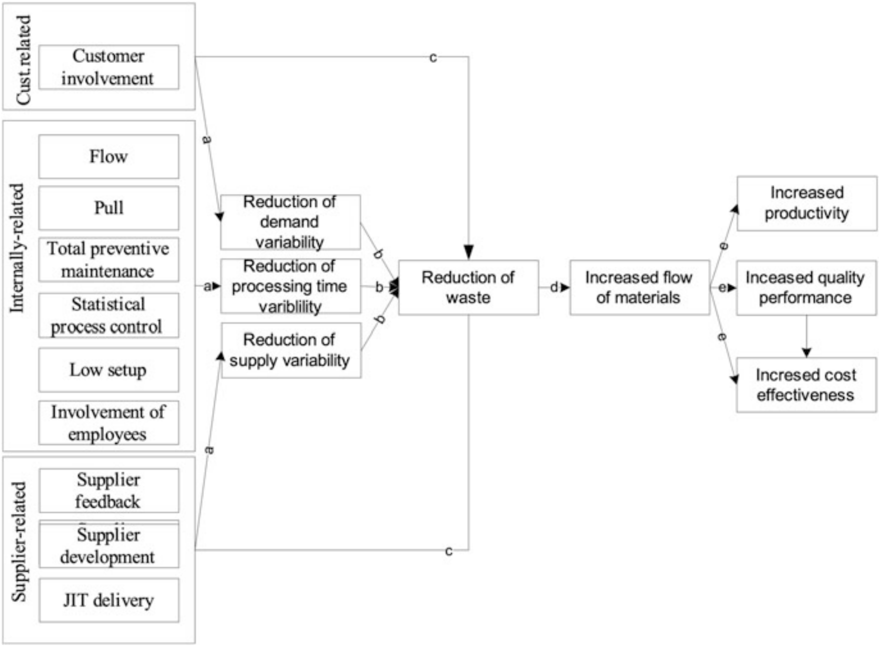

Fig. 3.1 The effects of lean production on operational performance

Stage 1. Lean methods decrease supply, demand, and processing time variability (a) Lean methods decrease supply, demand, and processing time variability in the production companies. Shah and Ward (2007) suggest that approximately fifty tools associated with lean production may be grouped into ten groups. Continuous flow, pull of production, setup time reduction, statistical process control, employee involvement, and total preventive maintenance tools constitute the internally-related lean methods. Customer involvement tools constitute customer-related methods. Finally, supplier feedback, JIT delivery by suppliers, and supplier development tools constitute the supplier-related lean methods.

Demand variability is a variance of the timing or quantities of the products demanded by customers. Organizations rely on forecasts of demand when planning their production. Some variation of demand is systematic and predictable (e.g., seasonal fluctuations); however, much of it stems from unpredictable, random factors. Demand variability increases as one moves upstream of the supply chain because of the bullwhip effect (Lee et al. 1997). The effects of demand variability are especially devastating because it directly affects the processing time and supply variability. The demand variability may be decreased by involving the customer in production. Lean companies involve customers in new product design and development. Customers also provide feedback on the quality and delivery performance and share future demand information. Customer-related methods enable to predict the customer demand more accurately and thus reduce demand-related variability.

Supply variability is the variance of timing or quantities of materials supplied by suppliers over time. Supply variability is influenced by demand variability and other factors, such as the ability of a supplier to deliver on the promised time and the quality of the delivered products. This variability is mitigated by the methods of Supplier development, Supplier feedback, and JIT delivery by the suppliers.

Companies adopting lean production tend to create a supplier base of the few key suppliers working on long-term contracts. Further, the inventory management, materials delivery, and feedback provision processes are integrated tightly between the lean organization and key suppliers. Finally, the processing time variability is the variance of batches' size or throughput time. Processing time variability is influenced by demand variability, supply variability as well as some other factors, such as scheduling policies, unexpected equipment failures, and unexpected reworks. The decreased demand and supply variability contributes to decreasing the processing time variability. Other internally-related methods also influence the reduction of processing time variability. Lean companies focus on matching the demand and supply by introducing such concepts as *takt time* and *heijunka*. Preventive maintenance helps to eliminate production stops because of equipment failures. Statistical process control methods allow managing process capability and stabilizing the processes while avoiding rework. Involved and quality-attentive employees identify quality issues as early as possible. In summary, the lean methods allow organizations to reduce the supply, demand, and processing time-related variability.

Stage 2. Decreased supply, demand, and processing time variability reduce waste within production (b, c) The decreased variability of the supply, demand, and processing time contributes to the reduction of waste within production. Waste is considered to represent everything that does not add value. Value-adding activities are the activities that transform materials into finished products. Any activities initiated to move products, inspect them, or rework them are considered as value non-adding. Overproduction, transportation, waiting, motion, unnecessary processing steps, stocks, and defects are generic types of waste occurring in manufacturing contexts.

The decreased variability of the demand, supply, and processing time also allows for decreasing the levels of the safety stock of the final products, supplies, and the work-in-process inventory which is stored while mitigating fluctuations of the demand, supply and processing time. Lean methods also directly influence the decrease of waste. Internally-related lean methods mitigate the level of the non-value activities. For example, value stream mapping methods help to identify and eliminate waiting time, unnecessary motion, transportation, and other value non-adding activities. Setup time reduction decreases the equipment's setup time and change-over times. Total preventive maintenance helps to eliminate production stops due to unexpected equipment failures.

Stage 3. Reduced waste increases the speed by which materials flow through the production system (d) The flow of materials through production processes increases when the lines/cells that are used in the production processes become more tightly connected, and the products with similar processing requirements are

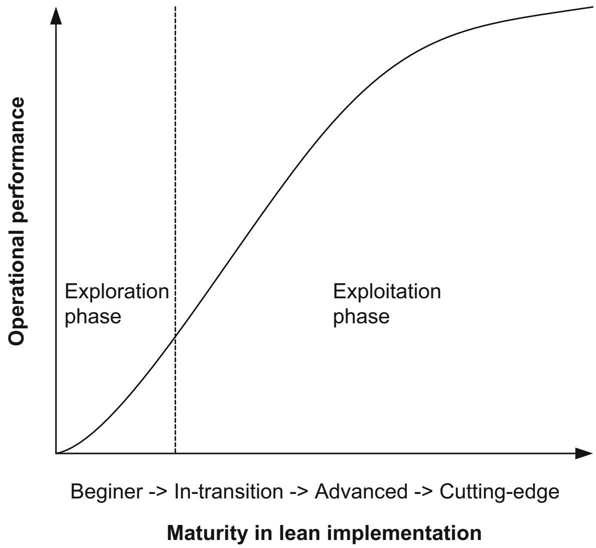

Fig. 3.2 Relationship between the maturity of lean implementation and operational performance in a plant (Source: Netland and Ferdows 2016)

processed. Any decrease in the unnecessary transportation, waiting, motion, unnecessary processing steps, defects, equipment downtime, and the time required to rework defective products also results in the increased speed of the materials flow through the production processes.

Stage 4. The increased flow of materials increases productivity and quality and reduces costs (e) Schmenner and Swink (1998) suggest that "the productivity of any process increases with the speed by which materials flow through the system, and it falls with increases in variability associated with the flow, be it variability of supply, demand or processing time" (p. 102). Following Little's law (Anupindi et al. 1999), the work-in-process inventory decreases as the throughput time becomes shorter. The decreased work-in-process inventory requires less of everything: less equipment, less space, and human labor, which, in turn, decreases the operating costs. Less work-in-process inventory also reduces the complexity of the operating system. The reduced complexity positively affects the quality performance.

In summary, lean production positively affects productivity and operational performance. Meta-analysis of lean outcomes suggests a strong and positive relationship between lean programs and operational performance (Gonçalves et al. 2019). Yet we may wonder how long lean production positively influences the operational outcomes.

Netland and Ferdows (2016) suggest that the relationship pattern between lean maturity and operational performance improvement follows an S-curve shape (Fig. 3.2). They claim that "as a plant progresses in its implementation of lean production, its operational performance improves slowly first, then grows rapidly, and finally tapers off" (p. 1106). The maturity of the lean production adoption is the combination of breadth and depth of the lean template implementation in the plant. Breadth refers to how widely the lean initiatives have spread in different parts of the plant, i.e., how many departments, teams, and operators are using lean tools. The depth of the lean production adoption refers to how thoroughly these entities are applying lean tools.

The organizations adhering to the lean template can be labeled as beginners, in-transition, advanced, or cutting-edge based on their maturity in lean production implementation. Netland and Ferdows (2016) studied 32 Volvo plants that started the lean program at the same time. One plant was stuck at the beginner's stage. Thirteen plants were in the in-transition stage. Fourteen plants were characterized as advanced in terms of lean production adoption. Finally, four plants stood out with the highest level of lean template adoption. During the beginner stage, organizations hardly experience any operational improvements. At this stage, they are still exploring the lean tools. The transfer to the next stage—the in-transition stage—is not inevitable. In the next stage, operational performance starts improving fast. The rapid improvement of performance suggests that the companies benefit from solving problems. These plants are characterized as in-transition because they can grasp the soft aspects of the lean production embodied in the symbolic dimension of the template. The plants in the advanced stage are still experiencing an increase in operational performance caused by lean programs. These plants have already succeeded in grasping the values and tools of the template. They continuously set high targets for themselves and have already initiated comprehensive improvement programs. Finally, operational performance improvement benefits start diminishing at the advanced stage. The authors quote a plant manager explaining: "The leaner we have become, the harder it has become to sustain a high rate of improvement" (p. 1115).

In this chapter, we explained the effects of the lean methods by using the theory of swift and even flow (Schmenner and Swink 1998). We also drew on the theory of S-curve benefits of the lean production implementation, explaining how the maturity of lean adoption relates to operational improvement (Netland and Ferdows 2016). In the next chapter, we concentrate on lean template adoption challenges.

3.4 Lean Template Adoption Challenges

The adoption of the lean template is challenging. Further, we review gaps in lean thinking, specifically, lack of the contingency approach while applying the lean methods, inability to consider the human factors during the implementation of the lean template, and inattention towards critical success factors of adopting the lean template.

According to the contingency theory, management methods are the most effective if they are tailored to the characteristics of the organization and its context (Sousa and Voss 2008). The contingency perspective raises the question of whether the lean template and its constituents are equally suitable for all manufacturing organizations. Previous studies show that such contingency factors as the manufacturing strategy, country, process, company size, and infrastructure explain to some extent the performance differences among companies (Hoss and ten Cate 2013). The manufacturing strategy may constitute an important predictor of using the lean template. If the innovation or flexibility constitutes the core orientation of the value proposition and operation strategy, the necessity of the adoption of the lean template may be questionable. The agile template of organizing and its variants may be more suitable in such situations. The manufacturing process type may limit some lean methods' applicability. The pull methods are unsuitable for the industries that apply the continuous process type of manufacturing. On top of that, Kanban-based coordination in the manufacturing processes with high product variety and complex routings may be ineffective (Sousa and Voss 2008).

Hasle et al. (2012) reviewed the adoption of the lean template on employees. Their message is unequivocal: "there is strong evidence for the negative impact of lean on both the working environment and employee health and well-being in cases of manual work with low complexity" (p. 829). For example, Lewchuk et al. (2001) measured control over work methods, work pace, breaks, work intensity, and pressure before and after the lean production introduction into a plant. They found an increase in employees' feelings of tension and exhaustion after adopting lean production on the shop floor. These findings raise concerns. Thus, more research on lean production's effects on employee well-being is warranted.

Netland (2016) compiled a list of the critical success factors of the adoption of the lean, *JIT*, *TQM*, and *Six Sigma* reported across 14 review papers. The top 10 critical success factors of the adoption of Japanese management techniques ranked according to the frequency they were mentioned in the reviews are the following: management commitment and involvement, training and education, employee participation and empowerment, alignment to strategy and long-term plan, managing cultural change, supplier involvement, customer involvement, teamwork, process management, structured approach, and project prioritizing. Companies should pay more attention to such factors as management commitment and involvement, training and education, employee participation and empowerment instead of focusing on lean tools introduction only.

In this section, we reviewed the challenges of the adoption of the lean template. We identified three challenges: lack of the contingency approach while applying the lean methods, inability to consider the human factors during the implementation of the lean production, and inattention towards critical success factors of adoption of the lean template. These challenges were identified as the most important issues related to the adoption of the lean production template. In the next chapter, we present the results of the empirical research using a representative sample of 500 companies in a single country. The research reveals how prevalent are lean-related competitive priorities, methods, and quality and cost performance capabilities. The research also reveals the effects of the lean methods, advanced manufacturing technologies, and bundles of services on the quality and cost performance.

3.5 Affordances of Organizational and Technological Innovations for Leanness

3.5.1 Model, Measures, and Methods

In this chapter, by using a representative sample of 500 manufacturing companies in a single country, we seek to shed light on the diffusion of the lean methods and the prevalence of cost and quality performance capabilities. We also aim to determine if lean methods are contingent on size, industry, product complexity, lot size, type of the design process, and the type of the manufacturing process of organizations. Finally, we concentrate on the question which lean practices, digital innovations, and services contribute to quality and cost performance. However, first, we describe the model guiding our empirical efforts, the constructs' measures, and the methods used in our empirical analysis.

In the first chapter, we proposed that the lean organizing template consists of goals, competitive priorities, practices, competencies, and differentiating competitive dimensions. Our empirical efforts are guided by the model presented in Fig. 3.3.

We seek to describe the prevalence of lean template-related competitive priorities, practices, and performance capabilities. We assume that lean methods, digital manufacturing innovations, and services positively affect quality and cost performance. Further, we elaborate on the measures of the constructs constituting our model.

The measures of the lean methods are based on the operationalization of the lean production proposed by Shah and Ward (2007). Shah and Ward (2007) suggested that lean production is constituted by internally-related, supplier-related, and customer-related lean methods. They also proposed that these underlying constructs

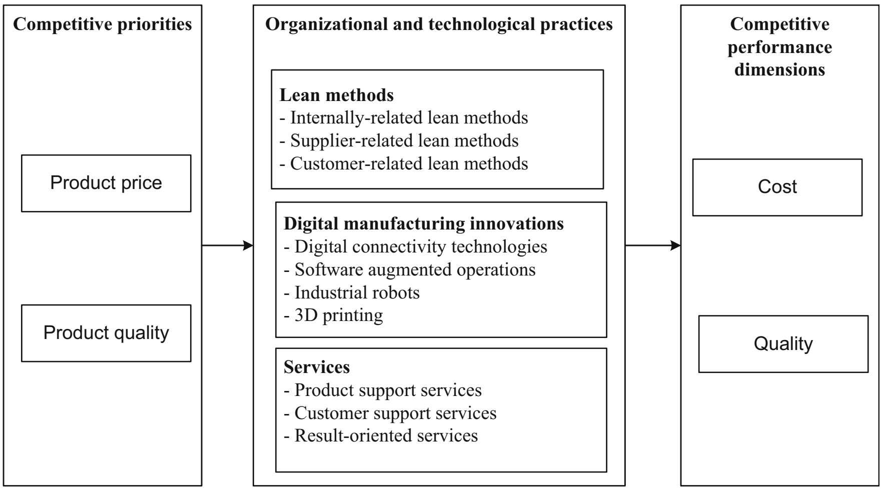

Fig. 3.3 The model of lean template of organizing for empirical analysis

consist of 10 latent lean constructs. These latent constructs were measured by 15 manifest indicators. The manifest indicators for lean, agile practices and services are provided in Table 3.3.

The selection of the measures of quality and cost competitive performance dimensions was based on an extensive review of scholarly literature. Several approaches to the operationalization of performance dimensions are available (Narasimhan et al. 2006; Grossler and Grubner 2006; Schroeder et al. 2011; Narasimhan and Schoenherr 2013; Singh et al. 2015). We used the operationalization proposed by Schroeder et al. (2011) for the measurement of quality and cost (Table 3.4). This operationalization captures the main aspects of the competitive performance dimensions since it is based on the measures that were most commonly applied in previous research (Roth et al. 2008). The questions provided in the questionnaire are listed in Annex 3.1.

Descriptive statistics were used to analyze the diffusion of the product quality and cost competitive priorities, lean methods, cost and quality performance capabilities. The ranking of competitive orientations from 1 to 6, with 1 indicating “the most important” and 6 “not at all important,” was used to measure the extent of prevalence of product cost and quality competitive priorities. The dichotomous variable “Currently used lean methods” (0—No, 1—Yes) was used to measure the diffusion of lean methods in a country. The ordinal variable “Extent of the used potential of the lean methods” (1—Low, 2—Medium, 3—High) was used to evaluate the extent of the used potential of Lean methods. A five-point scale was used to assess quality and cost performance, where 1 indicates the poor/low end of the industry, 3 refers to the average, and 5 stands for the superior performance level compared to the competitors in the industry.

A comparison of the column proportions (by adjusting p-values with Bonferroni method) was used to investigate whether the lean methods are contingent on the size, industry, and type of the design process and the type of the manufacturing process of organizations. The dichotomous variable “Currently used lean methods” was employed for the comparison. Partial squares-based structural equation modeling was used for confirmatory factor analysis of the measurement models and to estimate the effects of the lean methods, digital manufacturing innovations, and services on the quality and cost performance. Endogenous cost and quality performance variables were treated as reflective latent multi-item constructs. The exogenous constructs of the lean methods, digital manufacturing innovations, and services were tested as single-item constructs. A PLS-consistent algorithm was used (path weighting scheme, stop criteria 300 iterations, or 1.0E-7 stop criteria). Casewise deletion of the missing values was employed. The analysis was performed by using SmartPLS software.

Table 3.3 Measures of lean methods, digital innovations, and services

Type of methods	Latent constructs	Manifest indicators
Lean methods	Internally-related lean methods	Standardized work instructions
		Value stream mapping
		Customer or product-oriented lines/cells
		5S
		Visual management
		Pull of production
		Setup time reduction
		Total preventive maintenance
		Statistical process control
		Involvement of employees
		Integration of tasks
	Customer-related lean methods	Customer involvement
	Supplier-related lean methods	Supplier development
		Supplier feedback
		JIT delivery
Digital manufacturing innovations	Digital connectivity technologies	Mobile programming and controlling of facilities and machinery
		Digital solutions to provide documentation directly to the shop floor
		Digital exchange of product/process data with suppliers/customers
	Software augmented operations	Software for production planning and scheduling
		Near real-time production control systems
		Systems for automation and management of internal logistics
		Simulation for product design and development
	Industrial robots	Industrial robots for manufacturing processes
		Industrial robots for handling processes
	3D printing	3D printing technologies for prototyping
		3D printing technologies for manufacturing
Services	Product support services	Installation, start-up
		Maintenance and repair
		Training
		Remote support for clients
		Design, consulting, project planning
		Software development
		Revamping or modernization
		Take-back services
	Customer support services	Online training, documentation, error description

(continued)

Table 3.3 (continued)

Type of methods	Latent constructs	Manifest indicators
		Web services product configuration or product design
		Remote monitoring of operating status
		Mobile devices for diagnosis, repair or consultancy
		Data-based services based on big data analysis
	Result-oriented services	Renting products, machinery, or equipment
		Full-service contracts
		Operation of products at customer site for the customer
		Taking over the management of maintenance activities

Table 3.4 Measures of quality and cost performance

Competitive performance	AVE	Composite reliability	Reliability (alpha)	Dimensions of competitive performance	Loading	*p* values of loadings
Quality	0.882	0.974	0.967	Product capability and performance	0.945	0.000
				Product conformance	0.930	0.000
Cost	0.903	0.965	0.946	Unit cost	0.960	0.000
				Manufacturing over-head cost	0.964	0.000
				Inventory turnover	0.926	0.000

3.5.2 Diffusion of Lean Template-Related Competitive Priorities, Practices, and Competitive Performance Dimensions

3.5.2.1 Diffusion of the Product Price and Quality Competitive Priorities

In this chapter, we describe the prevalence of product price and quality competitive priorities among manufacturing firms. The importance of the product price and quality competitive priorities is provided in Table 3.5.

The graphical representation of the importance of product price and product quality competitive priorities is provided in Figs. 3.4 and 3.5. The analysis reveals that only 9.6% of companies compete on low product price competitive priority. On the contrary, product quality is a very popular competitive priority. 49.5% of companies argue that product quality constitutes their primary competitive orientation.

Table 3.5 The prevalence of product price and quality competitive priorities

	Product price		Product quality	
	No.	%	No.	%
The most important	48	9.6	247	49.5
Important	71	14.2	124	24.8
Slightly important	95	19.0	59	11.8
Not so much important	70	14.0	47	9.4
Not important	68	13.6	15	3.0
Not at all important	147	29.5	7	1.4

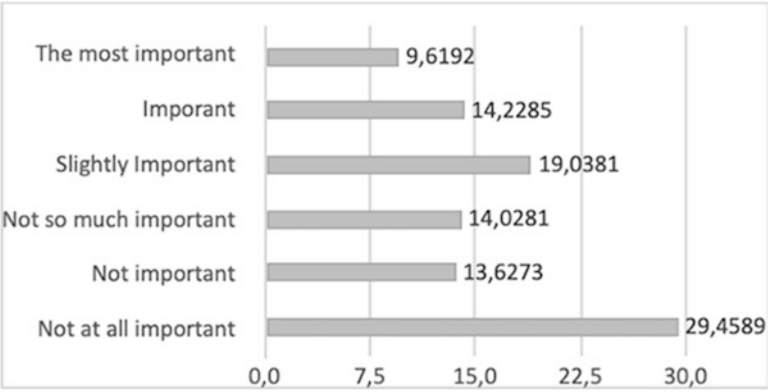

Fig. 3.4 The importance of product price competitive priority, %

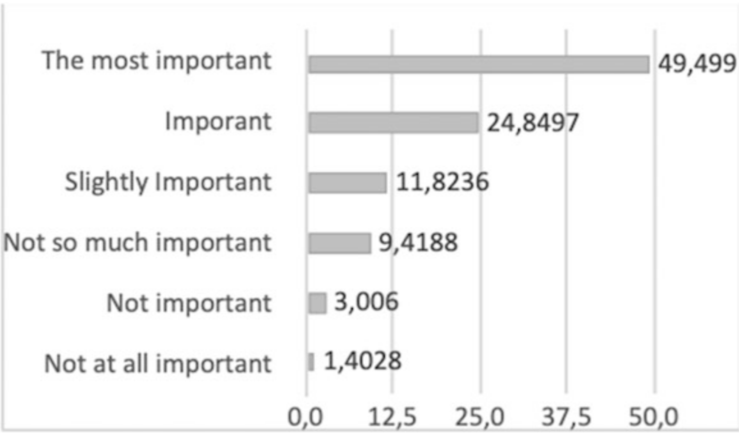

Fig. 3.5 The importance of product quality competitive priority, %

The importance of the product quality and price competitive priorities were measured on a six-point scale. The top three choices reveal a varied level of importance, while the last three categories reveal the absence of importance of a competitive priority. The analysis reveals that 42.9% of organizations indicate that product price is an important competitive priority. 57.1% of organizations tend to devalue the product price as a strategic differentiator. The situation with the quality competitive priority is different. 86.2% of organizations state that competitive priority is important, while only 13.8% have the opposite opinion. In the next chapter, we concentrate on the prevalence of lean methods among the sample of organizations representing the population.

3.5.2.2 Diffusion of Lean Practices

This chapter describes the prevalence of lean practices and the extent of quality and cost performance capabilities in the sample organizations. The frequencies of the usage of the lean methods, together with the used potential of the lean methods in organizations, are provided in Table 3.6.

Ranking of the lean methods according to their usage in the sample of organizations is provided in Fig. 3.6.

The supplier-related (i.e., supplier feedback, Just-in-time delivery), customer-related (involvement of customers), and internally-related (i.e., standardized work instructions, involvement of employees, total preventive maintenance) lean methods are practiced by more than half of the organizations representing the population of the country. Other internally-related methods (i.e., customer or product-oriented lines/cells, setup time reduction, value stream mapping, 5S, visual management, statistical process control, integration of tasks) are less diffused than previously mentioned methods. Interestingly, the extent of the used potential of supplier-related and customer-related methods is greater than that of the most internally-related methods. Supplier and customer-related methods are more problematic as they involve other organizations in the supply chain whose cooperation is necessary. Especially surprising is the low prevalence of 5S and visual management methods. These methods tend to be the first to be deployed by organizations that adopt the lean template.

The extent of the used potential of the lean methods in the sample organizations is shown in Fig. 3.7. The extent of the utilized potential is low for the initial attempt to utilize a practice, medium for a partly utilized practice, and high for extensive utilization of a practice.

Organizations feel confident with the lean methods they are using. The extent of the used potential of the lean methods varies from partly utilized to extensive utilization. The extent of the used potential of the lean methods is similar and varies by 0.4 of a point. It implies that organizations tend to exploit their potential extensively if they start using a method. Supplier-related practices (i.e., Just-in-time delivery, supplier feedback) and a customer-related tool such as the involvement of customers are characterized by the highest used potential among the lean methods. Internally-related practices (i.e., value stream mapping, pull of production, statistical process control) are characterized by the partial extent of the used

Table 3.6 The used potential of the lean methods

Title	Used by			The extent of the used potential			
	No.	%	Not used, %	Initial attempt to utilize, %	Partly utilized, %	Extensively utilized, %	Mean of used potential, max 3
Standardized work instructions	325	65.1	28.5	7.4	2.3	22.2	2.2
Value stream mapping	126	25.3	64.7	4.2	2.1	3.8	2
Setup time reduction	129	25.9	62.1	3.8	2	5.2	2.1
Pull of production	99	19.8	65.9	4.4	2.2	4.4	2
Customer or product-oriented lines/cells	118	23.6	62.5	2.6	2.1	8.2	2.2
5S	144	28.9	55.5	3	2.1	6.6	2.1
Total preventive maintenance	271	54.3	38.7	7.2	2.1	13.8	2.1
Statistical process control	153	30.7	58.9	6.4	2.2	7.4	2
Visual management	148	29.7	56.3	5.2	2	7.4	2.1
Involvement into improvement	288	57.7	35.9	9.4	2.3	15.4	2.1
Integration of tasks	183	36.7	53.1	4.6	2.1	11.2	2.2
Customer involvement	307	61.5	31.3	8.8	2.4	25.6	2.3
Development of suppliers	215	43.1	48.1	6.2	2.1	11.8	2.1
Supplier feedback	369	73.9	19.6	7.2	35.8	30.2	2.3
Just-in-time delivery	312	62.5	30.5	4	2.2	31.2	2.4

potential. The extensive deployment of the lean methods is surprising. The organizations that use the methods are beyond the initial experimentation of the lean methods.

3.5.2.3 Diffusion of Quality and Cost Effectiveness Performance Dimensions

Competitive performance dimensions are the ability to compete on the performance dimensions relative to the primary competitors in the target markets (Schroeder et al.

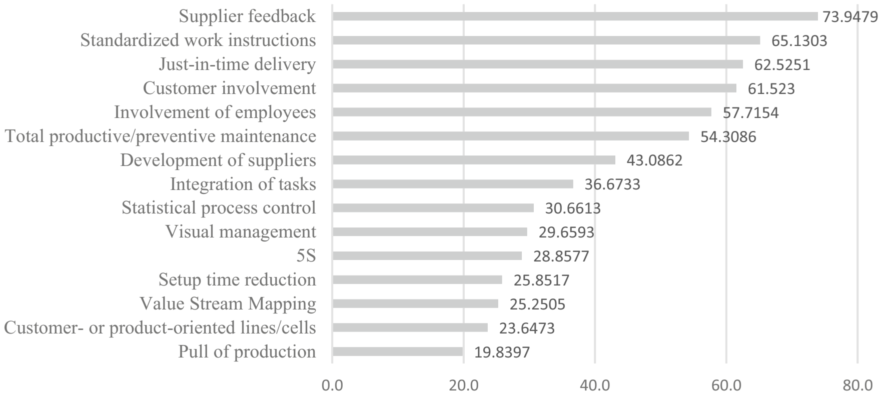

Fig. 3.6 Prevalence of lean methods, %

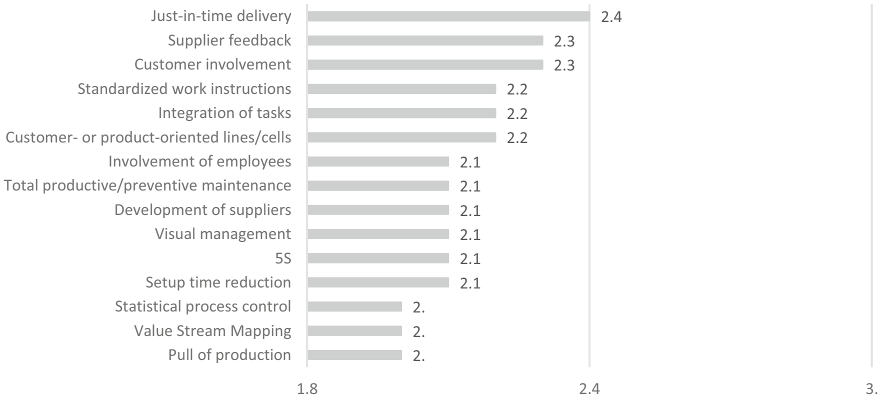

Fig. 3.7 The extent of the used potential of mean methods, max 3

2011). A quality performance is an extent to which an organization can design and offer products that exhibit high levels of conformance and performance (Sansone et al. 2017; Boon-itt and Wong 2016). Cost performance refers to the extent to which an organization is capable of providing low-cost products (Sansone et al. 2017; Boon-itt and Wong 2016). Adoption of the lean template enables to provide high-quality products at a lower price by drawing on low operating expenses.

The constituents of the quality and cost performance dimensions are provided in Tables 3.7 and 3.8. Companies are more confident with quality performance than with cost performance. The mean of the quality performance is 3.6. The mean cost capability is lower (at the level of 3.22). All the dimensions of quality and cost capabilities are perceived as very close to each other.

Analysis of the evaluation of quality and cost performance confirms the insight that companies perceive their quality performance as stronger when compared with cost performance (Fig. 3.8). 28.1% of companies report that their quality

Table 3.7 Evaluation of quality performance

		Much worse	Somewhat worse	About the same	Somewhat better	Much better	I don't know	Mean	Mean of all
Product overall quality performance	Frequency	0	4	216	155	84	41	3.69	3.65
	Percent	0	0.8	43.2	31.0	16.8	8.2		
Product conformance	Frequency	0	3	240	136	74	47	3.62	
	Percent	0	0.6	48.0	27.2	14.8	9.4		

Table 3.8 Evaluation of cost performance

		Much worse	Somewhat worse	About the same	Somewhat better	Much better	I don't know	Mean	Mean of all
Unit cost	Frequency	0	31	220	81	10	158	3.20	3.22
	Percent	0	6.2	44.0	16.2	2.0	31.6		
Manufacturing overhead cost	Frequency	0	28	223	77	11	161	3.21	
	Percent	0	5.6	44.6	15.4	2.2	32.2		
Inventory turnover	Frequency	0	22	219	86	9	164	3.24	
	Percent	0	4.4	43.8	17.2	1.8	32.8		

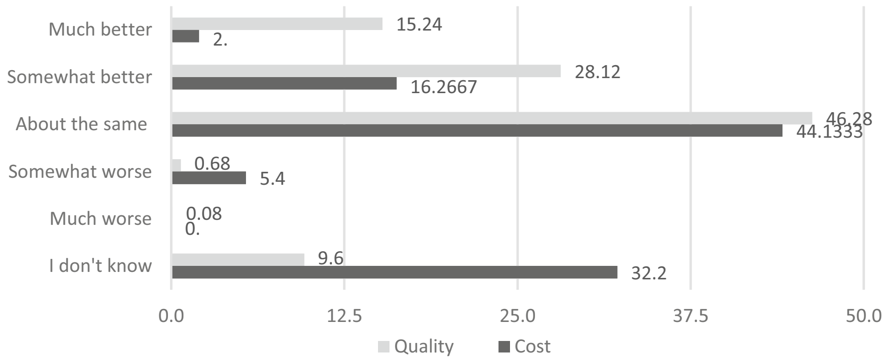

Fig. 3.8 Evaluation of quality and cost performance, %

performance is somewhat better compared to 16.3% of companies that feel the same about the cost. The difference compared to the companies that report their quality performance as much better compared to competitors is 15.2%. Only 2.0% of companies report their superiority in cost-effectiveness.

The analysis shows that cost performance is much more difficult to benchmark. The percentage of companies that struggle to evaluate their cost performance is three times higher compared to the companies that cannot benchmark their quality performance. In summary, the cost and quality capabilities analysis based on multi-item perceptual measures revealed that companies are much more confident with their quality than their cost performance.

3.5.3 Differences in Lean Methods Usage Among Organizations

In this chapter, we investigate whether lean methods are contingent on the size of a company, industry, type of product development process, and the type of the manufacturing process of an organization.

Initially, we analyze if the use of the lean methods depends on the company's size. We propose that the extent of adoption of the lean methods is positively associated with the organization's size. The results of comparing the proportions of the usage of the lean methods across organizations of different sizes are presented in Table 3.9.

Our analysis shows that size is a crucial variable allowing us to predict the extent of the usage of the lean methods. In general, the usage of the lean methods increases with the company's size. In most cases, there are statistically significant differences in the proportions of usage of the lean methods among micro, small, medium, and large companies. The highest diffusion of lean methods is observed in large companies. There are several arguments supporting this tendency. First, operations in

Table 3.9 Difference in usage of lean methods in terms of company size

	1–9 employees (1), %	10–49 employees (2), %	50–249 employees (3), %	250+ employees (4), %	Difference
Standardized work instructions	55.1	64.4	87.3	**92.9**	1 < 3.4
Value stream mapping	11.1	29.8	40.5	**71.4**	1 < 2.3.4; 2 < 4
Setup time reduction	16.2	27.4	39.2	**64.3**	1 < 2.3.4; 2 < 4
Pull of production	14.6	18.3	34.2	**35.7**	1.2 < 3
Customer- or product-oriented lines/cells	15.7	21.6	40.5	**71.4**	1.2 < 3.4
5S	19.2	28.8	46.8	**64.3**	1.2 < 3.4
Total preventive maintenance	42.4	54.3	79.7	**78.6**	1.2 < 3
Statistical process control	15.2	29.3	63.3	**85.7 c**	1 < 2 < 3.4
Visual management	17.7	31.7	48.1	**64.3**	1 < 2.3.4
Involvement of employees	62.1	53.4	53.2	**85.7**	No stat. sign. differences
Integration of tasks	21.2	38.5	64.6	**71.4**	1 < 2.3.4; 2 < 3
Customer involvement	53.0	62.0	75.9	**92.9**	1 < 3.4
Development of suppliers	35.9	44.2	54.4	**64.3**	1 < 3
Supplier feedback	65.2	76.9	84.8	**92.9**	1 < 3
Just-in-time delivery	**68.7**	62.5	51.9	35.7	No stat. sign. differences

medium and large companies are more repetitive than in micro and small companies. Lean production is more easily understood in the context of repetitive operations than low-volume, project-oriented operations. Second, slack resources are more readily available for large companies. Resources allow acquiring knowledge on operational excellence methods more swiftly.

There are also notable exceptions regarding the usage of lean methods in terms of the size of organizations. The Involvement of employees in improvement does not differ statistically significantly regarding the size classes. Micro, small, and medium companies tend to involve their employees in the improvement of operations equally. The extent of the usage of Just-in-time delivery follows the opposite pattern: the smaller a company is, the higher the probability that Just-in-time delivery will be used. The operations of micro and small companies are characterized by low complexity. Such enterprises tend to operate on a make-to-order basis. This allows

Table 3.10 The difference in usage of lean methods across sectors

	Engineering (1), %	Food (2), %	Textile (3), %	Wood and furniture (4), %	Difference
Standardized work instructions	64.8	**79.7**	61.4	60.0	2 > 4
Value stream mapping	23.2	**39.1**	14.3	25.8	2 > 3
Setup time reduction	24.0	**31.3**	24.3	29.0	No stat. sign. differences
Pull of production	16.8	**26.6**	17.1	21.9	No stat. sign. differences
Customer or product-oriented lines/cells	21.6	**32.8**	21.4 a	23.9	No stat. sign. differences
5S	30.4	**40.6**	22.9	20.6	2 > 4
Total preventive maintenance	48.0	**62.5**	50.0	59.4	No stat. sign. differences
Statistical process control	29.6	**42.2**	28.6	28.4	No stat. sign. differences
Visual management	27.2	**34.4**	25.7	31.6	No stat. sign. differences
Involvement of employees	**60.8**	59.4	52.9 a	54.2	No stat. sign. differences
Integration of tasks	36.8	**43.8**	24.3 b	43.2	3 < 4
Customer involvement	64.8	**70.3**	61.4 a	60.6	No stat. sign. differences
Development of suppliers	47.2	**51.6**	37.1 a	42.6	No stat. sign. differences
Supplier feedback	75.2	**79.7**	64.3 a	75.5	No stat. sign. differences
Just-in-time delivery	61.6	56.3	**65.7**	62.6	No stat. sign. differences

stocking no raw materials inventory and sourcing materials on demand. Given large companies' complexity, Just-in-time delivery usage requires close integration with the suppliers. The complexity of Just-in-time delivery increases as the company's size increases; thus, medium and large companies tend to use it less than micro and small companies.

Furthermore, we analyzed if the usage of lean methods differs across sectors. We analyzed the difference in the usage of lean methods across engineering, food, textile, and wood and paper sectors. The results of our analysis are presented in Table 3.10.

We could confirm that the food sector companies use standardized work instructions, value stream mapping, and 5S more extensively than the wood and paper sector companies. While there are only several statistically different proportions of the usage of the lean methods across the sectors, there is a tendency that the food sector companies tend to employ the lean methods more extensively compared to companies from other sectors. Standardized work instructions, value stream mapping, and 5S methods are diffused wider among food companies than in the wood and furniture companies.

Further, we analyzed if the extent of the use of the lean methods depends on the design and development process type. We consider the following types of product development processes: development of products according to customer specification, incorporating customer-specific options into standard products during the development, and developing standard products from which the customer can choose. We propose that the flexibility of the design and development process is negatively associated with the extent of usage of the lean methods. The results of our analysis are provided in Table 3.11.

The results reveal that there is no strong association between the design and development process and the extent of the use of the lean methods. Value stream mapping, total preventive maintenance, and statistical process control are less commonly used by companies that design products according to customer specifications than companies that incorporate customer-specific options into standard products. Just-in-time delivery is used more extensively by the companies that provide products according to the customer specifications compared with the companies with a fixed assortment of products from which the customers can choose.

Finally, we tested if the type of the manufacturing process contributes to the extent of the usage of the lean methods. We propose that the companies whose manufacturing is characterized by the make-to-stock mode use lean methods more extensively than those whose manufacturing is characterized by the make-to-order model. The results of our analysis are provided in Table 3.12.

The companies that produce while focusing on the make-to-stock policy tend to use total preventive maintenance and statistical process control more than the companies that focus on the make-to-order production process. However, in other cases of the application of the lean methods, we were unable to confirm a statistically significant difference in the proportions of usage of the lean methods.

In this chapter, we explored whether the usage of the lean methods is contingent on the size, industry, the type of product development process, and the type of the manufacturing process. The obtained results reveal that size is the most important contingency variable. All the lean methods, except for the Just-in-time delivery, are used more extensively as the size of the company increases. Our analysis revealed that food companies tend to use the lean methods more extensively than other sectors; however, in many cases, we could not reject the null hypothesis while comparing these differences. The repetitiveness of operations tends to be positively related to the usage of preventive maintenance and statistical process control. Value stream mapping, total preventive maintenance, and statistical process control are less used by companies designing products according to customer specifications than by companies incorporating customer-specific options into standard products. Finally, the companies that manufacture products on a make-to-stock basis use statistical process control and total preventive maintenance methods more extensively compared to those manufacturing on a make-to-order basis.

Table 3.11 Differences in the usage of lean methods across different types of design and development process

	According to the customers specification (1), %	As a standardized basic program incorporating customer-specific options (2), %	For a standard program from which the customer can choose options (3), %	Difference
Standardized work instructions	65.1	64.8	**67.6**	No stat. sign. differences
Value stream mapping	19.9	**36.4**	29.6	1 < 2
Setup time reduction	23.2	28.4	27.5	No stat. sign. differences
Pull of production	15.8	22.7	**25.4**	No stat. sign. differences
Customer or product-oriented lines/cells	21.2	26.1	**27.5**	No stat. sign. differences
5S	25.7	30.7	**31.0**	No stat. sign. differences
Total preventive maintenance	48.5	**65.9**	57.0	1 < 2
Statistical process control	24.9	**39.8**	35.2	1 < 2
Visual management	29.0	29.5	**33.8**	No stat. sign. differences
Involvement of employees	**63.1**	53.4	56.3	No stat. sign. differences
Integration of tasks	33.2	**48.9**	35.2	1 < 2
Customer involvement	62.2	**64.8**	60.6	No stat. sign. differences
Development of suppliers	41.9	42.0	**50.7**	No stat. sign. differences
Supplier feedback	73.0	77.3	**76.1 a**	No stat. sign. differences
Just-in-time delivery	**70.1**	56.8	56.3 b	1 > 3

Table 3.12 Differences in the usage of lean methods across different types of the manufacturing processes

	Make-to-order (1), %	Make-to-stock (2), %	Difference
Standardized work instructions	64.7	64.7	No stat. sign. differences
Value stream mapping	22.9	**32.9**	No stat. sign. differences
Setup time reduction	24.2	**32.9**	No stat. sign. differences
Pull of production	18.3	**23.5**	No stat. sign. differences
Customer- or product-oriented lines/cells	22.4	**29.4**	No stat. sign. differences
5S	27.6	**31.8**	No stat. sign. differences
Total preventive maintenance	51.8	**67.1**	1 < 2
Statistical process control	27.3	**42.4**	1 < 2
Visual management	28.1	**37.6**	No stat. sign. differences
Involvement of employees	57.7	**58.8**	No stat. sign. differences
Integration of tasks	**35.1**	42.4	No stat. sign. differences
Customer involvement	61.1	**63.5**	No stat. sign. differences
Development of suppliers	41.8	**52.9**	No stat. sign. differences
Supplier feedback	74.2	**75.3**	No stat. sign. differences
Just-in-time delivery	**62.9**	62.4	No stat. sign. differences

3.5.4 *Relationships of Lean Methods*

Some authors (e.g., Womack et al. 1990; Shah and Ward 2007) argue that the lean methods constitute a system. The main objective of lean production is to provide customers with goods and services characterized by high customer value in a low-cost manner by eliminating waste (Womack and Jones 1996; Hines et al. 2004). Waste is eliminated by minimizing variability related to supply, processing time, and demand (Shah and Ward 2007). The supplier-related methods allow for minimizing supply-related variability. Customer-related methods contribute to low demand-related variability. Customer-related, supplier-related, and internally related methods contribute to low processing time variability. The synergistic and interrelated manner of the lean methods contributes to low cost and high quality (Shah and

Ward 2007). A high relationship among methods may indicate the benefits of bundled adoption when several methods are introduced together.

The relationships among the lean methods are provided in Table 3.13. The correlation coefficient characterizes the relationships.

All the relationships are positive, which indicates that the lean methods reinforce each other. The lean methods seem to be correlated extensively. Standardized work instructions correlate with all the methods except for pull of production. The relationship between customer or product-oriented lines or cells and 5S is characterized by the strongest relationship (0.615**). Surprisingly, pull of production is not associated extensively with other lean methods. Pull of production is reinforced by value stream mapping, customer or product-oriented lines or cells, statistical process control, and integration of employee tasks. Externally-related lean methods are associated with each other more strongly than with the internally-related methods. All the supplier-related and customer-related methods correlate with each other. It implies the possibility of bundled implementation of the methods as they reinforce each other. The analysis of the relationship between the methods revealed a high interrelation among the lean methods. Lean methods mutually reinforce each other. The results are in line with previous research (e.g., Shah and Ward 2003, 2007; Jayaram et al. 2008), which showed that lean methods are extensively interrelated. The high interrelation of the methods implies that the full extent of lean production potential is achieved only when a complete set of lean methods are adopted.

3.5.5 Effect of Lean Methods, Digital Manufacturing Innovations, and Services on Quality and Cost Performance

3.5.5.1 Effects of Lean Methods, Digital Innovations, and Services on Quality Performance

Path analysis using the partial squares structural equation modeling approach is used to determine which lean practices, digital innovations, and services influence quality performance. Three models were constructed. The first model estimates the effects of the lean methods on quality performance. The second model establishes the magnitude of the effects of digital innovations on quality performance. Finally, the estimation of the effects of services on quality capability is performed in the third model. The results are presented in Table 3.14.

The results of the first model reveal that pull of production, customer- or product-oriented lines/cells, and development of suppliers have a statistically significant direct effect on quality performance. Pull of production (0.139*) and customer or product-oriented lines/cells (0.103*) have a weak direct effect on quality. Development of suppliers has a negative direct effect on quality (−0.110*). The results indicating that only 3 methods out of 15 have a direct effect on quality performance are in line with previous research. For example, Shah and Ward (2003) measured the

Table 3.13 The relationships among lean methods

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Standardized work instructions	1.000														
2. Value stream mapping	**0.350****	1.000													
3. Setup time reduction	**0.570****	**0.297***	1.000												
4. Pull	0.172	**0.462****	−0.155	1.000											
5. Customer- or product-oriented lines/cells	**0.459****	**0.556****	**0.472****	**0.348***	1.000										
6. 5S	**0.588****	**0.562****	**0.469****	0.168	**0.615****	1.000									
7. Total productive/preventive maintenance	**0.444****	**0.440****	**0.427****	0.119	**0.258***	**0.457****	1.000								
8. SPC	**0.403****	**0.331****	**0.289***	**0.306***	**0.449****	**0.380****	**0.346****	1.000							
9. Visual management	**0.255****	0.220	**0.395****	0.151	**0.322***	**0.487****	**0.318****	0.128	1.000						
10. Involvement of employees	**0.310****	**0.348****	**0.321****	**0.282***	0.101	**0.324****	**0.284****	**0.394****	**0.410****	1.000					
11. Integration of tasks	**0.255****	**0.288****	−0.090	**0.289***	**0.250***	**0.338****	**0.333****	**0.282****	**0.302****	**0.338****	1.000				
12. Customer involvement	**0.265****	0.117	0.073	0.101	0.198	**0.224***	0.139	−0.037	0.020	**0.266****	**0.327****	1.000			
13. Development of suppliers	**0.316****	**0.309****	0.168	0.221	0.055	0.151	**0.334****	0.143	0.068	**0.335****	**0.412****	**0.465****	1.000		
14. Supplier feedback	**0.361****	**0.314****	0.186	0.208	**0.302****	**0.307****	**0.269****	**0.207***	**0.232***	**0.437****	**0.324****	**0.457****	**0.322****	1.000	
15. Just-in-time delivery	**0.297****	0.110	0.225*	0.158	0.192	0.123	**0.186***	−0.004	0.252*	**0.214****	0.153	**0.259****	**0.341****	**0.350****	1.000

Spearman, Listwise deletion, $N = 497$; ** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed)

Table 3.14 Effects of lean methods, digital innovations, and services on quality performance

Model/methods	Model 1: Lean methods -> Quality		Model 2: Digital innovations -> Quality		Model 3: Services -> Quality	
Effects/methods	Path estimate**	*p* values	Path estimate	*p* values	Path estimate	*p* values
Pull of production *	0.139	0.005	–	–	–	–
Customer- or product-oriented lines/cells	0.103	0.048	–	–	–	–
Development of suppliers	−0.110	0.045	–	–	–	–
Systems for automation and management of internal logistics (e.g., warehouse management systems, RFID)	–	–	0.295	0.000	–	–
Data-based services based on big data analysis	–	–	–	–	−0.115	0.001
Web-based offers for product utilization (online training, documentation, error description)	–	–	–	–	0.103	0.019
R^2	0.074		0.089		0.192	
N	396		120		371	

* Only statistically significant path estimates are shown
** Standardized path estimates

impact of 19 lean-related methods on operational performance. They found that only two methods—competitive benchmarking and total preventive maintenance—directly affected operational performance. A possible way of explanation is as follows. Lean production constitutes a system of methods. Each method may not contribute to quality directly. However, the accumulated effect of the lean methods on quality may be considerable. Some lean methods may indirectly affect quality through other lean or even lean-unrelated organizational practices and structures. For example, standardized work instructions may not directly influence quality operational performance. However, they have high correlations with almost all other lean methods. It is possible that standardized work instructions positively affect other lean methods, which later directly affect quality. Thus, standardized work instructions have an indirect effect on quality. Further, we comment on the direct effects of the lean methods on quality performance which the first model revealed.

The results show that companies seeking a fast and direct effect on quality should consider the adoption of customer or product-oriented lines and cells, pull of production, and also should evaluate practices constituting development of suppliers carefully. Interestingly, pull of production and customer or product-oriented lines and cells are the least used methods in the sample (see Figs. 3.3 and 3.4), which are adopted only by 23.4% and 19.6% of organizations. Customer or product-oriented cells is the central method of concept of *Flow* which is central to lean production (Shah and Ward 2007). The adoption of Customer or product-oriented cells or lines helps “straighten” production processes binding different processes in continuous flow. In the beginning, products are classified into groups with similar processing requirements. The equipment and employees are grouped accordingly. The batch sizes decrease under cell production methods. Cells also positively influence job depth and breadth, thus contributing to job enrichment and enlargement (Huber and Brown 1991). The grouping of products allows decreasing the complexity of production, which positively influences conformance quality. Cellular production decreases the size of batches, resulting in smaller scraped quantities of production. Job enrichment and enlargement create a context where employees take more responsibility for quality operational performance. Pull of production is one of the core methods of the lean template (Shah and Ward 2007). The production of products is pulled by the most upstream station in the production process while using Kanban systems. Pull of production has a direct effect on conformance quality. Work-in-process inventory (WIP) experiences less damage as production is pulled from station to station in a concerted way by using designated spaces for WIP. Customer or product-oriented cells and pull of production have a direct positive influence on quality performance. Our findings show that the development of suppliers has a negative effect (−0.110*) on quality. As the results are surprising, further analysis of the findings is warranted. Such practices as supplier-managed inventory or a small number of suppliers may have a negative impact on product quality if not managed adequately. Considering the high number of methods that production companies use, the direct association of customer or product-oriented lines/cells and pull of production with quality performance is a significant result.

The results of the second and third models reveal that systems for automation and management of internal logistics such as warehouse management systems or RFID (0.295**), and Web-based offers for product utilization (0.115*) exert direct positive effects on quality capability. Data-based services based on big data analysis (−0.115**) have a small direct negative effect on quality. The magnitude of the effect of warehouse management systems and RFID systems on quality is considerable. Companies seeking fast quality improvement should consider these systems. On the other hand, data-based services based on big data analysis, which require rare competencies, have a minor negative effect on quality.

In his chapter, we interpreted the results of three path models, which were constructed to reveal which lean methods, digital innovations, and services directly influence quality performance. Our findings show that pull of production, customer or product-oriented lines and cells, systems for automation and management of internal logistics, and Web-based offers for product utilization have a direct positive effect on quality. The development of suppliers and data-based services based on big data analysis exerts direct negative results on quality. The practices modeled in all the three models cumulatively account for 35.5% of the variation of quality performance, which is a substantial value. In the next chapter, we present the results of path analysis which is initiated to reveal which lean methods, digital innovations, and services directly influence cost performance.

3.5.5.2 Effects of Lean Methods, Digital Innovations and Services on Cost Performance

Path analysis using the partial squares structural equation modeling approach was used to determine which lean practices, digital innovation, and services influence cost performance. Three models were constructed. The first model estimates the effects of lean methods on cost performance. The second model predicts the effects of digital innovations on cost performance. Finally, the estimation of the effects of services on costs is performed in the third model. The results are presented in Table 3.15.

The results reveal that only one lean method—the pull of production—has a direct positive effect on costs. The pull method promotes the pull of production from the most upstream station in the production process by using Kanban systems. Pull of production has a direct positive effect on costs (0.161*). Pull of production reduces the work-in-process inventory, which has a direct positive effect on cost-effectiveness.

The results of the second and third models reveal that near real-time production control system, such as MES (0.229*), and systems for automation and management of internal logistics (0.187*) have a direct positive effect on cost. The MES systems optimize the scheduling process, immediately evaluate the progress of orders, and ensure the identification and traceability of products. The systems for automation and management of internal logistics allow precise identification of the raw material inventory and the finished goods inventory. The accurate information on the stock increases the throughput times of manufacturing processes and decreases the inventory level, which in turn decreases operating costs. Full-service contracts with a defined scope to maintain products (−0.193*) have a direct negative effect on costs.

Table 3.15 Effects of lean methods, digital innovations, and services on cost performance

Model/methods	Model 1: Lean methods -> Costs		Model 2: Digital innovations -> Costs		Model 3: Services -> Costs	
Effects	Path estimate*	*p* values	Path estimate	*p* values	Path estimate	*p* values
Pull of production	0.161	0.022	–	–	–	–
Near real-time production control system (e.g., MES)	–	–	0.229	0.013	–	–
Systems for automation and management of internal logistics (e.g., warehouse management systems, RFID)	–	–	0.187	0.047		
Full-service contracts with a defined scope to maintain products	–	–	–	–	−0.193	0.025
R^2	0.100		0.151		0.259	
N	375		120		341	

* Only statistically significant path estimates are shown

** Standardized path estimates

Companies working towards providing products on full-service contracts risk maintaining the products they provide; thus, they substantially alter the company's business model. The business model requires capital investment in the service infrastructure and spare parts of products, which may take time to pay off.

In his chapter, we presented the results of three path models constructed to reveal the direct effects of the lean methods, digital innovations, and services on cost performance. The results show that the methods that statistically significantly affect cost performance cumulatively account for 51.0% of the variation of cost performance. In the next chapter, we summarize the results of our empirical research.

3.6 Summary

In this chapter, we aimed at conceptual and empirical elaboration of the lean template of organizing. We reviewed the available definitions of lean production, the rationale of the effects of the lean methods on performance, and the challenges of adopting the lean production template. Further on, using a representative sample of 500 businesses within a single country, we determined the diffusion product price and quality competitive priorities, lean methods, and the prevalence of quality and cost performance capabilities. We also determined if the adoption of lean methods is contingent on the size, industry, product complexity, lot size, the type of the design process, and the type of the manufacturing process of organizations. Finally, we revealed which lean practices, digital manufacturing innovations, and services contribute to the quality and cost performance.

We revealed that only 9.6% of companies indicate that product price is the most critical competitive priority. 49.5% of companies argue that product quality constitutes their primary competitive priority. Such findings conflict with the belief that Lithuanian manufacturing companies differentiate on low prices. The analysis also reveals the overall importance of quality as a competitive priority. 86.2% of organizations state that quality competitive priority is more important than unimportant.

We found that the diffusion of the lean methods varies from 73.2% to 23.4% of organizations representing a manufacturing companies' population in a single country. Organizations using the lean methods report the medium-to-high extent of the used potential of the methods. We also discovered that the quality performance dimension is more prevalent than the cost-effectiveness capability. 43.3% of companies argue that their quality performance is much or somewhat better than their competitors, compared to 18.3% of companies claiming the same regarding cost. The low diffusion of the cost performance capability is unanticipated. It is argued that companies from emerging economies have more efficient levers to achieve low-cost performance than companies from more advanced economies (Boon-itt and Wong 2016).

We also discovered that adopting the lean methods varies depending on the size, industry, the type of product development process, and the manufacturing process. While scholars disagree on whether the size is an important contingency factor influencing the adoption of the lean template (Yusof and Aspinwall 2000), our analysis shows that size moderates the extent of the adoption of the lean methods. We found that the extent of adoption of all the measured lean methods, except for Just-in-time delivery and Involvement of employees, increases as the size of the company increases. Our analysis revealed that the adoption of standardized work instructions, value stream mapping, and 5S in the food companies is higher than in the wood and furniture sector. Our analysis also identified that value stream mapping, total preventive maintenance, and statistical process control are adopted more commonly by companies with lower product mix flexibility. We also found that total preventive maintenance and statistical process control methods are more extensively used by organizations using the make-to-stock operating mode than those using the make-to-order operating model. Therefore, the study reveals that the lean methods are contingent on a number of the essential phenomena of operations management.

Our results indicate a high interrelation of the lean methods. Such findings support the proposition that lean production constitutes a system of interrelated and reinforcing methods. For example, the method of standardized work instructions correlates with all the methods except for pull pf production. Externally-related lean methods are more strongly associated with each other than with internally-related methods. All the supplier-related and customer-related methods correlate with each other. Such findings confirm that lean methods are interdependent, and template-related performance improvements result from adopting a complete set of lean template-related methods.

Further, we determined which lean methods, digital manufacturing innovations, and services contribute to quality and cost performance. We established that the exogenous variables of our models cumulatively account for 35.5% of quality and even 51% of cost performance variation. Pull of production, customer or product-oriented lines and cells, development of suppliers, systems for automation and management of internal logistics, and Web-based offers for product utilization positively contribute to the quality competitive performance. Data-based services based on big data analysis negatively contribute to quality performance. Pull of production, near real-time production control system, and systems for automation and management of internal logistics positively influence the cost performance. Full-service contracts with a defined scope to maintain products negatively affect cost performance. Our findings allow empirically elaborating lean template revealing how lean template-associated competitive priorities, methods, and performance capabilities are dispersed among manufacturing organizations. The findings argue that the lean template is not uniform among all the manufacturing companies and that important contingency factors determine the use of lean methods. Further, we contribute to lean literature by revealing which lean methods, digital manufacturing innovations, and services contribute to cost and quality competitive performance dimensions. In the next chapter, we turn to the agile template of organizing.

Annex 3.1 Measurement Scales[1]

Measurement of Competitive Priorities

Please rank the following competitive factors in order of significance to distinguish your factory positively from competitors.

Please rank from 1 to 6, 1 indicating “the most important“. Please do not assign equal importance to any factors.

- Product price
- Product quality
- Innovative products
- Customization to customers’ demands
- Delivering on schedule/short delivery times
- Services

Measurement of Organizational Characteristics

Which of the following characteristics best describes your main product or line of products?

Product Development

- According to customers’ specification
- As a standardized basic program incorporating customer-specific options
- For a standard program from which the customer can choose options
- Does not exist in this factory

Batch or Lot Size

- Single unit production
- Small or medium batch/lot
- Large batch/lot

[1]European manufacturing survey scales (EMS 2022).

Manufacturing Process

- Upon receipt of customer's order, i.e. made-to-order
- Final assembly of the product is carried out upon receipt of customer's order, i.e. assembly-to-order
- To stock (before customer's order)
- Does not exist in this factory

Product Complexity

- Simple products
- Products with medium complexity
- Complex products

Measures of Lean Methods

Which of the following organizational concepts are currently used in your factory? 0—No; 1—Yes.

If Yes, what is the extent of the used potential of the method? 1—Low; 2—Medium; 3—High.

(Extent of the used potential—Extent of actual utilization compared to the most reasonable maximum potential utilization in your factory: Extent of the utilized potential 'low' for an initial attempt to utilize, 'medium' for partly utilized, and 'high' for extensive utilization.)

- Standardized and detailed work instructions (e.g., standard operation procedures SOP, MOST);
- Measures to improve internal logistics (e.g., Value Stream Mapping/Design, changed spatial arrangements of production steps);
- Fixed process flows to reduce setup time or optimize change-over time (e.g., SMED, QCO);
- KANBAN, Internal zero-buffer principle);
- Customer- or product-oriented lines/cells in the factory (instead of task-/operation-structured shop floors);
- Detailed regulations on the arrangement and setting of the work equipment and storage of intermediary products (e.g., Method of 5S);
- Decreasing the time of equipment downtime (Total Productive/Preventive Maintenance);
- SPC, process capability analysis);
- Display boards in production to illustrate work processes and work status (e.g., Visual Management);

– Involvement of employees into improvement (e.g., A3, KAIZEN, PDCA, etc.);
– Integration of tasks (planning, operating or controlling functions with the machine operator);
– Involvement of customers into production (e.g., sharing demand information, joint product development);
– Inventory managed by suppliers, exchange of cost structure information);
– Collecting supplier feedback (e.g., sharing information on quality and delivery problems).

Measures of Digital Manufacturing Innovations

Which of the following technologies are currently used in your factory? 0—No; 1—Yes.

If Yes, What is the extent of the used potential of the method? 1—Low; 2—Medium; 3—High. Extent of used potential—Extent of actual utilization compared to the most reasonable maximum potential utilization in your factory: Extent of utilized potential “low” for an initial attempt to utilize, “medium” for partly utilized and “high” for extensive utilization.

– Mobile/wireless devices for programming and controlling facilities and machinery (e.g., tablets);
– Digital solutions to provide drawings, work schedules or work instructions directly on the shop floor;
– Software for production planning and scheduling (e.g., ERP system);
– Digital Exchange of product/process data with suppliers/customers (Electronic Data Interchange EDI);
– Near real-time production control system (e.g., Systems of centralized operating and machine data acquisition, MES);
– Systems for automation and management of internal logistics (e.g., Warehouse management systems, RFID);
– Virtual Reality or simulation for product design or product development (e.g., FEM, Digital Prototyping, computer models);
– Industrial robots for manufacturing processes (e.g., welding, painting, cutting);
– Industrial robots for handling processes (e.g., depositing, assembling, sorting, packing processes, AGV);
– 3D printing technologies for prototyping (prototypes, demonstration models, 0 series);
– 3D printing technologies for manufacturing of products, components and forms, tools, etc.).

Measures of Services

Which of the following product-related Services do you offer your customers? 0—No; 1—Yes.

- Installation, start-up;
- Maintenance and repair;
- Training;
- Remote support for clients (e.g., User Helpdesk, web platform);
- Design, consulting, project planning (incl. R&D for customers);
- Software development (e.g., software customization);
- Revamping or modernization (incl. enhancement of functions, software extensions, etc.);
- Take-back Services (e.g., recycling, disposal, taking back).

Which of the following digital solutions do you offer as part of your Service portfolio? 0—No; 1—Yes.

- Web-based offers for product utilization (online training, documentation, error description);
- Web-based Services for customized product configuration or product design (development);
- Digital (remote) monitoring of operating status (e.g., condition monitoring);
- Mobile devices for diagnosis, repair or consultancy (e.g., digital camera, smartphone, tablets, etc.);
- Data-based Services based on big data analysis.

Which of the following business models do you offer your customers? 0—No; 1—Yes.

- Renting products, machinery or equipment;
- Full-service contracts with a defined scope to maintain your products;
- Operation of your own products at customer site/for the customer (e.g., pay on production);
- Taking over the management of maintenance activities for the customer in order to guarantee availability or costs.

Measurement of Operational Performance

Indicate how well your factory performed compared to its competition within your industry along these different performance dimensions, 1—Much worse, 2—Somewhat worse, 3—About the same, 4—Somewhat better, 5—Much better, 6—I don’t know.

Quality

– Product overall quality performance
– Product reliability
– Product features
– Product conformance
– Product durability

Cost

– Unit cost
– Manufacturing overhead cost
– Inventory turnover

Flexibility

– Ability to adjust production volumes
– Ability to respond to changes in delivery requirements
– Ability to customize products
– Ability to produce a range of products
– Speed of new product introduction into the plant

Delivery

– Delivery accuracy
– Delivery dependability
– Delivery quality
– Delivery availability
– Delivery speed

Innovation

– Lead time to introduce new products
– Number of new products introduced each year
– The extent of innovativeness of products

Service

- Regular products support services
- Online product support services
- Advanced service provision models
- Data driven services

Digitalization

- Digitalization of production data
- Connection production system elements
- Autonomous production data collection and analysis
- Automation of production processes

Measures of Financial Performance

Please characterize your factory:

- Annual turnover
- in 2017 XX million €
- in 2015 XX million €

- Number of employees
- in 2015 XX number
- in 2015 XX number

- Return on sales (before tax, 2017)
- negative
- 0 up to 2%
- >2 up to 5%
- >5 up to 10%
- >10%

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Chapter 4
Agile Performers

Abstract Agile, lean, and service-oriented templates of organizing constitute manufacturing companies' most popular organizational forms. Companies that adhere to the agile template differentiate on flexibility or innovation competitive priorities, adopt a set of digital manufacturing innovations, and are characterized by superior flexibility or innovation performance. Despite huge attention, representative empirical studies of companies adhering to the agile template are rare. In this chapter, we use a representative sample of 500 manufacturing companies to reveal the diffusion of agile template-related characteristics. The results show that flexibility competitive priorities, and performance capabilities are far more prevalent than innovation-related ones. Our findings reveal that manufacturing companies use digital manufacturing innovations non-extensively. We also discover that large companies use digital innovations more extensively than SMEs. Our analysis reveals that engineering companies use more digital innovations than companies from other sectors. Finally, our models reveal that systems for automation and management of internal logistics, simulation for product design or product development, and remote monitoring of the operating status positively contribute to the flexibility performance. We cannot find any influence of digital innovations on innovation performance. Such findings contribute to a more nuanced understanding of agile template diffusion among manufacturing firms.

4.1 Introduction

In the first chapter, we proposed a typology consisting of the lean, agile, and service-oriented templates of organizing. We proposed that organizing templates could be described using a framework constituted of goals, competitive priorities, practices, competencies, and differentiating competitive dimensions. We also proposed a system of propositions regarding the agile template:

– The goal of the agile template is to provide customers with goods denoted by enough variety and customization so that nearly everyone finds exactly what they want (Pine 1993).

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- Organizations that adhere to the agile template differentiate on product customization, innovative products, and/or fast delivery competitive priorities.
- Organizations that adhere to the agile template could be differentiated by extensive use of practices of advanced manufacturing technologies, design-product platforms, supply chain coordination, rapid prototyping, concurrent engineering, design for manufacturing, and modular product design.
- Organizations that adhere to the agile template excel at the solution space development for choice navigation, integrated supply chain, lead time compression, rapid reconfiguration, and robust process design competencies.
- Organizations that adhere to the agile template are superior in flexibility performance compared to those that adhere to the lean and service-oriented templates.

These propositions about the agile template provide a background for further analysis of the agile template of organizing. In this chapter, we aim to conceptually and empirically elaborate the agile template by determining:

- The extent of companies that compete on innovative products, customization to customers' demands, and fast delivery competitive priorities.
- The diffusion of digital manufacturing innovations, agility-related flexibility, fast delivery, and innovation competitive performance dimensions.
- Whether digital manufacturing innovations are contingent on size, industry, product complexity, lot size, type of design process, and the type of the manufacturing process of organizations.
- Which digital manufacturing innovations, lean methods, and services contribute to agility-related flexibility, fast delivery, and innovation performance.

The chapter is organized as follows. First, we review the definitions of agility. Later, using a proposed framework, we describe three types of agile organizations and summarize the challenges of adopting the agile template. Later in the chapter, by using a representative sample of 500 enterprises in a country, we shed light on the prevalence of agility-related competitive priorities, digital manufacturing innovations, and capabilities of flexibility, fast delivery, and innovation associated with the agile template. Then, we explore if digital manufacturing innovations are contingent on size, industry, product complexity, lot size, the type of the design process, and the type of the manufacturing process of organizations. Finally, we reveal which digital manufacturing innovations, lean practices, and services contribute to flexibility, fast delivery, and innovation performance.

4.2 Defining Agile Manufacturing

The concept of agility was introduced in a report from the Iacocca Institute at Lehigh University in 1991. The position paper aimed to answer how US enterprises should change to reclaim manufacturing leadership in the twenty-first century. The vision formulated in the report stands relevant today: "The term *Agile manufacturing*

Table 4.1 Streams of research contributing to the agility movement

	Agile manufacturing and supply chains	Agile project management	Digital transformation
Focus	Agility drivers, characteristics, and practices facilitating agility	Roles, practices, and artifacts that facilitate coordination of projects	Digital transformation antecedents, mechanisms, and outcomes
Key business processes	Order management, product design, manufacturing, supply chains	Product/service design and innovation and other projects	Organization as a whole
Industry sectors	Manufacturing companies	IT and other service and manufacturing companies	All companies
Contributing authors	Gunasekaran (1998), Gunasekaran (1999), Yusuf et al. (1999), Nagel and Dove (1991), Pine (1993)	Schwaber (2004), Rigby et al. (2020)	Ghobakhloo (2018), Centobelli et al. (2020), Perkin and Abraham (2021), Hanelt et al. (2021)

describes a manufacturing system with an extraordinary capability to meet the rapidly changing needs of the marketplace, a system that can shift quickly among product models or between product lines, ideally in real-time response to customer demand" (Nagel and Dove 1991, preface). The books by Nagel and Dove (1991) and Pine (1993), together with the success of Dell company, increased interest in agility substantially. Other companies started embracing mass customization practices. At the same time, stakeholders started channeling resources for companies that aim to provide customers with goods denoted by enough variety and customization so that nearly everyone finds exactly what they want. The agile template was incepted.

The agility movement matured extensively during the last 30 years. The following three streams of research contributed to the knowledge of how companies develop capabilities of continuous transformation in the context of relentless changes: agile manufacturing and supply chains, agile project management, and digital transformation (Table 4.1).

Identified streams of the research are not the stages of the agility movement. These streams represent productive research communities that attract readers trying to understand how agility could be achieved. The core topics of each stream of research will be summarized in the following paragraphs.

The first stream of research dominated by operations and technology management scholars focuses on manufacturing companies' agility. The literature on agile manufacturing falls into two categories. The first category concerns the conceptual frameworks that facilitate agility, including research describing what agility is, which capabilities are relevant, and what characterizes agile organizations (e.g., Goldman and Nagel 1992; Kidd 1995; Gunasekaran 1998, 1999; Gunasekaran et al. 2019). For example, Gunasekaran (1998) identifies specific strategies, systems, technologies, and HMR orientations resulting in a virtual enterprise, rapid partnership, reconfigurability, and mass customization capabilities that characterize agile manufacturing companies. The second category consists of research that proposes socio-technical enablers for agility. For example, Gunasekaran et al. (2019) summarize that the practices associated with agile manufacturing generally fall into five groups: mass customization, manufacturing automation, technology utilization, employee empowerment, and supply chain networking. In summary, the research on agile manufacturing provided a conceptual framework revealing the nature of agility, the drivers of agility, the characteristics of agility, and practices that facilitate the agility of organizations and supply chains.

The agile project management programs, such as Scrum, emerged in the Information technology sector. The methodology is used as coordination means for software development projects. The evidence suggests that Scrum has diffused beyond the IT sector, and production companies started using Scrum practices to manage new product development and other projects (Rigby et al. 2018). The Scrum approach is usually contrasted with more traditional project management approaches, such as waterfall project management (e.g., Fowler and Highsmith 2001). The Scrum approach proposes that projects should build around motivated people, not processes or tools. The continuous adaptation to circumstances should be prioritized over plans. The working prototypes and customer collaboration are more important than rigid contracts with excessive documentation. The work is coordinated through roles, events, and artifacts associated with agile project management (Rigby et al. 2020; Kakar 2017). Product owner, team member, and Scrum master roles have predefined responsibilities which facilitate shared expectations. The work is executed through iterative sessions called "sprints" punctuated with sprint planning and daily and retrospective work improvement meetings. Finally, the work is facilitated by common artifacts such as product backlog, spring backlog, potentially shippable product, and sprint burndown chart, which contribute to efficiency and coordination. Scrum does not apply to repetitive tasks and processes. It provides effective coordination tools for product development, change management, strategy development, resource allocation, and improvement projects (Rigby et al. 2020). The empirical evidence suggests that the Scrum techniques contribute to project success, especially in medium-to-big projects (Jørgensen 2018). Even more, some companies (e.g., Spotify) tend to be managed as bundles of multidisciplinary teams. Such companies rely on agile techniques to achieve organizational agility (Rigby et al. 2020). In summary, the agile project management stream of research provided a unique approach to understanding how flexibility, speed, and responsiveness could be achieved while pursuing unique outcomes.

Digital transformation literature constitutes the third stream of literature that provides insights on achieving organizational agility (Schwarzmüller et al. 2018; Hanelt et al. 2021). Hanelt et al. (2021) provided a systematic review of the literature on digital transformation. They identified that the digital transformation literature deals with the antecedents, mechanisms, and outcomes of digital transformation. They proposed that material (emergence and diffusion of social, mobile, cloud, and Internet of Things technologies and increased data availability), organizational (digital transformation awareness, digitalization strategy), and environmental (legal and infrastructural conditions, technology-driven industry dynamics, digital

Table 4.2 Definitions of the agile manufacturing

Gunasekaran (1998)	"The capability to survive and prosper in a competitive environment of continuous and unpredictable change by reacting quickly and effectively to changing markets driven by customer-designed products and services" (p. 1223)
Yusuf et al. (1999)	"The successful exploration of competitive bases (speed, flexibility, innovation proactivity) through the integration of reconfigurable resources and best practices in a knowledge-rich environment to provide customer-driven products and services in the fast-changing market environment" (p. 37)
Narasimhan et al. (2006)	"Production is agile if it efficiently changes operating states in response to uncertain and changing demands placed upon it" (2006, 443)

consumer demand) antecedents constitute contextual conditions for digital transformation. According to the review, innovation and integration constitute organizations' two mechanisms to realize digital transformation. Companies innovate by developing a digital strategy, mobilizing for digital transformation, exploiting and leveraging digital capabilities, creating digital innovation, and merging human–machine interaction. In addition, companies initiate integration mechanisms such as developing digital transformation strategy, increasing technological flexibility, and promoting physical-digital harmonizing by promoting cross-functional cooperation and various means to assimilate digital technologies in organizations. Finally, the outcome of digital transformation is an agile organization embedded in a dynamic and ever-changing ecosystem. Such an organization is characterized by a malleable, agile organizational structure, technology-supported management style, digital and customer experience-focused business models, smart, connected customized products, and supported by automatized, data-driven, and virtual business processes. In summary, the digital transformation approach complements agile manufacturing and project management approaches, explaining when and how agile organizations emerge.

The research on agile manufacturing and supply chains helped to accumulate agile template-related knowledge, facilitating its diffusion among manufacturing companies. Further, manufacturing companies taped on agile project management literature to increase the effectiveness of new product design projects. Recently, companies have exploited lessons from digitally transformed companies to increase their agility. Together these three streams of research, in particular agile manufacturing and supply chains, agile project management, and digital transformation, contributed to contemporary understanding of how companies can survive in continuously changing environments. These three streams provide unique insights into organizational agility.

Being agile is defined in various ways. We draw on three definitions of agility in the context of production companies (Table 4.2).

The definitions capture different levels of agility. Gunasekaran's (1998) explanation defines the rationale for agile organizations, characterized as a capability to prevail in continuously changing environments through reactively following or proactively shaping customers' needs. Yusuf et al. (1999) provide competitive characteristics that differentiate agile manufacturing organizations. Finally, Narasimhan et al. (2006) describe the properties of the agile production system. In summary, the authors use the agility concept to refer to a business-level concept, strategic differentiator, and manufacturing system characteristic. Drawing on Bernardes and Hanna (2009), we refer to agility as a concept addressing "competitiveness in the current fast-paced and unpredictable industrial environment" through the "ability to fundamentally change states to accommodate unforeseen circumstances in a timely manner" (p. 42).

In this chapter, we proposed that understanding how industrial companies become agile could be explained by taping on the three sources of literature that deal with agile manufacturing and supply chains, agile project management, and digital transformation literature. The literature provides a complete picture for companies willing to create a malleable, agile organization design characterized by flexible manufacturing processes that together allow thriving in the constantly changing environment. In the next chapter, we focus on the agility framework that reveals the complexity of the Agile template.

4.3 Agility Framework

In this chapter, drawing on Zhang and Sharifi's (2007) and Zhang (2011) taxonomy of agile organizations, we present a framework that relates agility drivers, agility practices, types of agile firms, and their performance characteristics (Fig. 4.1). Zhang and Sharifi (2007) provided empirical evidence that three types of agile companies can be distinguished: responsive, quick, and proactive companies which are motivated by a unique set of drivers, facilitated by different sets of practices, and eventually characterized by different characteristics such as responsiveness, quickness or proactiveness.

The agility drivers are external and internal forces that facilitate organizations to become more agile. Authors identify various factors that contribute to adopting agility-oriented strategies. Yusuf et al. (1999) propose the factors influencing

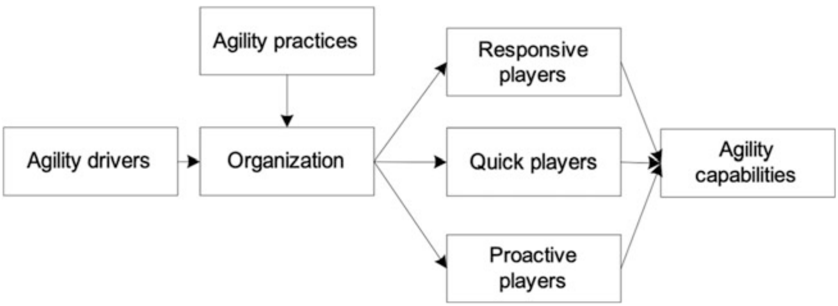

Fig. 4.1 The typology of agile organizations based on Zhang and Sharifi (2007)

firms' decision to increase agility: automation and price/cost consideration, widening customer choice and expectations, competing priorities, integration and proactivity, and achieving manufacturing requirements in synergy. Zhang and Sharifi (2007) propose the following agility drivers: change in the marketplace, change in competitive basis, change in customer requirements, change in technology, change in social factors (i.e., environmental, cultural, and political pressures) and internal drivers (i.e., strategy for continuous improvement or moving toward excellence). Tseng and Lin (2011) argue that the main changes in the business environment can be summarized into five categories: "market volatility caused by growth in the market niche, increasing the introduction of new products and product life; intense competition caused by rapidly changing markets, pressure from increasing costs, international competitiveness, Internet usage and a short development time for new products; changes in customer requirements caused by demands for customization, increased expectations about quality and a quicker delivery time; accelerating technological changes caused by the introduction of new and efficient production facilities and system integration; and changes in social factors caused by environmental protection, workforce/workplace expectations, and legal pressure" (p. 3698). In summary, the authors outlined that companies experience a varied mix of technology, customer, and business environment-related factors that drive the necessity to increase agility. One can say that these trends are even more intense than ten years ago, making the body of knowledge in agile manufacturing even more critical. After reviewing agility drivers, we turn on practices facilitating agility.

Gunasekaran et al. (2019) propose that the practices associated with agile manufacturing generally fall into five groups: mass customization, manufacturing digitalization and automation, technology utilization, employee empowerment, and supply chain networking. Mass customization refers to practices that allow tailoring products to customers' preferences. First, mass customization practices depend on the level of customization of the products pursued by the company. There are at least six levels of customization named after the stage where customization is performed: design customization, fabrication customization, assembly customization, sale customization, packaging and distribution customization, and usage customization (Da Silveira et al. 2001).

Second, manufacturing automation and digitalization facilitate elicitation of customer needs, flexibility, and efficiency of design and manufacturing. The core automation and digitalization technologies for agile organizations include computer-aided design and manufacturing technologies contributing to customer needs elicitation, augmentation, integration, analytics, and automation affordances. Customer needs elicitation affordance denotes the hardware and software infrastructure which enables customers to design their products. Augmentation refers to the means to enhance human abilities to perform tasks (Raisch and Krakowski 2021). Connect affordance is the ability to connect technologies and people through wireless communication networks in the organization to share data and information (Lenka et al. 2017). Analytic affordance is the ability to collect data from the organization's activities and environment and transform it into valuable insights and actionable directives for the company (Lenka et al. 2017). Finally, automation affordance denotes the capability of a process or system to operate automatically (Raisch and Krakowski 2021).

Third, agility-oriented companies utilize various socio-material technologies contributing to agility. Rapid prototyping, concurrent engineering, design for manufacturing, and modular product design constitutes the cornerstone of socio-material practices facilitating organizational agility. Rapid prototyping constitutes the arrangement of technologies for producing accurate models of products or parts directly from CAD models quickly with little need for human intervention (Pham and Gault 1998). Concurrent engineering is the organization of the product development process from a sequential process to a concurrent process where marketing, product engineering, process engineering, manufacturing planning, and sourcing activities overlap (Koufteros et al. 2001). Design for manufacturing is the application of the manufacturing technology at an early stage of design (Hallgren and Olhager 2009). Finally, modular product design is an approach to designing a variety of products while using the same modules of components called "platforms" (Jose and Tollenaere 2005). This is not an exhaustive list of agility-related socio-material practices, but it provides a glimpse into contemporary agility-related practices.

Fourth, there is a consensus among scholars of agile organizations that employee empowerment is critical for companies in turbulent markets (Gunasekaran et al. 2019). Empowerment refers to organizational policies regarding employee training, teaming, and involvement in decision-making. The higher the instability of markets, the more differentiated and loosely coupled organizations tend to become. Such organizational designs require decentralized decision-making, problem solving skills, creativity, and improvisation.

Finally, the last group of practices is related to supply chain networking. Supply chain networking refers to integrating supply chain members, coordinating the flow of information, and selecting the decoupling point (Naylor et al. 1999). Developing new products and manufacturing current ones depend on collaboration with customers and suppliers. Customer involvement in product design speeds up the new product design processes. The timely supply of materials and components decreases production costs and results in a shorter lead time. Eventually, supply chain networking and integration practices constitute the last groups of essential agility-related practices. After reviewing practices contributing to agility, we reveal the performance capabilities that characterize agile companies.

The research on agility capabilities is clustered into two streams. The first stream identified capabilities as competitive performance characteristics allowing companies to differentiate themselves from competitors. Responsiveness and flexibility are two essential capabilities associated with agile organizations. Zhang and Sharifi (2007) propose that responsiveness is "the capability to identify, respond to and recover from changes" (p. 354). Holweg (2005) defines responsiveness as "the ability of the manufacturing system or organization to respond to customer requests in the marketplace." Finally, Bernardes and Hanna (2009) define responsiveness as a "propensity for purposeful and timely behavior change in the presence of modulating stimuli" (p. 41). In summary, we consider responsiveness a firm-level capability that refers to a timely response to customer-related changes. Flexibility is another capability associated with agile organizations. Zhang and Sharifi (2007) propose that flexibility denotes “the capability to perform different tasks and achieve different objectives with the same set of resources/facilities” (p. 354). Bernardes and Hanna (2009) define flexibility as the “ability of a system to change status within an existing configuration (of pre-established parameters)” (p. 41). Finally, Zhang et al. (2003) refer to flexibility as the ability “to meet an increasing variety of customer expectations without high costs, time, organizational disruptions, or performance losses” (p. 142). In summary, flexibility is the organizational ability to accommodate changes within existing configurations, such as effectively managing demand variability or a predefined variety of production options. Quickness, proactiveness, and customer focus constitute other capabilities associated with agile organizations. Quickness is the organizational ability to operate at high speed, for example, offering concise product lead time. Customer focus denotes the capability of an organization to understand its customers. Finally, agile organizations tend to be associated with proactiveness, which refers to an organization’s ability to create or control a market situation rather than just responding to it after it has happened.

The second research stream of agile-related capabilities focused on the bundle of assets and processes allowing companies to perform agility-related tasks in a superior way. The organization is as agile as its processes are agile. Following the logic, the authors proposed capabilities that contribute to the agility of the order processing, design and development, manufacturing, and supply chain-related processes. For example, Salvador et al. (2009) argue that organizations should possess solution space development capability while managing orders, allowing customers to customize products while minimizing the complexity of choice (Salvador et al. 2009). Naylor et al. (1999) argue that companies should embrace an integrated supply chain, lead time compression, rapid reconfiguration, and robust process design capabilities while managing their supply chains. The integrated supply chain capability mobilizes all the supply chain members and eases the flow of information, resources, and goods. Lead time compression is the ability to respond quickly to a customer’s order. Rapid reconfiguration capability introduces new products into manufacturing and low changeover times among the product mix. Finally, robust process design is the ability to reuse and recombine existing organizational and supply chain resources to fulfill heterogeneous and ever-changing customer requirements (Naylor et al. 1999). In summary, both research streams identified organizational characteristics necessary to retain competitiveness in the fast-changing and unpredictable environment by developing new products, transforming its resource base, and reconfiguring resources according to external changes.

The unique environmental drivers and practices result in three types of agile firms characterized by exclusive characteristics, specifically *responsive*, *quick*, and *proactive performers* (Zhang and Sharifi 2007) and Zhang (2011), described in Table 4.3. Further, we describe these types of agile companies following Zhang and Sharifi’s (2007) and Zhang (2011) findings.

Proactive performers operate in the most volatile environment compared with quick and responsive performers. Such companies suffer from high pressures in a

Table 4.3 Types of agile firms (based on Zhang and Sharifi 2007; Zhang 2011)

	Responsive performers	Quick performers	Proactive performers
Context	The environment is moderately volatile	The environment is the least volatile	The environment is highly volatile
Strategic focus and capabilities	Flexibility and responsiveness to changes	Quick delivery	Proactiveness and customer focus
Description	Preoccupied with flexibility and responsiveness to changes, these companies do not emphasize proactiveness and partnerships with other organizations. The companies also are not characterized by quickness	Preoccupied with strong customer focus, the companies do not emphasize flexibility and responsiveness to changes. They also place a low priority on proactiveness	Preoccupied with proactiveness and customer focus, they emphasize all agility-related capabilities. The companies try to be flexible, quick, and responsive simultaneously

rapidly changing environment. They are exposed to fast change in the market, competition, changing customer requirements, complex social factors, and changing technology compared with other agile organizations. The proactive performers report more extensive usage of agility-related practices. These companies exploit relationships with suppliers and customers, use advanced technology, integrate horizontally and vertically, and involve customers in operations more extensively than other agile performers. Focused on proactiveness and customer focus, they emphasize all agility-related capabilities. The companies try to be flexible, quick, and responsive simultaneously. Proactive performers are the quintessence of agility.

The responsive performers' environment is moderately volatile. Such companies report the most extensive usage of information technology compared with other types of agile performers, especially information systems that enable tracking changes in the environment. Flexibility and responsiveness to changes constitute their strategic focus. Focused on flexibility and responsiveness to changes, these companies are less engaged in proactiveness and partnerships with other organizations. They are not characterized by quickness as well. In summary, responsive performers respond to customer demands by offering a wide variety of products and variable volumes. They closely follow customer needs changes and tend to be responsive as much as possible.

Finally, quick performers operate in an environment characterized by low changes and uncertainty compared with proactive and responsive performers. Such companies tend to integrate with their suppliers and customers extensively. The companies tend to integrate vertically and horizontally. Quickness constitutes the strategic focus of these companies. Preoccupied with strong customer focus, the companies are less concerned with flexibility and responsiveness to changes. They also place a low priority on proactiveness. Eventually, quick performers choose a quick delivery as a critical differentiator.

In summary, using the Agility framework proposed at the beginning of this chapter, we described three types of agile companies: proactive, responsive, and quick performers. We characterized these types of organizations by illuminating their drivers, practices, and performance capabilities. These three types of companies reveal a multiplicity of agile templates. However, there is a common denominator among all three types of organizations: they try to survive in the fast-changing industrial environment through the "ability to fundamentally change states to accommodate unforeseen circumstances in a timely manner" (Bernardes and Hanna 2009, p. 42).

4.4 Agile Template Adoption Challenges

Our review revealed a multiplicity of agile templates. Becoming an agile organization, especially becoming a proactive performer, could be challenging because proactive performers emphasize all agility-related capabilities. Further, we review challenges associated with agile template adoption, specifically inadequate demand for mass customization and the challenge of becoming efficient and innovative simultaneously.

The agile template was proposed to answer the increasing heterogeneity of customers' preferences. The more considerable the heterogeneity of customer preferences in the market, the higher potential mass customization provides for a company. Further, we will refer to Piller et al. (2004), whose discussion regarding the demand for mass customized products is still relevant today. First, it is usually assumed that customer preferences are heterogeneous and change quickly. Despite this assumption, the demand for mass customized products is rarely measured precisely. Second, from the company's perspective, customization can be carried out with regard to style, functionality, and fit (Piller 2004). Style refers to the aesthetic design of products. Functionality addresses product performance characteristics. Customization with regard to fit denotes tailoring a product according to a body measurement or the dimensions of a room or other physical objects. Customizing the product's functionality requires gathering customer preferences regarding the performance of the products, which further must be implemented during the manufacturing stage. Research shows that despite a desire to be unique, customers more often desire to adapt to fashion trends but not to create them (Thompson and Haytko 1997). Customization of functionality requires elicitation of customer needs and places challenges for manufacturing which should be ready to manufacture different variants of products. The customization for product fit poses the highest challenges for manufacturers. It requires expensive systems to gather customers' preferences regarding dimensions and may require a complete redesign of the products. The customization is challenging not only for manufacturers but also for consumers. Customization of product style, functionality, and fit requires intentional co-creation from consumers. The customer needs elicitation process requires time and places a cognitive burden on a consumer. Customers could easily be overwhelmed by the number of possibilities at their disposal, negatively affecting their satisfaction. Think of the apparel industry. Would you prefer to customize all clothing that you buy? Apparel producers offer standard products incorporating some variety based on fit (i.e., size) and style (i.e., colors) customization. In many industries, such an approach of providing standard products incorporating some variety is still attractive, while mass customization efforts are bound to niche markets.

The agile template is based on the assumption that organizations can achieve significant innovation and change while retaining the efficiencies of mass production (MacCarthy 2013). Agile organizations should become innovative and efficient at the same time. Balancing efficiency and exploitation with innovation and exploration is known as a productivity dilemma (Abernathy 1978; Adler et al. 2009) or a challenge of ambidexterity (O'Reilly and Tushman 2013). The dilemma emerges because long-term adaptability and short-term efficiency are achieved by fundamentally different means (Farjoun 2010). Exploitation enables efficiency, while exploration facilitates innovation (March 1991). Exploitation is achieved through control, formalization, standardization, the introduction of discipline, tight coupling, a decrease in variance, and the development of skills and habits (Farjoun 2010; Vilkas et al. 2021). Exploration is achieved through processes of mindfulness, searching, experimentation, preoccupation with failure, fostering of imagination and openness, loose coupling, and an increase in variance (Farjoun 2010; Vilkas et al. 2021). The previous research reveals that the quest to become efficient or innovative does not pose a challenge for organizations because the mechanisms responsible for exploration and exploitation are well known (Adler et al. 2009; Farjoun 2010). The challenge emerges when companies seek to become innovative and efficient simultaneously. The challenge arises because the means of exploitation and exploration are conflicting. Companies struggle to engage in standardization and experimentation simultaneously. It is challenging to be loosely and tightly coupled at the same time. Even more, the processes of exploitation that lead to efficiency tend to overwhelm processes of exploration, leading to innovation (March 1991; Eisenhardt et al. 2010) because exploitation provides faster results and is less risky. Scholars have proposed several approaches to overcoming the productivity dilemma. The research on ambidexterity exposed several meaningful approaches to how contextual, structural, and individual factors may contribute to ambidextrous organizations (Chakma et al. 2021).

In this section, we reviewed the challenges of adopting the agile template. We identified two challenges: inadequate demand for mass customization and the challenge of becoming efficient and innovative simultaneously. In the next chapter, we present the results of the empirical research using a representative sample of 500 companies in a single country. The research reveals how prevalent agile template-related competitive priorities, methods, and quality and cost performance capabilities are. The research also reveals the effects of digital manufacturing innovations, lean methods, and bundles of services on flexibility, fast delivery, and innovation performance.

4.5 Affordances of Organizational and Technological Innovations for Agility

4.5.1 Model, Measures, and Methods

In this chapter, by using a representative sample of 500 manufacturing companies in a single country, we shed light on the prevalence of digital manufacturing innovations and performance capabilities associated with agility, such as flexibility, fast delivery, and innovation. We also seek to explore whether digital innovations are contingent on size, industry, product complexity, lot size, the type of design process, and the type of manufacturing process of organizations. Finally, we engage in predicting which digital manufacturing innovations, lean practices, and services contribute to flexibility, delivery, and innovation performance.

The model that guides our empirical efforts is presented in Fig. 4.2.

We assume that digital manufacturing innovations, lean methods, and services positively affect flexibility, delivery speed, and innovation performance. Further, we elaborate on the measures of the constructs constituting our model.

The operationalization of digital manufacturing practices consisting of latent constructs of digital connectivity methods, software-enabled operations, industrial robots, and 3D printing was proposed for the study. The proposed latent constructs were measured by 11 items. The manifest indicators for lean, agile practices and services are provided in Table 4.4.

The selection of competitive performance measures was based on an extensive review of scholarly literature. Several approaches to the operationalization of performance dimensions are available (Narasimhan et al. 2006; Grossler and Grubner 2006; Schroeder et al. 2011; Narasimhan and Schoenherr 2013; Singh et al. 2015).

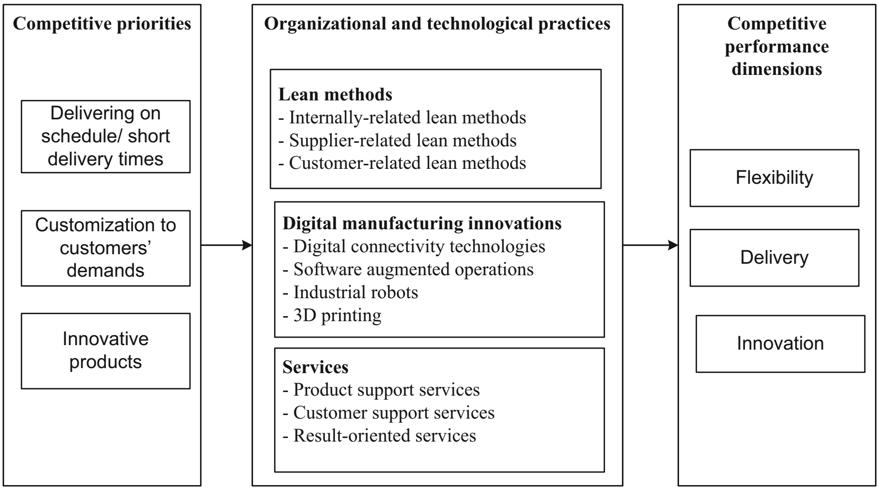

Fig. 4.2 The model of agile template of organizing for empirical analysis

Table 4.4 Measures of digital manufacturing innovations, lean practices, and services

Type of methods	Latent constructs	Manifest indicators
Lean methods	Internally related lean methods	Standardized work instructions
		Value stream mapping
		Customer or product-oriented lines/cells
		5S
		Visual management
		Pull of production
		Setup time reduction
		Total preventive maintenance
		Statistical process control
		Involvement of employees
		Integration of tasks
	Customer-related lean methods	Customer involvement
	Supplier-related lean methods	Supplier development
		Supplier feedback
		JIT delivery
Digital manufacturing innovations	Digital connectivity technologies	Mobile programming and controlling of facilities and machinery
		Digital solutions to provide documentation directly to the shop floor
		Digital exchange of product/process data with suppliers/customers
	Software augmented operations	Software for production planning and scheduling
		Near real-time production control systems
		Systems for automation and management of internal logistics
		Simulation for product design and development
	Industrial robots	Industrial robots for manufacturing processes
		Industrial robots for handling processes
	3D printing	3D printing technologies for prototyping
		3D printing technologies for manufacturing
Services	Product support services	Installation, start-up
		Maintenance and repair
		Training
		Remote support for clients
		Design, consulting, project planning
		Software development
		Revamping or modernization
		Take-back services
	Customer support services	Online training, documentation, error description

(continued)

Table 4.4 (continued)

Type of methods	Latent constructs	Manifest indicators
		Web services product configuration or product design
		Remote monitoring of operating status
		Mobile devices for diagnosis, repair, or consultancy
		Data-based services based on big data analysis
	Result-oriented services	Renting products, machinery, or equipment
		Full-service contracts
		Operation of products at customer site for the customer
		Taking over the management of maintenance activities

Table 4.5 The measures of flexibility, delivery, and innovation performance

Competitive performance	AVE	Composite reliability	Reliability (alpha)	Dimensions of competitive performance	Loading	*p* values of loadings
Flexibility	0.789	0.949	0.95	Ability to adjust production volumes	0.954	0.000
				Ability to produce a range of products	0.859	0.000
				Speed on new product introduction into the plant	0.883	0.000
Delivery	0.88	0.973	0.966	Delivery dependability	0.947	0.000
				Delivery speed	0.931	0.000
Innovation	0.874	0.954	0.954	Lead time to introduce new products	0.912	0.000
				Number of new products introduced each year	0.916	0.000
				The extent of innovativeness of products	0.975	0.000

The items used to measure delivery, flexibility, and innovation performance dimensions are provided in Table 4.5. Operationalization captures the main aspects of the performance dimensions since it is based on the measures most commonly applied in previous research (Roth et al. 2008). The questions provided in the questionnaire are listed in Annex 4.1.

Descriptive statistics were used to analyze the diffusion of product innovation, customization, fast delivery competitive priorities, digital manufacturing innovations, flexibility, delivery, and innovation performance dimensions. The ranking of competitive performance from 1 to 6, 1 indicating “the most important” and 6 “not at all important," was used to measure the prevalence of product innovation, customization, and fast delivery competitive priorities. The dichotomous variable "Currently used Digital manufacturing innovations" (0—No, 1—Yes) was used to measure the diffusion of digital technologies in a country. The ordinal variable "Extent of the used potential of the Digital manufacturing innovations" (1—Low, 2—Medium, 3—High) was used for the evaluation of the extent of the used potential of the digital technologies. A five-point scale was used to assess delivery, flexibility, and innovation performance, where 1 indicates the poor/low end of the industry, 3 refers to the average, and 5 stands for the superior performance level compared to the competitors in the industry.

A comparison of the column proportions (while adjusting p values with the Bonferroni method) was conducted to investigate whether digital innovations are contingent on size, industry, design process type, and the manufacturing process of organizations. The dichotomous variable "Currently used Digital manufacturing innovations" (0—No, 1—Yes) was used for the analysis. Partial squares-based structural equation modeling was used for confirmatory factor analysis of the measurement models and to estimate the effects of the digital technologies, lean methods, and services on flexibility, fast delivery, and innovation performance. Endogenous variables of flexibility, fast delivery, and innovation were treated as reflective latent multi-item constructs. Exogenous constructs of the digital technologies, lean methods, and services were tested as single-item constructs. PLS consistent algorithm was used (path weighting scheme, stop criteria 300 iterations, or 1.0E-7 stop criteria). Casewise deletion of missing values was employed. The analysis was performed by using *SmartPLS* software.

4.5.2 Diffusion of Agile Template-Related Competitive Priorities, Digital Innovations, and Performance Dimensions

4.5.2.1 Diffusion of Product Customization, Delivery, and Innovation Competitive Priorities

In this chapter, we describe the prevalence of product customization, fast and on-time delivery, and innovative product competitive priorities among manufacturing firms. The importance of these competitive priorities is provided in Table 4.6.

The graphical representation of the importance of product customization, fast delivery, and innovative product competitive priorities is provided in Figs. 4.3, 4.4, and 4.5. The analysis reveals that only 5.6% of companies compete using innovative products competitive priority. 12.0% of companies compete on delivery on schedule/short delivery competitive priorities. Finally, 20.8% of companies argue that product customization is the most important strategic priority.

The importance of the competitive priorities was measured on a six-point scale. The top three choices reveal a varied level of importance, while the last three

Table 4.6 The prevalence of product customization, fast and on-time delivery, and innovative product competitive priorities

Level of importance/Competitive priority	Product customization		Delivery on schedule/short delivery		Innovative products	
	No.	%	No.	%	No.	%
The most important	104	20.8	60	12.0	28	5.6
Important	101	20.2	133	26.7	43	8.6
Slightly important	120	24.0	117	23.4	61	12.2
Not so much important	93	18.6	103	20.6	93	18.6
Not important	52	10.4	56	11.2	129	25.9
Not at all important	29	5.8	30	6.0	145	29.1

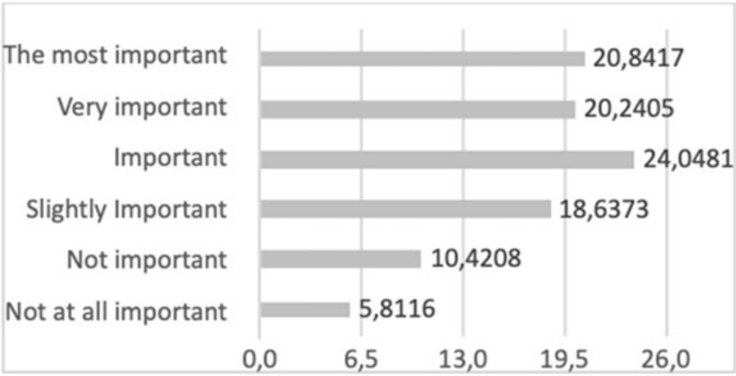

Fig. 4.3 The importance of product customization competitive priority, %

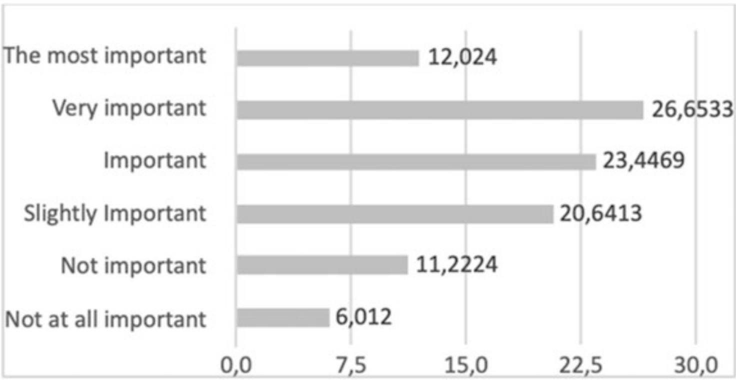

Fig. 4.4 The importance of fast and on-time delivery competitive priority, %

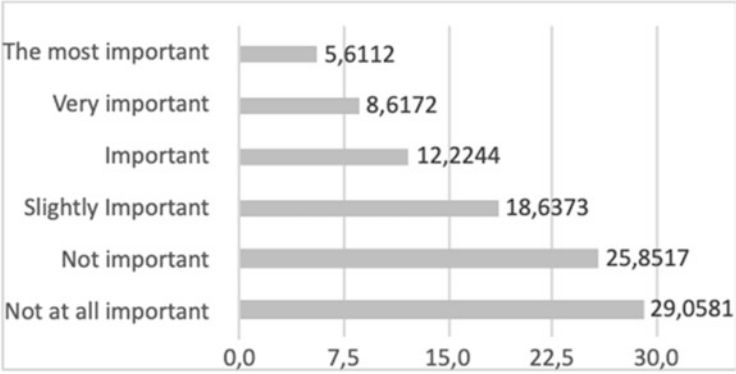

Fig. 4.5 The importance of innovative products competitive priority, %

categories reveal the absence of importance of a competitive priority. The analysis reveals that only 26.5% of organizations indicate that innovative products are an important competitive priority. 73.5% of organizations tend to devalue innovative products as a strategic differentiator. The fast and on-time delivery strategic priority is important for 62.1% of organizations compared with 37.9% of organizations that argue that this priority is overall of little importance. Finally, the product customization strategic priority is more prioritized by the companies. 65.1% of companies identify this priority as important. The findings propose that product innovation is not at the top of strategic priorities among organizations.

4.5.2.2 Diffusion of Digital Innovations

In this chapter, we describe the prevalence of digital innovations, the extent of delivery, flexibility, and innovation competitive capabilities in the sample organizations. The frequencies of the usage of digital innovations, together with the used potential of digital innovations in organizations, are provided in Table 4.7.

The ranking of digital manufacturing methods according to their usage is provided in Fig. 4.6.

Overall, digital innovations are not extensively diffused among organizations. Software for production planning and scheduling (e.g., ERP) is the most commonly used digital manufacturing innovation. Other digital innovations are even less prevalent. One-third of the explored organizations use mobile devices for programming and controlling facilities and machinery, digital solutions that provide documentation to the shopfloor, near real-time production control systems (e.g., MES), and engage in the digital exchange of product/process data with suppliers/customers. A quarter of the researched organizations use systems for automation and management of internal logistics (e.g., RFID) and simulation methods for product design and development. Industrial robots are employed by 14.4% of organizations. Finally, 3D printing is used by 4.7% of organizations.

Table 4.7 Prevalence and the used potential of digital innovations ($N = 199$)

	Used by		The extent of the used potential			
	No.	%	Initial attempt to utilize, %	Partly utilized, %	Extensively utilized, %	Mean of used potential
Mobile programming and controlling of facilities and machinery	71	35.7	7.5	18.1	10.1	2.070
Digital solutions to provide documentation directly to the shop floor	70	35.2	8.0	13.6	13.1	2.145
Software for production planning and scheduling	86	43.2	3.0	20.6	18.6	2.369
Digital exchange of product/ process data with suppliers/ customers	59	29.6	4.0	16.6	9.0	2.169
Near real-time production control systems	67	33.7	6.5	14.6	12.1	2.167
Systems for automation and management of internal logistics	50	25.1	3.5	12.1	9.0	2.224
Simulation for product design and development	48	24.1	5.5	10.6	8.0	2.104
Industrial robots for manufacturing processes	32	16.1	3.5	6.0	5.5	2.133
Industrial robots for handling processes	25	12.6	5.0	5.0	2.0	1.750
3D printing technologies for prototyping	9	4.5	2.5	1.5	0.0	1.375
3D printing technologies for manufacturing	10	5.0	3.5	1.0	0.5	1.400

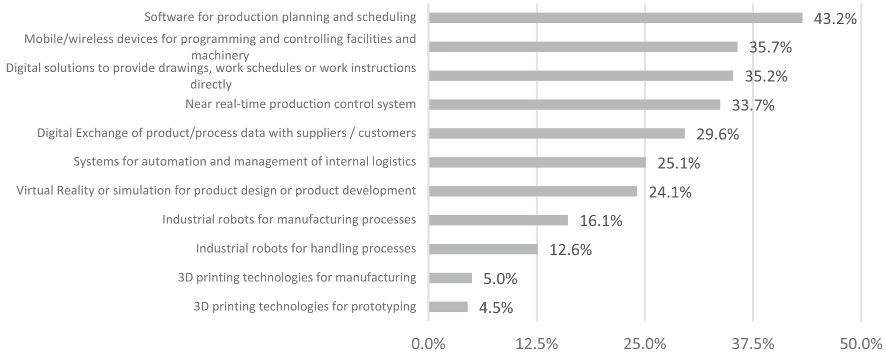

Fig. 4.6 Diffusion of digital innovations, %

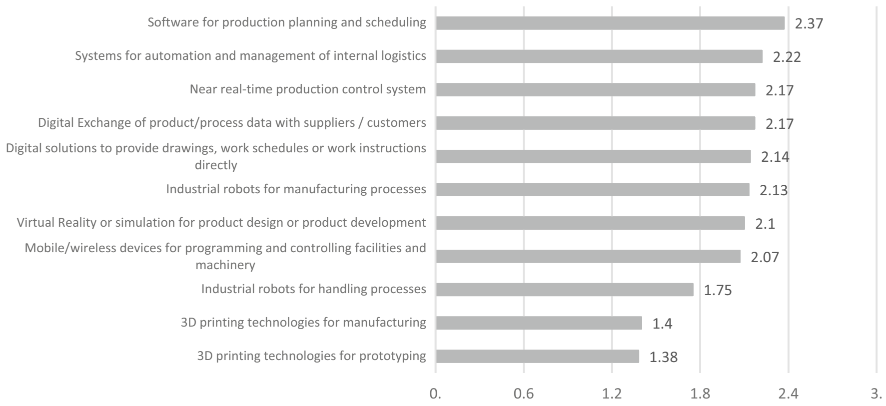

Fig. 4.7 The extent of the used potential of digital innovations (max 3, $N = 199$)

We expected higher diffusion of software for production planning and scheduling (e.g., ERP) among organizations. ERP systems, or their substitute MES systems, constitute the main production control point allowing for the integration of manufacturing processes, efficient variety handling, and digitalization of part of the manufacturing documentation (Hendricks et al. 2007). ERP systems are used by 43.2% of organizations. MES systems are used by 33.7% of organizations. However, 22.6% of organizations use both ERP and MES systems. Thus, only 56.3% of organizations are using either ERP, MES, or both systems. On the other hand, it is encouraging that around a quarter of the explored organizations use systems for automation and management of internal logistics (e.g., Warehouse management systems, RFID) and simulation methods for product design and development.

The extent of the used potential of digital innovations is shown in Fig. 4.6. The extent of the utilized potential is low for the initial attempt to utilize a practice, medium for the partly utilized practice, and high for the extensive utilization of a practice (Fig. 4.7).

The organizations that employ digital innovations are confident with their usage. Except for 3D printing and industrial robots for handling processes, organizations report higher than the medium extent of the used potential of the digital innovations they use. Software for production planning and scheduling (e.g., ERP) stands out as the highest utilized innovation among all the measured digital innovations. At the same time, the findings reveal that organizations are at the experimentation stage with 3D printing and industrial robots for handling processes.

4.5.2.3 Extent of Diffusion of Delivery, Flexibility, and Innovation Performance Dimensions

Delivery, flexibility, and innovation performance capabilities allow competition with rivals in the target markets (Schroeder et al. 2011). Delivery performance is the extent to which an organization can quickly deliver the type and quantity of products required by its customers (Sansone et al. 2017; Schroeder et al. 2011). Flexibility performance explains the extent to which an organization can manage production resources and accommodate varying customer requests (Sansone et al. 2017, Schroeder et al. 2011). Finally, innovation performance is the extent to which the company is capable of implementing new ideas or changes, both large and small ones, that have the potential to contribute to organizational objectives (Peng et al. 2008; Schroeder et al. 1989).

The constituents of delivery, flexibility, and innovation performance dimensions are provided in Tables 4.8, 4.9, and 4.10. A comparison of the means of the delivery, flexibility, and innovation performance shows that companies are most confident with their flexibility performance (3.76), followed by the delivery performance (3.58), and, finally, innovation performance (3.25). All the dimensions of delivery, flexibility, and innovation capabilities are perceived as very close to each other.

Analysis of delivery, flexibility, and innovation performance confirms that companies are the most confident with their flexibility performance, then with delivery, and, finally, with innovation performance. 44.8% of companies argue that their flexibility performance is much or somewhat better than that of the competitors.

Table 4.8 Evaluation of flexibility performance

		Much worse	Worse	Equal	Better	Much better	Mean	Overall mean
Ability to adjust production volumes	Frequency	1	5	168	149	71	3.721	3.72
	Percent	0.2	1	33.6	29.8	14.2		
	Percent	0.2	0.4	29.6	29.6	19		
Ability to produce a range of products	Frequency	2	9	160	137	86	3.751	
	Percent	0.4	1.8	32	27.4	17.2		
Speed of new product introduction into the plant	Frequency	0	9	164	138	68	3.699	
	Percent	0	1.8	32.8	27.6	13.6		

Table 4.9 Evaluation of delivery performance

		Much worse	Worse	Equal	Better	Much better	Mean	Overall mean
Delivery dependability	Frequency	0	3	210	147	59	3.625	3.61
	Percent	0	0.6	42	29.4	11.8		
	Percent	0	2.4	44.8	23.4	9.6		
Delivery speed	Frequency	0	4	220	136	57	3.590	
	Percent	0	0.8	44	27.2	11.4		

Table 4.10 Evaluations of innovation performance

		Much worse	Worse	Equal	Better	Much better	Mean	Overall mean
Lead time to introduce new products	Frequency	7	26	213	80	26	3.261	3.250
	Percent	1.4	5.2	42.6	16	5.2		
Number of new products introduced each year	Frequency	6	27	221	69	28	3.245	
	Percent	1.2	5.4	44.2	13.8	5.6		
Innovativeness of products	Frequency	8	23	222	75	29	3.263	
	Percent	1.6	4.6	44.4	15	5.8		

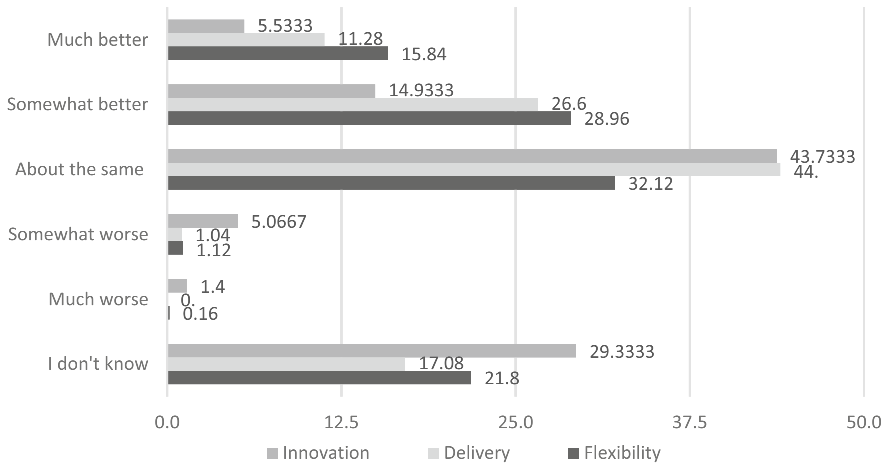

Fig. 4.8 Evaluation of delivery, flexibility, and innovation performance, %

37.9% of companies argue that their delivery performance is much or somewhat better than the competitors. In comparison, only 20.4% of companies argue that their innovation performance is much or somewhat better than the competitors. The findings are somewhat unexpected as it is thought that delivery is a capability that is less difficult to develop compared to the flexibility competitive performance dimension (Ferdows and De Meyer 1990; Rosenzweig and Roth 2004) (Fig. 4.8).

In this chapter, we presented our analysis of the prevalence of agile template-related competitive priorities, digital innovations, and performance capabilities. Analysis of the delivery, flexibility, and innovation performance in relation to competitors reveals that companies are the most confident with their flexibility performance, then with delivery performance, and, finally, with innovation performance. Analysis of the diffusion of digital manufacturing innovations shows that most of the digital innovations are used by less than half of the companies representing the population of the companies employing 20 and more employees within the researched country. Such results are worrying. Digital manufacturing innovations are considered to be the driving force of the contemporary manufacturing industry (Manyika et al. 2012; Schlaepfer et al. 2015; Roland Berger 2014; Brynjolfsson and McAfee 2014; Ford 2015).

4.5.3 Differences in Digital Manufacturing Innovations Usage Among Organizations

In this chapter, we investigate whether digital innovations are contingent on the size of the company, industry, the type of the product development process, and the type of the manufacturing process of the organization. The extent of the usage of digital innovations was measured only for organizations with at least 20 employees. This decision is based on the premise that organizations with fewer than 20 employees seldom use complex digital innovations.

First, the analysis was conducted to determine whether the adoption of digital innovations depends on the size of the company. We propose that the extent of adoption of digital innovations is positively associated with the size of the organization. The results of comparing the proportions of the usage of digital innovations across differently sized organizations are presented in Table 4.11.

Our analysis reveals that, with some exceptions, the extent of adoption of digital innovations increases as the size of the organization increases. Large companies use production planning and scheduling software, automation and management of internal logistics systems, and digital exchange of product/process data with suppliers/customers more extensively than small and medium companies. In the case of other digital innovations, there is no statistically significant difference in the usage of innovations across different organizations. Large companies have more motifs to adopt digital innovations as these allow countering the complexity of operations. They also have more financial resources to invest in digital innovations. Moreover, large companies possess IT expertise for adopting, maintaining, and integrating digital innovations.

Further, we analyzed whether the usage of digital innovations differs across sectors. We analyzed the difference in the usage of digital innovations across engineering, food, textile, and wood and furniture sectors. The results of our analysis are presented in Table 4.12.

The results show that engineering companies adopt digital solutions designed to provide documentation directly to the shop floor and systems for automation and management of internal logistics compared with the other sectors. However, the analysis reveals that engineering companies tend to use digital innovations more extensively than companies from other sectors. Engineering companies may be better integrated into global automotive, machinery, and electronics value chains where the competition is fiercer than in local markets. These companies tend to invest more into digital innovations as digital innovations are associated with competitiveness.

Table 4.11 Difference in usage of the lean methods in terms of the company size

Digital innovations	20–49 employees (1), %	50–249 employees (2), %	250+ employees (3),%	Difference
Mobile programming and controlling of facilities and machinery	34.0	37.7	**64.3**	No stat. sign. differences
Digital solutions to provide documentation directly to the shop floor	34.0	**42.7**	38.5	No stat. sign. differences
Software for production planning and scheduling	33.0	56.8	**78.6**	1 < 2.3
Digital exchange of product/process data with suppliers/customers	33.7	24.6	**69.2**	1.2 < 3
Near real-time production control systems	31.9	37.8	**64.3**	No stat. sign. differences
Systems for automation and management of internal logistics	22.4	26.7	**61.5**	1.2 < 3
Simulation of product design and development	19.4	32.9	**38.5**	No stat. sign. differences
Industrial robots	18.2 a	**28.6a**	21.4 a	No stat. sign. differences
3D printing	5.4 a	8.5 a	**14.3a**	No stat. sign. differences

Further on, we analyzed whether the extent of digital innovation usage depends on the design and development process type. We propose that the flexibility of the design and development process is positively associated with the extent of usage of digital innovations. The results of our analysis are presented in Table 4.13.

The analysis of the comparison of proportions of digital innovations adoption across contrasting types of the design process does not reveal any statistically significant differences. The means of the adoption of digital innovations are so close to each other that it could be stated that the design and development process type is not associated with the extent of usage of digital innovations that were measured in this study.

Finally, we tested whether the type of the manufacturing process contributes to the extent of the usage of the lean methods. We propose that the companies whose manufacturing is characterized by the make-to-order model use digital innovations more extensively than those whose manufacturing is characterized by the make-to-stock model. The results of our analysis are provided in Table 4.14.

The results show that there is again no difference in the adoption of digital innovations based on the type of the manufacturing process. The extent of the adoption of digital innovations in companies that operate make-to-stock and

Table 4.12 Difference in the usage of digital innovations across sectors

Digital innovations	Engineering (1), %	Food (2), %	Textile (3), %	Wood and furniture (4), %	Difference
Mobile programming and controlling of facilities and machinery	36.2 a	**37.5**	36.7	36.4	No stat. sign. differences
Digital solutions to provide documentation directly to the shop floor	**55.3**	20.0	21.4	43.6	1 > 2.3
Software for production planning and scheduling	**60.9**	39.4	35.5 a	42.6	No stat. sign. differences
Digital exchange of product/process data with suppliers/customers	34.0	35.5 a	24.1	**37.3**	No stat. sign. differences
Near real-time production control systems	**47.8**	38.7	26.7	35.8	No stat. sign. differences
Systems for automation and management of internal logistics	**40.4**	24.2	31.0	13.2	1 > 4
Simulation for product design and development	**31.9**	12.9	22.6 a	30.8	No stat. sign. differences
Industrial robots	**35.4**	18.2	23.3	14.5	No stat. sign. differences
3D printing	**10.9**	10.0	NA	7.8	No stat. sign. differences

make-to-order operations is close, thus revealing that the manufacturing process does not have an association with the adoption of digital innovations.

In this chapter, we analyzed whether the adoption of digital innovations is contingent on the size, industry, the type of product development process, and the type of manufacturing process. The results reveal that the size and the type of the industry are the most important contingency variables. Digital innovations are used more extensively by large companies. However, we were able to confirm statistically significant differences in the case of software for production planning and scheduling, systems for automation and management of internal logistics, and digital exchange of product/process data with suppliers/customers. Further, our analysis shows that engineering companies use more digital innovations than companies from other sectors. However, statistically significant differences were confirmed only in the case of digital solutions to provide documentation directly to the shop floor and systems for automation and management of internal logistics. Finally, the study shows that the extent of design mix flexibility is not associated with the adoption of digital innovations. The research also suggests that the manufacturing

Table 4.13 Difference in the usage of digital innovations across different types of design and development processes

Digital innovations	According to the customers' specification (1), %	As a standardized basic program incorporating customer-specific options (2), %	For a standard program from which the customer can choose options (3), %	Difference
Mobile programming and controlling of facilities and machinery	**40.5**	31.1	37.7	No stat. sign. differences
Digital solutions to provide documentation directly to the shop floor	**39.0**	36.4	33.9	No stat. sign. differences
Software for production planning and scheduling	38.7	**54.5**	45.9	No stat. sign. differences
Digital exchange of product/process data with suppliers/customers	**34.7**	26.2	32.1	No stat. sign. differences
Near real-time production control systems	32.4	35.6	**39.0**	No stat. sign. differences
Systems for automation and management of internal logistics	24.0	22.7	**33.9**	No stat. sign. differences
Simulation for product design and development	27.0	20.0	**28.1**	No stat. sign. differences
Industrial robots	**25.0**	18.2	20.6	No stat. sign. differences
3D printing	4.3	**9.1**	8.8	No stat. sign. differences

process type–whether make-to-stock or make-to-order—is also not associated with the extent of the introduction of digital innovations.

4.5.4 Relationships of Digital Manufacturing Innovations

In this chapter, we consider the relationships between digital manufacturing innovations. The relationships between digital manufacturing innovations have not been well explored, except for some preliminary studies (e.g., Tortorella and Fettermann

Table 4.14 The difference in the usage of digital innovations across different types of the manufacturing process

Digital innovations	Make-to-order (1), %	Make-to-stock (2), %	Difference
Mobile programming and controlling of facilities and machinery	33.3	**47.5**	No stat. sign. differences
Digital solutions to provide documentation directly to the shop floor	**37.4**	32.4	No stat. sign. differences
Software for production planning and scheduling	**46.0**	43.9	No stat. sign. differences
Digital exchange of product/process data with suppliers/customers	30.1	**40.5**	No stat. sign. differences
Systems for automation and management of internal logistics	24.3	**39.0**	No stat. sign. differences
Simulation for product design and development	**28.1**	20.5	No stat. sign. differences
Industrial robots	21.0	**30.2**	No stat. sign. differences
3D printing	5.4a	**12.5**	No stat. sign. differences

2018; Rossini et al. 2019). The high relationship among digital innovations indicates the cumulative nature of the technologies. The relationships of digital manufacturing innovations are provided in Table 4.15.

Software for production planning and scheduling (e.g., ERP) correlates statistically significantly with all the digital manufacturing innovations. ERP systems are central to manufacturing operations (Jacobs 2007; Hendricks et al. 2007; Bendoly and Cotteleer 2008). Software for production planning and scheduling (e.g., ERP) digitizes part of manufacturing documents, such as the bill of materials, production schedules, lists, and reports. ERP systems may be used to connect to customers or suppliers. ERP systems can be integrated with MES systems. ERP system's database may be used as the central manufacturing information database where the data from automated management of internal logistics (e.g., RFID) is kept. Our findings confirm the centrality of software for production planning and scheduling (e.g., ERP and MES) in the context of digital manufacturing innovations.

Other digital innovations also highly correlated with each other. The analysis of the relations of digital innovations reveals the cumulative nature of digital innovations. The digital manufacturing innovations may complement each other. For example, systems for automation and management of internal logistics (e.g., RFID) may not provide benefits unless software for production planning and scheduling (e.g., ERP) has been introduced. The cumulative nature of digital innovations is an important result providing insight into how advanced manufacturing technologies may be related to competitive performance. In the next section, we will explore the effects of digital manufacturing innovations, lean methods, and services on agility-related performance dimensions, such as flexibility, delivery speed, and innovation.

Table 4.15 The relationships among digital manufacturing innovations

	1	2	3	4	5	6	7	8	9	10	11
1. Mobile devices for controlling facilities and machinery	1.000										
2. Digital solutions to provide documentation directly to the shop floor	**0.294****	1.000									
3. Software for production planning and scheduling	**0.191****	**0.299****	1.000								
4. Digital exchange of product/process data with suppliers/customers	**0.271****	**0.249****	**0.307****	1.000							
5. Near real-time production control system	0.086	**0.227****	**0.403****	**0.202****	1.000						
6. Systems for automation and management of internal logistics	0.097	**0.150***	**0.316****	**0.168***	**0.307****	1.000					
7. Simulation for product design and development	0.111	**0.302****	**0.300****	**0.198****	0.099	**0.303****	1.000				
8. Industrial robots for manufacturing processes	0.102	**0.228****	**0.179***	0.012	0.043	**0.153***	0.182**	1.000			
9. Industrial robots for handling processes	0.112	0.088	**0.139***	0.065	−0.045	**0.266****	**0.214****	**0.363****	1.000		
10. 3D printing technologies for prototyping	0.061	0.082	**0.212****	0.007	0.104	**0.249****	**0.188****	0.120	**0.162***	1.000	
11. 3D printing technologies for manufacturing	0.118	**0.194****	**0.228****	**0.140***	0.111	**0.197****	**0.144***	0.087	0.127	0.649**	1.000

Spearman, Listwise deletion, $N = 497$; **. Correlation is significant at the 0.01 level (2-tailed); *. Correlation is significant at the 0.05 level (2-tailed); c. Listwise $N = 202$

4.5.5 Effect of Digital Manufacturing Innovations, Lean Methods and Services on Flexibility, Delivery, and Innovation Performance Dimensions

Following Zhang and Sharifi (2007), it was proposed that there are three types of agile companies: responsive, quick, and proactive performers. Responsive players are characterized by flexible performance. Quick performers exhibit fast delivery performance. Finally, proactive players exhibit a broad range of competitive performance, such as flexibility, delivery, and innovation. Path analysis using partial squares structural equation modeling approach is used to determine which digital innovations, lean practices, and services influence flexibility, fast delivery, and innovation performance. In total, nine models were constructed. The first three models were constructed to estimate the effects of digital manufacturing innovations, lean practices, and services on flexibility performance. The three other models predicted the effects of digital manufacturing innovations, lean practices, and services on delivery performance. Finally, the last three models were introduced to determine the effects of digital manufacturing innovations, lean practices, and services on innovation performance. The results of the models are presented in Tables 4.15, 4.16, and 4.17.

Effects of digital innovations, lean methods, and services on flexibility are shown in Table 4.16. Systems for automation and management of internal logistics (e.g., Warehouse management systems and RFID) and Virtual Reality or simulation for product design or product development (e.g., FEM, Digital Prototyping and

Table 4.16 Effects of digital innovations, lean methods, and services on flexibility performance

Model/methods	Model 1: Lean methods -> Flexibility		Model 2: Digital innovations -> Flexibility		Model 3: Services -> Flexibility	
Effects*	Path estimate**	*p* values	Path estimate	*p* values	Path estimate	*p* values
Involvement of employees	0.145	0.017	–	–	–	–
Methods of statistical control of production and quality	0.15	0.009	–	–	–	–
Systems for automation and management of internal logistics	–	–	0.232	0.008	–	–
Simulation for product design and product development	–	–	0.219	0.034	–	–
Digital (remote) monitoring of operating status (e.g., condition monitoring)	–	–	–	–	0.158	0.043
R^2	0.114		0.175		0.049	
R^2 adjusted	0.074		0.116		0.007	
N	354		151		372	

* Only statistically significant path estimates are shown
** Standardized path estimates

Table 4.17 Effects of lean methods, digital innovations, and services on delivery performance

Model/methods	Model 1: Lean methods -> Delivery		Model 2: Digital innovations -> Delivery		Model 3: Services -> Delivery	
Effects*	Path estimate**	*p* values	Path estimate	*p* values	Path estimate	*p* values
Customer or product-oriented lines/cells	0.143	0.024	–	–	–	–
Mobile programming and controlling of facilities and machinery	–	–	0.186	0.026	–	–
Installation, start-up	–	–	–	–	0.145	0.041
Web-based offers for product utilization (online training, documentation, error description)	–	–	–	–	0.032	0.653
R^2	0.063		0.097		0.053	
R^2 adjusted	0.025		0.041		0.015	
N	309		412			

* Only statistically significant path estimates are shown
** Standardized path estimates

computer models) contribute statistically significantly to flexibility performance. FEM, Digital Prototyping, and computer modeling enable to introduce of new products more effectively as prototypes may be electronically tested (Sass and Oxman 2006). Warehouse management systems and RFID provide instant information on the availability of raw materials, work-in-process materials, and the finished goods inventory, which is critical in managing a high variety of products effectively (Lim et al. 2013). However, we were unable to confirm the effect of production planning and scheduling software (e.g., ERP) (-0.091, $p = 0.309$) and digital exchange of product/process data with suppliers/customers (-0.076, $p = 0.432$), which, by some authors (e.g., Fugate and Mentzer 2004) are identified as important methods contributing to flexibility.

We found that two lean methods and one service practice contribute to flexibility performance. Involvement of employees in the improvement and statistical control of production and quality contributes to flexibility performance. However, we were unable to confirm the impact of pull of production (-0.008, $p = 0.884$) and setup time reduction (0.109, $p = 0.055$), which are associated with the agile template (e.g., Qamar et al. 2018). Finally, digital monitoring of the operating status (e.g., condition monitoring) positively contributes to flexibility performance. However, we surprisingly fail to associate Web-based services for customized product configuration or product design (development) with flexibility (0.111, $p = 0.114$). In summary, digital manufacturing innovations have the highest contribution to the variation of flexibility performance (17.5%), followed by lean methods (11.4%) and services (4.9%). In total, all the methods in the three modes account for 33.8% performance variation of the flexibility performance.

Table 4.18 Effects of lean methods, digital innovations, and services on innovation performance

Model/methods	Model 1: Lean methods -> Innovation		Model 2: Digital innovations*** -> Innovation		Model 3: Services**** -> Innovation	
Effects*	Path estimate**	*p* values	Path estimate	*p* values	Path estimate	*p* values
Involvement of employees	0.118	0.042	–	–	–	–
Renting products, machinery, or equipment	–	–	–	–	0.15	0.047
Revamping or modernization	–	–	–	–	0.137	0.041
R^2	0.049		0		0.092	
R^2 adjusted	0.004		0		0.047	
N	329		146		399	

* Only statistically significant path estimates are shown
** Standardized path estimates

The effects of digital innovations, lean methods, and services on delivery performance are shown in Table 4.17. Two dimensions of delivery performance were measured: delivery speed and delivery dependability, i.e., on-time delivery. Out of 15 lean methods, 11 digital manufacturing innovations, and 18 services, only four methods contribute to delivery performance, in particular, customer or product-oriented lines or cells, mobile/wireless devices for programming and controlling facilities and machinery, installation services, and Web-based offers for product utilization.

Some authors treat fast delivery as an effect of the lean template (e.g., Womack and Jones 1996). However, we fail to relate other lean methods (except for customer- or product-oriented lines/cells) with fast delivery. Customer or product-oriented lines or cells contribute to quicker delivery by reducing the throughput time. We would have expected that lean methods, such as standardized work instructions (0.071, $p = 0.238$), value stream mapping (0.021, $p = 0.71$), setup time reduction (0.014, 0.81), 5S (−0.018, 0.776), and visual management (0.044, $p = 0.469$) would contribute or be associated with delivery speed. Furthermore, we also failed to associate such digital innovations as software for production planning and scheduling (e.g., ERP) (0.091, $p = 0.349$) and digital exchange of product/process data with suppliers/customers (−0.047, $p = 0.62$) with fast delivery as expected. In total, the models explain 21.3% of the variation in delivery performance.

Finally, the effects of digital innovations, lean methods, and services on innovation performance are shown in Table 4.18. All the models explain only 14.1% of innovation performance variability. However, neither the lean methods nor digital innovations are associated with innovation performance. We found that the involvement of employees in improvement increases innovation performance. Such results are in line with other previous research (e.g., Vilkas et al. 2021), which shows that the involvement of employees contributes to incremental process innovations. We also found that particular result-oriented services, such as renting products, machinery, or equipment and revamping or modernization services, may contribute to innovation performance.

This section explores which digital innovations, lean practices, and services influence flexibility, delivery, and innovation performance. Our predictors could predict 33.8% of the variation in flexibility performance, 21.3% of the variation in delivery performance, and 14.1% of the variation in innovation performance.

4.6 Summary

In this chapter, we aimed to conceptually and empirically elaborate on the agile template of organizing. We reviewed definitions of agility, summarized the drivers motivating companies to adhere to the agile template, and elaborated on the multiplicity of agile templates. Using a representative sample of 500 enterprises in a single country, we shed light on the diffusion of digital manufacturing innovations associated with agility. We also revealed the prevalence of performance dimensions of flexibility, fast delivery, and innovation across organizations. We determined if digital manufacturing innovations are contingent on size, industry, product complexity, lot size, the type of the design process, and the type of the manufacturing process of organizations. Finally, we predicted which digital manufacturing innovations, lean practices, and services contribute to flexibility, delivery, and innovation performance.

The literature review revealed a multiplicity of templates related to agility. Following Zhang and Sharifi (2007), it was proposed that there are three types of agile companies: responsive, quick, and proactive. Responsive players are characterized by flexible performance. Quick performers exhibit fast delivery performance. Finally, proactive players exhibit a broad range of performance capabilities, such as flexibility, delivery, and innovation. Our findings show that 5.6% of companies compete on innovative products' strategic priority. 12.0% of companies compete on delivery on schedule/fast delivery, and 20.8% of companies identify product customization as the most critical differentiator. The findings are surprising because only 26.5% of organizations indicate that innovative products are an important competitive priority, while 73.5% tend to devalue innovative products as an important strategic differentiator. The obtained empirical analysis results show that the diffusion of digital manufacturing innovations varies from 43.3% to 4.5%. We may conclude that the diffusion of digital innovations is not extensive enough. Especially worrying is that only 56.3% of organizations are using either ERP, MES, or both systems, which are considered the main production control point. We found that flexibility is the most prevalent capability. It was followed by delivery and, finally, innovation. 44.8% of companies claim that their flexibility performance is much or somewhat better than competitors. 37.9% and 20.4% claimed the same about delivery and innovation.

Further, we determined that digital innovations are contingent on size, industry, design process type, and organizations' manufacturing process. The obtained results reveal that the size and the type of the industry are the most important contingency variables. Large companies use digital innovations more extensively than small and medium companies. However, we could confirm statistically significant differences in the case of software for production planning and scheduling, systems for automation and management of internal logistics, and digital exchange of product/process data with suppliers/customers. Further, our analysis revealed that engineering companies use more digital innovations than companies from other sectors. However, the statistically significant differences were confirmed only in the case of digital solutions to provide documentation directly to the shopfloor and the systems for automation and management of internal logistics. Finally, our study showed that the extent of the design mix flexibility is not associated with adopting digital innovations. The research also demonstrated that the type of the manufacturing process, either make-to-stock or make-to-order, is also not associated with the extent of the introduction of digital innovations.

Analysis of the relationships among digital manufacturing innovations revealed a high level of interpretation of the innovations. Software for production planning and scheduling (e.g., ERP) correlates statistically significantly with all the digital manufacturing innovations. Other innovations are also extensively related and reinforcing. Finally, we sought to determine which digital innovations, lean methods, and services contribute to flexibility, fast delivery, and innovation performance. Our analysis revealed that digital innovations, lean methods, and services account for 33.8% of flexibility, 21.3% of delivery, and 14.1% of innovation performance variation. Involvement of employees in improvement, statistical control of production and quality, systems for automation and management of internal logistics (e.g., RFID), Virtual Reality or simulation for product design or product development, and remote monitoring of the operating status positively affect flexibility performance. Customer or product-oriented lines or cells in the factory, mobile/wireless devices for programming and controlling facilities and machinery, installation services, and Web-based offers for product utilization services positively influence the delivery performance. Finally, the involvement of employees in improvement, renting products, machinery or equipment services, and revamping or modernization services are positively associated with innovation performance. These findings show the unequal contribution of digital manufacturing innovations, lean methods, and services to flexibility, fast delivery, and innovation competitive performance.

Annex 4.1 Measurement Scales[1]

Measurement of Competitive Priorities

Please rank the following competitive factors in order of significance to distinguish your factory positively from competitors.

Please rank from 1 to 6, 1 indicating "the most important." Please do not assign equal importance to any factors.

- Product price
- Product quality
- Innovative products
- Customization to customers' demands
- Delivering on schedule/short delivery times
- Services

Measurement of Organizational Characteristics

Which of the following characteristics best describes your main product or line of products?

Product Development

- According to customers' specification
- As a standardized basic program incorporating customer-specific options.
- For a standard program from which the customer can choose options.
- Does not exist in this factory.

Batch or Lot Size

- Single unit production
- Small or medium batch/lot
- Large batch/lot

[1] European manufacturing survey scales (EMS 2022).

Manufacturing Process

– Upon receipt of customer's order, i.e., made-to-order.
– Final assembly of the product is carried out upon receipt of customer's order, i.e., assembly-to-order.
– To stock (before customer's order).
– Does not exist in this factory.

Product Complexity

– Simple products
– Products with medium complexity
– Complex products

Measures of Lean Methods

Which of the following organizational concepts are currently used in your factory? 0—No; 1—Yes.

If Yes, what is the extent of the used potential of the method? 1—Low; 2—Medium; 3—High.

(Extent of the used potential—Extent of actual utilization compared to the most reasonable maximum potential utilization in your factory: Extent of the utilized potential "low" for an initial attempt to utilize, "medium" for partly utilized, and "high" for extensive utilization.)

– Standardized and detailed work instructions (e.g., standard operation procedures SOP and MOST).
– Measures to improve internal logistics (e.g., Value Stream Mapping/Design, changed spatial arrangements of production steps).
– Fixed process flows to reduce setup time or optimize change over time (e.g., SMED, QCO).
– KANBAN, Internal zero-buffer principle.
– Customer- or product-oriented lines/cells in the factory (instead of task-/operation-structured shopfloors).
– Detailed regulations on the arrangement and setting of the work equipment and storage of intermediary products (e.g., Method of 5S).
– Decreasing the time of equipment downtime (Total Productive/Preventive Maintenance).
– SPC (process capability analysis).
– Display boards in production to illustrate work processes and work status (e.g., Visual Management).

- Involvement of employees in improvement (e.g., A3, KAIZEN, and PDCA).
- Integration of tasks (planning, operating, or controlling functions with the machine operator).
- Involvement of customers in production (e.g., sharing demand information and joint product development).
- Inventory managed by suppliers, exchange of cost structure information.
- Collecting supplier feedback (e.g., sharing information on quality and delivery problems).

Measures of Digital Manufacturing Innovations

Which of the following technologies are currently used in your factory? 0—No; 1—Yes.

If Yes, What is the extent of the used potential of the method? 1—Low; 2—Medium; 3—High. Extent of used potential—Extent of actual utilization compared to the most reasonable maximum potential utilization in your factory: Extent of utilized potential "low" for an initial attempt to utilize, "medium" for partly utilized and "high" for extensive utilization.

- Mobile/wireless devices for programming and controlling facilities and machinery (e.g., tablets).
- Digital solutions to provide drawings, work schedules, or work instructions directly on the shopfloor.
- Software for production planning and scheduling (e.g., ERP system).
- Digital Exchange of product/process data with suppliers/customers (Electronic Data Interchange, EDI).
- Near real-time production control system (e.g., Systems of centralized operating and machine data acquisition, MES),
- Systems for automation and management of internal logistics (e.g., Warehouse management systems, RFID).
- Virtual Reality or simulation for product design or product development (e.g., FEM, Digital Prototyping, and computer models).
- Industrial robots for manufacturing processes (e.g., welding, painting, and cutting).
- Industrial robots for handling processes (e.g., depositing, assembling, sorting, packing processes, and AGV).
- 3D printing technologies for prototyping (prototypes, demonstration models, 0 series).
- 3D printing technologies for manufacturing of products, components and forms, tools, etc.).

Measures of Services

Which of the following product-related Services do you offer your customers? 0—No; 1—Yes.

- Installation, start-up
- Maintenance and repair
- Training
- Remote support for clients (e.g., User Helpdesk and web platform)
- Design, consulting, project planning (incl. R&D for customers)
- Software development (e.g., software customization)
- Revamping or modernization (incl. enhancement of functions, software extensions, etc.)
- Take-back services (e.g., recycling, disposal, and taking back)

Which of the following digital solutions do you offer as part of your Service portfolio? 0—No; 1—Yes.

- Web-based offers for product utilization (online training, documentation, error description).
- Web-based Services for customized product configuration or product design (development).
- Digital (remote) monitoring of operating status (e.g., condition monitoring).
- Mobile devices for diagnosis, repair, or consultancy (e.g., digital camera, smartphone, and tablets).
- Data-based Services based on big data analysis.

Which of the following business models do you offer your customers? 0—No; 1—Yes.

- Renting products, machinery, or equipment.
- Full-service contracts with a defined scope to maintain your products.
- Operation of your own products at customer site/for the customer (e.g., pay on production).
- Taking over the management of maintenance activities for the customer in order to guarantee availability or costs.

Measurement of Operational Performance

Indicate how well your factory performed compared to its competition within your industry along these different performance dimensions, 1—Much worse, 2—Somewhat worse, 3—About the same, 4—Somewhat better, 5—Much better, 6—I don't know.

Quality

- Product overall quality performance
- Product reliability
- Product features
- Product conformance
- Product durability

Cost

- Unit cost
- Manufacturing overhead cost
- Inventory turnover

Flexibility

- Ability to adjust production volumes
- Ability to respond to changes in delivery requirements
- Ability to customize products
- Ability to produce a range of products
- Speed of new product introduction into the plant

Delivery

- Delivery accuracy
- Delivery dependability
- Delivery quality
- Delivery availability
- Delivery speed

Innovation

- Lead time to introduce new products
- Number of new products introduced each year
- The extent of innovativeness of products

Service

- Regular products support services
- Online product support services
- Advanced service provision models
- Data-driven services

Digitalization

- Digitalization of production data
- Connection production system elements
- Autonomous production data collection and analysis
- Automation of production processes

Measures of Financial Performance

Please characterize your factory:

- Annual turnover
- In 2017 XX million €
- In 2015 XX million €

- Number of employees
- In 2015 XX number
- In 2015 XX number

- Return on sales (before tax, 2017)
- negative
- 0 up to 2%
- >2 up to 5%
- >5 up to 10%
- >10%

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Chapter 5
Service-Oriented Performers

Abstract Service-oriented, lean, and agile templates of organizing constitute manufacturing companies' most popular organizational forms. Companies that adhere to the service-oriented template differentiate on services competitive priority, provide product and customer support services, and are characterized by superior service and digitalization performance. Despite huge attention, representative empirical studies of companies adhering to the service-oriented template are rare. In this chapter, we use a representative sample of 500 manufacturing companies to reveal the diffusion of service-oriented template-related characteristics. The results show that only 2.4% of companies compete on services competitive priority. 1.4% and 2.6% of companies claim better servitization and digitalization performance than their competitors. Our analysis reveals that engineering companies and companies which customize products provide more services than other companies. The results show that a mix of services contributes to service performance. Maintenance and repair, remote support for clients, online training, and taking over the management of maintenance activities are positively associated with service performance. In contrast, Full-service contracts and take-back services have a negative effect on service performance. Such findings contribute to a more nuanced understanding of Service-oriented template diffusion among manufacturing firms.

5.1 Introduction

In the first chapter, we proposed a typology consisting of lean, agile, and service-oriented templates of organizing. We stated that organizing templates could be described using a framework constituted of goals, competitive priorities, practices, competencies, and differentiating competitive capabilities. We suggested a system of propositions regarding the service-oriented template:

– The goal of the service-oriented template is to provide the customer with value by sharing risk and by reduction of the total cost of ownership of the product, and delivering new efficiencies and other benefits (Iansiti and Lakhani 2014).
– Organizations that adhere to the service-oriented template differentiate on the services' competitive priority.

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- Organizations that adhere to the service-oriented template provide a product, customer support, and result-oriented services enabled by advanced manufacturing and digital technologies.
- Organizations that adhere to the service-oriented template excel at intelligence, connect, analytic, and outcomes-based sales competencies.
- Organizations that adhere to the service-oriented template are superior along with service performance in comparison to organizations that adhere to the agile and lean templates.

The characterization of the service-oriented template provides a background for further studies of the service-oriented template. In this chapter, we aim to conceptually and empirically elaborate the service-oriented template by determining:

- The extent of companies that compete on service competitive priority.
- The diffusion of product, customer support, and result-oriented services, service-related digitalization, and services competitive performance dimensions.
- If product, customer support, and result-oriented services are contingent on size, industry, product complexity, lot size, the type of the design process, and the type of the manufacturing process of organizations.
- Which services, digital manufacturing innovations, and lean methods contribute to service-related digitalization and service performance?

The chapter is organized as follows. First, we review definitions of servitization, reveal the evolution of the concept of servitization, summarize drivers for servitization, and identify the challenges of adopting the service-oriented template. Later on, by using a representative sample of 500 manufacturing firms in a single country, we outline the diffusion of a product, customer support, and result-oriented services in the country. We also shed light on the prevalence of digitalization and service performance capabilities. Finally, we estimate which digital innovations, lean practices, and services contribute to digitalization and service performance.

5.2 Definition of Servitization

Our research shows that contemporary manufacturing companies are increasingly oriented toward services, i.e., they combine services with the products they produce. According to Neely et al. (2011), service infusion is mostly observed in companies that offer complex electromechanical products. Usually, manufacturing companies decide to integrate services while aiming to support the products they produce. It should be noted that the manufacturing companies that have integrated services are also oriented toward technological innovations, higher quality, and lower costs. The traditional manufacturing approach is risky in a time of changing demand considering the growing competitiveness of the developing countries, globalization, and the increased informational awareness of consumers.

Table 5.1 Definitions of servitization

Author	Definition of servitization
Vandermerwe and Rada (1988)	"Market packages or bundles of customer-focused combinations of goods, services, support, self-service, and knowledge."
Desmet et al. (2013)	"A trend in which manufacturing firms adopt more and more service components in their offerings."
Verstrepen et al. (1999)	"Adding extra service components to core products."
Lewis et al. (2004)	"Any strategy that seeks to change the way in which product functionality is delivered to its markets."
Ward and Graves (2005)	"Increasing the range of services offered by a manufacturer."
Ren and Gregory (2007)	"A change process wherein manufacturing companies embrace service orientation and/or develop more and better services, with the aim to satisfy customer's needs, achieve competitive advantages and enhance firm performance."
Baines et al. (2009)	"The innovation of an organization's capabilities and processes to better create mutual value through a shift from selling the product to selling product-service systems."
Macdonald et al. (2016)	"Offerings that combine supplier and customer resources to create value."

In scientific literature, such orientation toward services is frequently called servitization. Servitization, representing an area of convergence between services and products, has recently gained increasingly more attention among researchers in various fields, for example, production marketing (Grönroos 2000; Partanen et al. 2020; Spring and Araujo 2013; Ulaga and Loveland 2014), service management (Kindström et al. 2015; Raddats et al. 2015; Witell and Löfgren 2013), operations management (Wilkinson et al. 2009; Smith et al. 2014). Servitization opens up various opportunities for manufacturing companies. According to Coreynen et al. (2017), servitization is associated with product innovation, standardization, and increased consumer satisfaction and loyalty. Such integration between services and products relates to innovative organizational competencies and processes that allow shifting from selling products to selling services that create value for the company and the consumer. Coreynen et al. (2017) find that services help to maintain positive revenue flows and increase profitability in manufacturing.

Despite the attention toward servitization, the united definition of servitization is still lacking. Vandermerwe and Rada (1988) introduced the concept of servitization in the 1980s. They described servitization as a more extensive market package that includes products, services, support, knowledge, and self-service options aiming to offer added consumer value. Later, some authors referred to servitization as product-related services or product-service systems (Mont 2002; Tukker and Tischner 2006) and integrated solutions (Brax and Jonsson 2009; Davies 2004; Davies et al. 2007; Windahl 2007; Baines et al. 2009; Kowalkowski et al. 2017). Several definitions of servitization representing its nature are offered in Table 5.1.

Our literature review suggests that servitization combines offerings and transformation processes. In this chapter, we draw on the definition of servitization by Kowalkowski et al. (2017), proposing that servitization is an "overarching concept that includes but goes beyond service infusion, where servitization is defined as the transformational process of shifting from a product-centric business model and logic to a service-centric approach (p. 7)." Our research shows that the concepts *of* servitization, service infusion, and service transition are used as synonyms to define service development processes in manufacturing companies. In the next chapter, we analyze the evolution of the servitization field.

5.3 Evolution of Servitization

The interest in servitization boomed after publications by Vandermerwe and Rada (1988) and Oliva and Kallenberg (2003). Vandermerwe and Rada (1988) describe how product manufacturers shift to the service-oriented business model and become consumer-oriented companies offering a package of products, services, support, self-service, and knowledge. The authors referred to such transition of manufacturing companies as servitization. Oliva and Kallenberg (2003) offered similar findings. However, they described stages of transition from products to services and convincingly identified the drivers and challenges of each stage. Later, servitization became the subject of research in several research communities in service marketing, service management, industrial marketing, operations management, and engineering. The main research directions are product–service differentiation, competitive strategy, consumer value, consumer relation, and product–service configuration.

Servitization Trajectories Servitization scholars propose that manufacturing companies have different options when transitioning to service-oriented companies (Brax and Visintin 2017; Kowalkowski et al. 2015). These authors define various transformation trajectories of manufacturing companies. They indicate that shifting from the suppliers of the "base" product companies, which are oriented toward goods and standardization, can usually move under three trajectories: possibility vendor, performance vendor, and industrializer (Table 5.2).

Despite defining trajectories representing increasingly complex service offers, scholars lack insights into how manufacturers could monetize their services successfully. The cost associated with servitization does not guarantee a quick financial return to manufacturing companies, while the interaction between the service-oriented business model and product innovation can result in a short-term performance decline (Visnjic et al. 2012). On the other hand, Coreynen et al. (2017) found that despite potentially adverse financial impact in the short term. Servitization creates a higher added value for a company in the long term.

For a better understanding of the servitization value, Coreynen et al. (2017) created a two-dimensional servitization pyramid where the horizontal dimension shows the difference between the services that support the product and the consumer

Table 5.2 Service transformation trajectories in manufacturing companies (Kowalkowski et al. 2015)

Strategic trajectory	Offer	Drivers and obstacles
Possibility vendor	Individual consumption offers based on product and service packages, including contracts of extended service usage. Greater attention is placed on consumer-oriented services and value efficiency	Drivers: Consumer loyalty, business growth, and stable revenue make top management consider service company configuration Obstacles: Inbound resistance to change, product-oriented culture and processes, low coordination skills
Performance vendor	Services are developed having a long-term attitude, aiming to meet specific customer needs and ensure on-time performance	Drivers: Specific consumer demand, differentiation needs, development of strategic partnerships, and consumer retraining Obstacles: Inability to properly develop and manage operational and financial risks as well as integration and coordination between partners
Industrialiser	Individual and/or standardized offers having separated product-service packages applied or recombining offer components	Drivers: Economies of scale, usage of standards, mass adaptation, inbound resources, and knowledge Obstacles: Low service experience due to lack of knowledge related to the product-service system and consumer experience accompanied by low modularization competence

processes, while the vertical dimension presents three different value offers that can be made by manufacturing companies delivering to the consumers particular input, performance agreement, or guaranteed result. Such value offers are oriented toward several consumer groups: consumers who want to make something themselves, consumers who want us to do something together with them, and consumers who want us to do something for them.

First, according to Beuren et al. (2013), manufacturers often face internal and external barriers when shifting to higher-value services. Often, manufacturers are skeptical about infusing services in their products and their economic value. On the other hand, the essential shift in the company culture in relation to the infusion of services is inevitable for such companies. Witell and Löfgren (2013) state that from the perspective of demand, consumers do not always agree to pay for additional services and seek to get them free of charge. Manufacturers can overcome this barrier when they reach the first stage of the pyramid. When entering the second stage of the pyramid, manufacturers encounter other barriers. Consumers usually tend to buy a product and not pay for input or performance. According to Matthyssens and Vandenbempt (2010), consumers are also reluctant to enter into close cooperation with vendors because of their reluctance to share company information externally. When coming to the last stage of the pyramid, manufacturers may feel a lack of experience structuring the company to allow efficient development and provision of services supporting their product. When concluding, it may be claimed that manufacturers face problems related to their current business model while going through all the stages of the servitization pyramid. Coreynen et al. (2017) support the servitization perspective based on the consumer process (the right side of the pyramid) when the manufacturer seeks added value when infusing the service into the consumer business process. In this perspective, service becomes a long-term and relationship-based process when both parties cooperate and commonly create value, products that meet consumer needs, and supporting services. On the other side, the left side of the pyramid, which is significant for the product function, should not be forgotten, either.

Digitalization and Servitization Servitization is very much related to digital technologies. Nevertheless, the role of these technologies in service business transformation is still under investigated. Our study of this research (Neu and Brown 2005; Kowalkowski and Kindström 2009; Belvedere et al. 2013; Porter and Heppelmann 2014; Vendrell-Herrero et al. 2017; Coreynen et al. 2017) confirms that digitization leads to service innovations, empowering new product and service offers, and changing supply chain structures and competition in the industry. On the other hand, manufacturing companies are facing problems related to their cross-functionality and management. According to Storbacka (2011), such problems are usually investigated in the context of two perspectives: industrial and commercial.

From the industrial perspective, manufacturers seek to improve their ability to develop solutions more efficiently, using automated systems and improving decision-making processes. Manufacturers can employ knowledge not only for improving their process(es) but also for consumer ones, delivering training and consultation. According to Storbacka (2011), from the commercial perspective, vendors better understand the consumer value creation process and empower consumers to pursue their objectives. In this context, digitization allows reaching consumers with the help of self-service touchpoints, e.g., personal digital assistants. Manufacturers can also offer digitization-based packages that radically change consumer processes and disrupt vendor and consumer relations, e.g., online control or product surveillance devices. Such modified products create new conditions for manufacturers while providing better services in such areas as support, repair, and operation. This determines the importance of specific skills, knowledge, and processes in manufacturing.

Based on a multiple case study about the Belgian manufacturing industry, Coreynen et al. (2017) offered two cross-functional areas, i.e., commercialization and industrialization, which engage the infusion of consumer support services to be performed by consumers, i.e., advice, training, consultation, online self-service management. The authors also outline value servitization which facilitates consumer processes. This is associated with radical changes in vendor and consumer relations by offering consumers new digitization tools that enable consumer data collection. Then, companies can customize, integrate, and reform hybrid offers and give consumers what they need. Their results reveal that digitalization improves servitization processes, impacts higher-order routines regulating skills development, integration, and modification, and encodes change-oriented routines.

Ardolino et al. (2018) analyzed the impact of the Internet of Things, cloud computing, and predictive analytics on the development of service innovations. Their research shows that intelligent products, connectivity, cloud computing, and big data directly facilitate service infusion. The authors outlined 11 key digital capabilities of service transformation: identification (user), identification (product), geo-localization, time-stamping, intensity assessment, condition monitoring, usage monitoring, prediction, adaptive, remote, and control, optimization and prescriptions, and autonomy. Further, Ardolino et al. (2018) also propose that the role of digital technologies should be analyzed in the context of service trajectory transformation. The authors say that Internet of Things technology exerts the most significant influence in cases of availability provider and performance provider. Also, companies heading the way of performance providers depend on predictive analytics since they have to extract knowledge from their databases and develop more complex services. The importance of digital technologies for these services is so great that scholars propose the concept of *digital servitization*. Vendrell-Herrero et al. (2017) define digital servitization as the provision of IT-enabled (i.e., digital) services relying on digital components embedded in physical products. Marjanovic et al. (2019) investigated the impact of digital service portfolio antecedents on a firm's performance. The authors found that digital services can significantly increase the turnover ratio in manufacturing companies. In general, servitization scholars agree on the impact of information technology on service transformation in manufacturing companies (Belvedere et al. 2013; Coreynen et al. 2017; Akaka and Vargo 2014).

In summary, it can be stated that the concept of servitization was first coined in 1988 and has been investigated mainly by scholars in the fields of operations management, services, and marketing. Scholars identified different types of servitization trajectories for manufacturing companies. Each trajectory is characterized with unique challenges. Servitization and digitalization are intertwined extensively. Digital technologies are treated as the main driver of complex product support and result-oriented services. In the next chapter, we focus on the drivers of servitization.

5.4 Drivers and Barriers of Servitization

Confente et al. (2015) state that the manufacturing sector faces a necessary transformation conditioned by increased competition, reduced profits, and fragility of demand. Product-service integration allows companies to stand out above their competitors and achieve sustainable competitive advantage.

Drivers of servitization as a research subject gained much attention (Baines et al. 2009; Gebauer and Fleisch 2007; Mathe and Shapiro 1993; Mathieu 2001; Oliva and Kallenberg 2003; Vendrell-Herrero et al. 2014). Most authors investigated the reasons for choosing the provision of services in manufacturing companies and found that companies commonly choose servitization to stimulate growth, profit, and innovations. Ward and Graves (2005) research defined three groups of servitization drivers: financial, strategic, and marketing. Vendrell-Herrero et al. (2014) highlighted profit and cost as the main drivers of the process. When aiming for growth, product-related services enable increasing sales of the product itself. According to Baines et al. (2009), profit is defined as a financial driver in the scientific literature. In this context, services can stabilize profit through increased capacity utilization, entering service markets, and avoiding price competition in a mature product market. According to Goh and McMahon (2009), service innovations are associated with better management and digitalization of relations with the consumer. Financial drivers are most often associated with higher profit margins and revenue stability. According to Malleret (2006), the product-service combination is not so sensitive to price-based competition and allows for higher profitability than in the case of offering the product alone. Gebauer and Fleisch (2007) admit that services supporting the "base" product (e.g., planes) are more resistant to economic circles that affect investment and the acquisition of goods. Strategic drivers are associated with gaining a competitive advantage. According to Dachs et al. (2014), the usage of services opens up new competitive advantages, and they are sufficiently sustainable due to their intangibility and invisibility and thus cannot be easily copied. According to Gebauer and Fleisch (2007), the markets where differentiation strategies are based on product innovation, technologies, or low prices, are pretty hard to enter. The authors say that consumer-oriented services that supplement the "base" product can increase consumer value and decrease competition barriers. Manufacturing companies can choose among various service strategies. Raddats and Kowalkowski (2014) offer product-related services, process-related services, and vendor-independent operations services. Opresnik and Taisch (2015) also offer the big data strategy where information becomes the central element of the servitization process and whose management should be paid great attention. Marketing opportunities are usually assumed as the usage of services aiming to sell more products. According to Gebauer and Fleisch (2007), the component of services affects the decision to buy. It is essential in the business-to-business context where consumers are characterized as oriented to services that increase their satisfaction with and loyalty to the "base" product. Confente et al. (2015) confirm that services impact the repeated purchase, which is associated with maintaining good consumer relations and finding limitations concerning the "base" product. In general, servitization most often is chosen because of financial drivers (i.e., the revenue flow and profit margin), strategic drivers (i.e., competitive advantage and possibilities), and marketing drivers (i.e., consumer relation and product differentiation). Although servitization is associated with a financial cost, effective implementation of the servitization strategy can condition the company's sustainable performance in the long term. After discussing servitization drivers, it is essential to mention the possible *barriers.* According to Hou and Neely (2013), scientific literature lacks discussion of the servitization barriers at the conceptual level.

Hou and Neely (2013) identified seven categories of servitization barriers. First of all, they outlined competitors, suppliers, and partners. Service provision is related to the competitive environment involving various actors and conditions coordination and cooperation difficulties. The next barrier is associated with society and the legal environment. The legal environment restricting data collection and use and maturity of digital infrastructure can interrupt or slow the servitization process. The third barrier is related to the consumers who might become antagonistic when they lack trust in the company offering a traditional product with a service infused in it as it might be perceived as a higher-cost solution. In this case, attracting and retaining the consumer may be hard. The fourth barrier is related to the financial resources that would allow the infusion of services into the traditional system and enable the achievement of sustainable competitive advantage. Usually, servitization initiatives result in unexpected costs and a lack of service pricing competencies. The fifth barrier is related to the lack of knowledge, especially in traditional manufacturing companies, since they often lack service innovation and digitalization skills. The sixth barrier encompasses the potential lack of human resources as the development and scaling of services requires additional employees. Also, manufacturing companies may face obstacles associated with the service package design. The last barrier outlined by Hou and Neely (2013) is the organizational structure and culture, whose condition challenges are associated with the change of the organizational culture toward the development of services. It becomes a significant challenge for traditional companies adopting service-oriented templates. Notwithstanding such problems, servitization is one of the most successful perspectives for manufacturing companies aiming to gain a competitive advantage.

In this chapter, we suggested that servitization is driven by financial, strategic, and marketing drivers. We also reviewed the most critical barriers that challenge the adoption of a service-oriented template of organizing. In the next chapter, we shall focus on the features of servitization.

5.5 Challenges in Adoption of Servitization

Despite the benefits of servitization, scientific literature highlights difficulties associated with implementing services in manufacturing companies. Case studies show that some manufacturers face problems launching their services (Gebauer et al. 2005). Manufacturing companies allocate (relatively) extensive resources but do not always get the appropriate financial benefits. The authors call it the *servitization paradox* in manufacturing companies.

Gustafsson et al. (2005) find that most challenges emerge due to their manufacturing-oriented approach to business development after conducting 35 focus groups. Qualitative research shows that manufacturing companies believe services should be implemented gradually—offer by offer—but this is often dangerous. According to Luoto et al. (2017), service development should be perceived as an organic process. On the other hand, services are often implemented using the

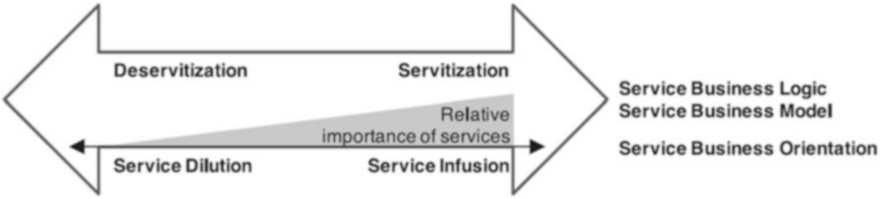

Fig. 5.1 Service growth and reduction processes: two continua (Kowalkowski et al. 2017)

trial and error approach (Kowalkowski et al. 2017). This is often associated with experimentation by adding or removing services to and from their market offer (servitization/deservitization).

According to Kowalkowski et al. (2017), involvement in services causes some risks. Auramo and Ala-Risku (2005) outline that challenges are associated with going downstream in supply and demand management. Gebauer (2008) agrees with such an approach and emphasizes that the strategy-structure match is vital for a successful service strategy; meanwhile, Baines et al. (2009) state that, in the case of servitization, companies face changes in the service culture.

In scientific literature, much attention is allocated to the concept of servitization, its drivers, and forms; however, not so much has been paid to the other forms of this phenomenon—deservitization. Kowalkowski et al. (2017) define deservitization as the transformation process when the company shifts from a service-oriented business model to a product-oriented business model and logic. The authors discuss such concepts in the context of two positions: service growth and service reduction, continuum processes (Fig. 5.1).

In cases of high price competition in the market, the company can decide to reduce or limit its services. When analyzing the computer production market, Cusumano et al. (2015) and Kowalkowski et al. (2017) confirmed that most prominent manufacturing companies use service inclusion and service dilution initiatives. Such dynamics are not limited by service flow from one actor to another but also involve such factors as innovation, maturity, and competencies.

Valtakoski (2017) defines deservitization as the case of the evolution of industrial companies. At the corporate level, service reduction or refusal may be achieved via selling or liquidation. In parallel, the service growth, which is related to the change in technologies, corresponds to cognitive changes in digital transformations characteristic to industries and global economic changes, which are conditioned by progress in the development of artificial intelligence (Spohrer 2017). The Industrial Internet, Internet of Things, or Industry 4.0 relieve the disassociation of machine software from hardware in the manufacturing system and enables more extensive product data combination synergy with other data. Such autonomous systems are predictive and reactive machines that communicate with each other and humans, thus offering inexhaustible possibilities for service growth and conditioning the implementation of service innovations, e.g., recognition as service. Spring and Araujo (2017) state that such progress enables shifting from linear manufacturing processes to a circular economy. On the other hand, the servitization dynamics of servitization-deservitization in such a technological context still lacks analysis (Kowalkowski et al. 2017).

In summary, the adoption of servitization by a manufacturer principally presents challenges for service design, organization strategy, and organization transformation. Sometimes, the choice of services infusion in manufacturing processes could lead to deservitization or service refusal. In the next chapter, we present the results of the empirical research using a representative sample of 500 companies in a single country. The research reveals how prevalent service-oriented template-related competitive priorities, methods, and digitalization and service performance capabilities are. The research also reveals the effects of different services, lean methods, and digital manufacturing innovations on digitalization and service performance.

5.6 Affordances of Organizational and Technological Innovations for Service-Oriented Firms

5.6.1 Model, Measures, and Methods

In this chapter, by using a representative sample of 500 manufacturing companies in a single country, we seek to shed light on the diffusion of product, customer support, and result-oriented services. We also reveal the extent of proficiency in service and digitalization performance. Further on, we explore whether the usage of the product, customer support, and result-oriented services are contingent on size, industry, product complexity, lot size, the design process, and the type of the manufacturing process of organizations. Finally, we engage in predicting which services, digital manufacturing innovations, and Lean practices contribute to services and digitalization performance.

The model that guides our empirical efforts is presented in Fig. 5.2.

We seek to describe the prevalence of Service-oriented template-related competitive priorities, practices, and performance dimensions. We assume that services, digital manufacturing innovations, and Lean methods positively affect service and digitalization performance. Further, we elaborate on the measures of the constructs constituting our model.

The selection of the product support services, customer support services, and result-oriented services was based on an extensive review of scholarly literature (Eggert et al. 2011; Gebaue et al. 2011; Martín-Peña et al. 2019; Sousa and da Silveira 2017; Visnjic et al. 2016) (Table 5.3). The manifest indicators for lean, agile practices, and services are provided in Table 5.3.

The selection of the competitive performance measures of service and digitalization performance was created for this study (Table 5.4). The measurement of the digitalization of production systems continues to emerge. After reviewing the literature on digital capabilities (Lenka et al. 2017; Ardolino et al. 2018; Srinivasan

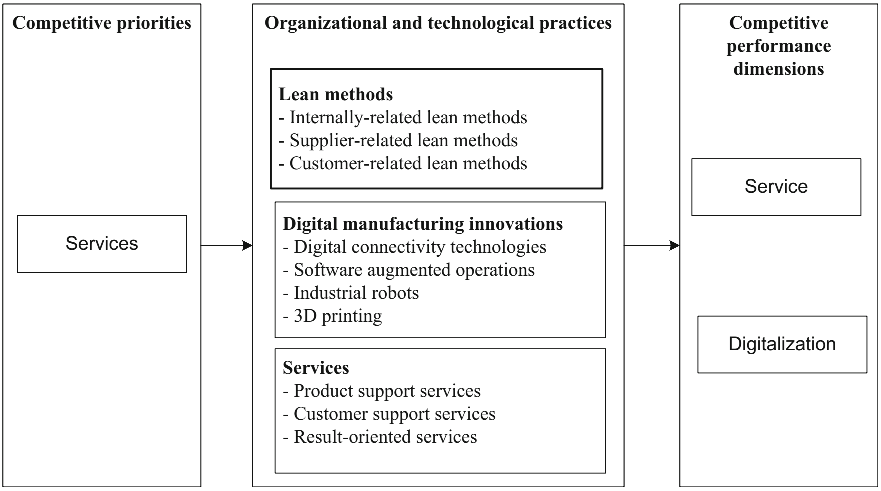

Fig. 5.2 The model of Service-oriented template of organizing for empirical analysis

and Swink 2018), frameworks, and maturity models (Basl 2018) of the digitization of manufacturing organizations, the following four key components of the digitalization of production systems were identified: digitizing production data, connecting equipment and devices, collecting and analyzing production data, and automating processes. These dimensions were used to measure the extent and breadth of the digitalization of a production system. After reviewing the literature on empirical measurement of services (Eggert et al. 2011; Gebaue et al. 2011; Martín-Peña et al. 2019; Sousa and da Silveira 2017; Visnjic et al. 2016), the following four key components of the service performance were used: product support services, online product support service, advanced Service provision models, and data-driven services. A five-point scale was used for the assessment of service and digitalization performance, where *1* indicates the poor/low end of the industry, *3* refers to the average, and *5* stands for the superior performance level compared to the competitors in the industry. The questions provided in the questionnaire may be found in Annex 5.1.

Descriptive statistics were used to analyze the diffusion of service competitive priority, product, customer support and result-oriented services, and service and digitalization performance dimensions. The ranking of competitive performance from 1 to 6, with 1 indicating "the most important" and 6 "not at all important," was used to measure the prevalence of service competitive priority. The dichotomic variable "Currently used Services" (0—No, 1—Yes) was used to measure the diffusion of Services in a country. Comparison of column proportions (by adjusting p values Bonferroni method) was used to investigate whether digital innovations are contingent on size, industry, and the type of the design process of organizations.

Table 5.3 Measures of services, digital manufacturing innovations, and lean methods

Type of methods	Latent constructs	Manifest indicators
Lean methods	Internally related lean methods	Standardized work instructions
		Value stream mapping
		Customer or product-oriented lines/cells
		5S
		Visual management
		Pull of production
		Setup time reduction
		Total preventive maintenance
		Statistical process control
		Involvement of employees
		Integration of tasks
	Customer-related lean methods	Customer involvement
	Supplier-related lean methods	Supplier development
		Supplier feedback
		JIT delivery
Digital manufacturing innovations	Digital connectivity technologies	Mobile programming and controlling of facilities and machinery
		Digital solutions to provide documentation directly to the shop floor
		Digital exchange of product/process data with suppliers/customers
	Software augmented operations	Software for production planning and scheduling
		Near real-time production control systems
		Systems for automation and management of internal logistics
		Simulation for product design and development
	Industrial robots	Industrial robots for manufacturing processes
		Industrial robots for handling processes
	3D printing	3D printing technologies for prototyping
		3D printing technologies for manufacturing
Services	Product support services	Installation, start-up
		Maintenance and repair
		Training
		Remote support for clients
		Design, consulting, project planning
		Software development
		Revamping or modernization
		Take-back services
	Customer support services	Online training, documentation, error description

(continued)

Table 5.3 (continued)

Type of methods	Latent constructs	Manifest indicators
		Web services product configuration or product design
		Remote monitoring of operating status
		Mobile devices for diagnosis, repair, or consultancy
		Data-based services based on big data analysis
	Result-oriented services	Renting products, machinery, or equipment
		Full-service contracts
		Operation of products at customer site for the customer
		Taking over the management of maintenance activities

Table 5.4 Measures of service and digitalization performance

Competitive performance	AVE	Composite reliability	Reliability (alpha)	Dimensions of competitive performance	Loading	*p* values of loadings
Services	0.941	0.985	0.979	Product support services	0.948	0.000
				Online product support services	0.977	0.000
				Advanced service provision models	0.982	0.000
				Data-driven services	0.973	0.000
Digitalization	0.964	0.991	0.991	Digitalization of production data	0.963	0.000
				Connection of production system elements	0.985	0.000
				Autonomous production data collection and analysis	0.988	0.000
				Automation of production processes	0.991	0.000

Partial squares-based structural equation modeling was used for confirmatory factor analysis of the measurement models and estimation of the effects of the services, Lean methods, digital technologies on services, and digitalization performance. Endogenous variables of services and digitalization performance were treated as reflective latent multi-item constructs. The exogenous constructs of the lean methods, digital innovations, and services were treated as single-item constructs. The analysis was performed by using *SmartPLS* software. A PLS consistent algorithm was used (a path weighting scheme, stop criteria 300 iterations, or 1.0E-7 stop criteria). Casewise deletion of the missing values was employed. In the next chapter, we present the results of the empirical investigation of the Service-oriented template.

5.6.2 Diffusion of Service-Oriented Template-Related Strategic Priorities, Practices, and Performance Dimensions

5.6.2.1 Diffusion of Services Strategic Priority

In this chapter, we describe the prevalence of service competitive priority among manufacturing firms. The importance of the services' competitive priority is provided in Table 5.5.

The graphical representation of the importance of services' competitive priority is provided in Fig. 5.3. The analysis reveals that only 2.4% of companies compete on services competitive priority.

Table 5.5 The prevalence of service competitive priority

	Services	
	No.	%
The most important	12	2.4
Important	27	5.4
Slightly important	47	9.4
Not so much important	93	18.6
Not important	179	35.9
Not at all important	141	28.3

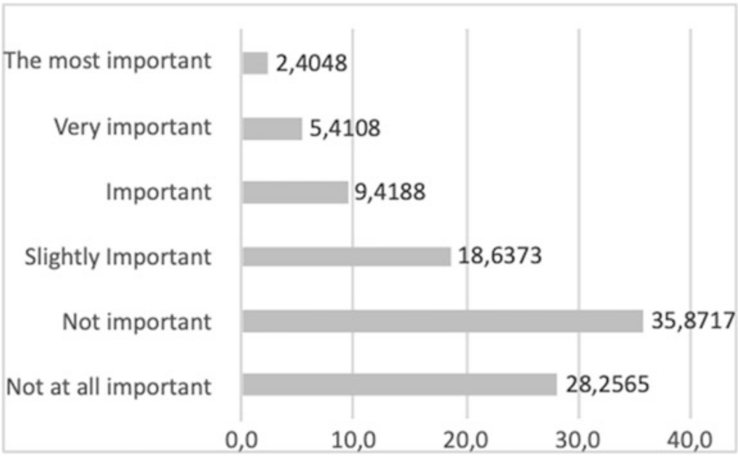

Fig. 5.3 The importance of services competitive priority, %

The importance of the services' priority was measured on a six-point scale. The top three choices reveal the varied level of importance, while the last three categories reveal the absence of importance of a competitive priority. The analysis reveals that 17.2% of organizations indicate that services are an important competitive priority. 82.8% of organizations tend to devalue the services as a strategic differentiator. The results reveal that services are not a prevalent strategic differentiator.

5.6.2.2 Diffusion of Product, Customer, and Result-Oriented Services

This chapter describes the prevalence of product, customer, and result-oriented services among manufacturing companies. The prevalence of services in organizations is provided in Table 5.6.

Table 5.6 Prevalence of services

		Used by organizations					
		N			%		
Dimension	Item	Yes	No	Missing	Yes	No	Missing
Product support services	1. Installation, start-up	113	262	125	22.6	52.4	25.0
	2. Maintenance and repair	138	242	120	27.6	48.4	24.0
	3. Training	79	301	120	15.8	60.2	24.0
	4. Remote support for clients	167	235	98	33.4	47.0	19.6
	5. Design, consulting, project planning	132	252	116	26.4	50.4	23.2
	6. Software development	47	276	177	9.4	55.2	35.4
	7. Revamping or modernization	80	253	167	16.0	50.6	33.4
	8. Take-back services	85	315	100	17.0	63.0	20.0
Customer support services	1. Online training, documentation, error description	75	293	132	15.0	58.6	26.4
	2. Web services product configuration or product design	65	297	138	13.0	59.4	27.6
	3. Remote monitoring of operating status	48	300	152	9.6	60.0	30.4
	4. Mobile devices for diagnosis, repair, or consultancy	49	302	149	9.8	60.4	29.8
	5. Data-based services based on big data analysis	8	132	360	1.6	26.4	72.0
Result-oriented services	1. Renting products, machinery, or equipment	32	424	44	6.4	84.8	8.8
	2. Full-service contracts	144	291	65	28.8	58.2	13.0
	3. Operation of products at customer site for the customer	70	368	62	14.0	73.6	12.4
	4. Taking over the management of maintenance activities	47	401	52	9.4	80.2	10.4

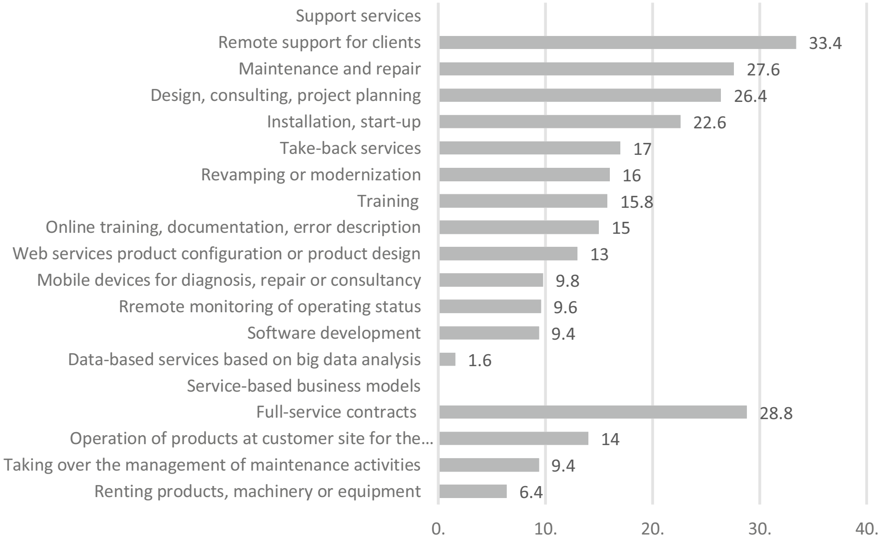

Fig. 5.4 Prevalence of services ($N = 500$, %)

Product support services are much more prevalent than customer support services or result-oriented services: half of the items from this group are in the top five most prevalent practices. These most prevalent product support services are:

(a) Remote support for clients (33.4%)
(b) Maintenance and repair (27.6%)
(c) Design, consulting, project planning (26.4%)
(d) Installation, start-up (22.6%)

The only service which is not included in product support services that reach a similar prevalence level is full-service contracts (28.8%). The least prevalent services from each service type are software development (9.4%) in product support services, data-based services based on big data (1.6%) in customer support services. The prevalence of service practices is presented in Fig. 5.4.

The extent of customer support services used in sample organizations is shown in Fig. 5.4. It can be seen that organizations are using web-based offers for product utilization and web-based services for customized product configuration.

Analysis of the intentions of manufacturing companies to use particular result-oriented services in the near future and the actual usage is quite positive in the case of the full-service contracts with the defined scope to maintain products (Table 5.7).

Table 5.7 Planned and used result-oriented services

	Used by organizations						Planned by 2021					
	N			%			*N*			%		
Item	Yes	No	Missing	Yes	No	Missing	Yes	No	Missing	Yes	No	Missing
Renting products, machinery, or equipment	32	424	44	6.4	84.8	8.8	23	374	102	4.6	74.9	20.4
Full-service contracts	144	291	65	28.8	58.2	13.0	6	259	234	1.2	51.9	46.9
Operation of products at customer site for the customer	70	368	62	14.0	73.6	12.4	3	336	160	0.6	67.3	32.1
Taking over the management of maintenance activities	47	401	52	9.4	80.2	10.4	11	352	136	2.2	70.5	27.3

5.6.2.3 Extent of Diffusion of Services and Digitalization Performance Dimensions

Competitive performance dimensions are the ability to compete on particular performance relative to the primary competitors in the target markets (Wilkinson et al. 2009). Service performance is the extent to which an organization perceives its competitive performance of regular product support services, online product support services, advanced service provision models, and data-driven services compared to the competitors' performance. Digitalization performance is the extent of digitalization of production data, connection production system elements, autonomous production data collection and analysis, and automation of the production processes compared to the competitors.

The constituents of services and digitalization dimensions are provided in Tables 5.8 and 5.9. The comparison of the digitalization and service performance capabilities shows that companies are more confident with their digitalization performance (2.675) than with service performance (1.44).

Most companies cannot benchmark their service and digitalization performance (Table 5.8). A high percentage of companies unable to compare their performance suggests that they lack interorganizational ties that share such a kind of information. Generally, companies find their digitalization performance more advanced than service performance. 25.3% of companies argue that their digitalization performance is equal to that of their competitors, compared with 11.6% of companies arguing the same about service performance. Even more, 21.8% of companies state that their service performance is much worse than that of their competitors. Only 8.5% of companies claim that their digitalization performance is much worse than that of their competitors (Fig. 5.5).

This chapter analyzed the diffusion of service practices and service and digitalization competitive performance dimensions. Our analysis shows low diffusion of services in the population of manufacturing companies. The finding that the Full-service contracts with a defined scope to maintain the products is used by 28.8% of the sample organizations is a positive surprise. However, most of the product and customer support services are used by a quarter of organizations or fewer. The infusion of products with services provides one of the most significant opportunities for manufacturing companies to increase their value. The service and digitalization performance results were consistent with the low infusion of the products with services. It shows that companies are not confident in their service and digitalization performance.

Table 5.8 Evaluation of service performance

		Much worse	Worse	Equal	Better	Much better	Total	Missing	Mean	Overall mean
Regular product support services	Frequency	108	1	70	29	11	219	281	2.24	1.44
	Percent	21.6	0.2	14	5.8	2.2	43.8	56.2		
Online product support services	Frequency	109	5	55	11	8	188	312	1.96	
	Percent	21.8	1	11	2.2	1.6	37.6	62.4		
Advanced service provision models	Frequency	110	4	58	14	3	189	311	1.92	
	Percent	22	0.8	11.6	2.8	0.6	37.8	62.2		
Data-driven services	Frequency	109	8	48	12	5	182	318	1.88	
	Percent	21.8	1.6	9.6	2.4	1	36.4	63.6		

Table 5.9 Evaluation of digitalization performance

		Much worse	Worse	Equal	Better	Much better	Total	Missing	Mean	Overall mean
Digitalization of production data	Frequency	43	30	120	20	14	227	273	2.70	2.675
	Percent	8.6	6.0	24.0	4.0	2.8	45.4	54.6		
Connection of production system elements	Frequency	43	31	108	19	10	211	289	2.63	
	Percent	8.6	6.2	21.6	3.8	2.0	42.2	57.8		
Autonomous production data collection and analysis	Frequency	42	30	107	16	12	207	293	2.64	
	Percent	8.4	6.0	21.4	3.2	2.4	41.4	58.6		
Automation of production processes	Frequency	41	33	111	23	16	224	276	2.73	
	Percent	8.2	6.6	22.2	4.6	3.2	44.8	55.2		

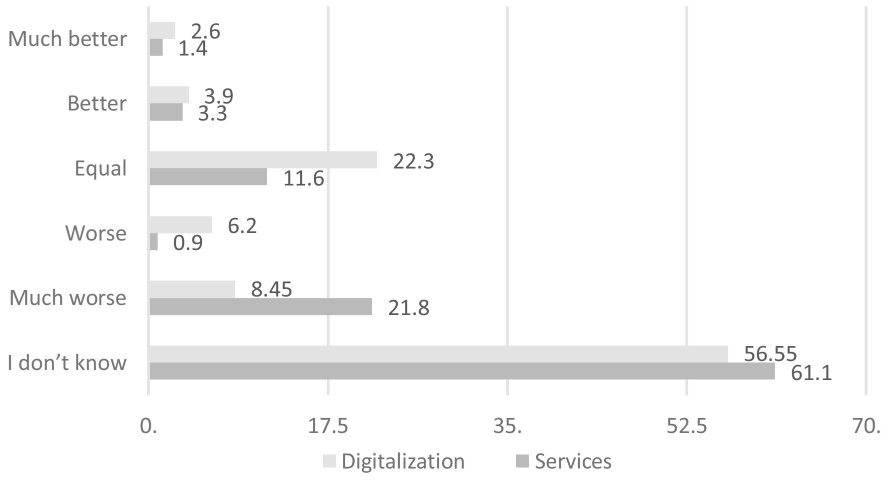

Fig. 5.5 Evaluation of service and digitalization performance, %

5.6.3 Differences in Servitization Extent Among Organizations

In this chapter, we shall explore whether the extent of the provision of the product, customer support, and result-oriented services is contingent on the size of a company, industry, the type of the product development process, and the type of the manufacturing process of an organization.

First, we investigated whether the provision of services depends on the company's size. The results of comparing the proportions of provision of services across differently sized organizations are presented in Table 5.10. We propose that the extent of the provision of services positively relates to the size of an organization (Damanpour 1992).

Our analysis reveals that there is no pattern relating the size of the enterprise and the extent of provision of services. Contrary to expectations, large companies provide fewer services than other companies. Large companies possess competencies and resources that may be useful for infusing products with services. On the other hand, it is proposed that large companies may suffer from the "incumbent's curse" when large companies tend to introduce incremental product innovations, whereas small ones are better positioned for radical product innovations (Chandy and Tellis 2000). Our analysis reveals that 6.3% of medium-sized firms experiment with data-based services based on big data analysis. Operation of products at the customer's site for the customer is more prevalent among small companies compared to medium ones.

Further on, we analyzed if the infusion of products with services differs across sectors. We analyzed the differences in the provision of services across the

Table 5.10 The difference in the provision of services in terms of company size

Types of services	1–9 employees (1)	10–49 employees (2)	50–249 employees (3)	250+ employees (4)	Difference
Product support services					
Installation, start-up	**24.7**	22.6	20.3	7.1	No stat. sign. differences
Maintenance and repair	31.3	**26.4**	25.3	7.1	No stat. sign. differences
Training	18.2	13.5	**19.0**	NA	No stat. sign. differences
Remote support for clients	34.8	30.3	**38.0**	35.7	No stat. sign. differences
Design, consulting, project planning	**28.3**	25.5	26.6	14.3	No stat. sign. differences
Software development	10.1	7.2	**13.9**	7.1	No stat. sign. differences
Revamping or modernization	18.7	12.5	**20.3**	7.1	No stat. sign. differences
Take-back services	18.2	14.9	19.0	**21.4**	No stat. sign. differences
Customer support services					
Online training, documentation, error description	15.7	14.4	**17.7**	NA	No stat. sign. differences
Web services product configuration or product design	**16.2**	12.5	8.9	NA	No stat. sign. differences
Remote monitoring of operating status	**11.1**	8.2	10.1	7.1	No stat. sign. differences
Mobile devices for diagnosis, repair, or consultancy	**14.1**	7.2	6.3	7.1	No stat. sign. differences
Data-based services based on big data analysis	NA	1.4	**6.3**	NA	2 < 3
Result-oriented services					
Renting products, machinery, or equipment	5.6	**8.7**	2.5	7.1	No stat. sign. differences

(continued)

Table 5.10 (continued)

Types of services	1–9 employees (1)	10–49 employees (2)	50–249 employees (3)	250+ employees (4)	Difference
Full-service contracts	**34.8**	25.0	26.6	14.3	No stat. sign. differences
Operation of products at customer's site for the customer	14.6	**17.8**	5.1	NA	2 > 3
Taking over the management of maintenance activities	**12.6**	6.7	10.1	NA	No stat. sign. differences

engineering, food, textile, and wood and paper sectors. The results of our analysis are presented in Table 5.11.

A comparison of the share of different sector companies providing services revealed that engineering companies tend to provide more services than companies representing other sectors. The peculiarities of the products may explain such findings. The companies that produce electromechanical products are best positioned for providing customer support services, such as remote monitoring of the operating status, the introduction of mobile devices for diagnosis, repair, or consultancy, and data-based services based on big data analysis. Our results show that engineering companies infuse their products with product support services more than companies from other sectors. Engineering companies are also leading in adopting result-oriented services in absolute numbers; however, the difference is not as statistically significant as in the case of product and customer support services.

Further, we analyzed whether the provision of services is dependent on the design and development as well as the manufacturing process. We consider the following types of product development processes: development of products according to customer specification, incorporating customer-specific options into standard products during the development and developing standard products from which the customer can choose. We propose that the flexibility of the design and development process is positively related to the extent of the provision of services. The results of our analysis are provided in Table 5.12.

Our analysis reveals that the companies that customize products to customer specifications tend to provide more services compared to those characterized by lesser product mix flexibility. The companies that customize products are leading other companies while providing installation and start-up, maintenance and repair, remote client support, design and consulting, Web services product configuration or product design, and Full-service contracts. The companies that engage in the customization of products are better positioned to infuse products with services. They tend to maintain a more extended contact with customers, thus obtaining additional opportunities to engage customers in service co-creation.

Table 5.11 The difference in the provision of services across sectors

Types of services	Engineering (1), %	Food (2), %	Textile (3), %	Wood and furniture (4), %	Difference
Product support services					
Installation, start-up	**30.4**	4.7	10.0	26.5	1,4 > 2,3
Maintenance and repair	**42.4**	4.7	15.7	23.9	1 > 2,3,4; 4 > 2
Training	**27.2**	7.8	5.7	12.3	1 > 2,3,4
Remote support for clients	**44.0**	17.2	27.1	31.0	1 > 2
Design, consulting, project planning	**35.2**	6.3	15.7	31.0	1 > 2,3; 4 > 2
Software development	**16.8**	1.6	4.3	10.3	1 > 2
Revamping or modernization	**27.2**	3.1	10.0	12.3	1 > 2,3,4
Take-back services	**24.8**	6.3	8.6	16.8	1 > 2,3
Customer support services					
Online training, documentation, error description	**22.4**	6.3	10.0	12.3	1 > 2
Web services product configuration or product design	**14.4**	6.3	11.4	12.9	No stat. sign. differences
Remote monitoring of operating status	**16.8**	1.6	5.7	7.1	1 > 2
Mobile devices for diagnosis, repair, or consultancy	**15.2**	1.6	7.1	7.7	1 > 2
Data-based services based on big data analysis	**2.4**	NA	1.4	1.9	No stat. sign. differences
Result-oriented services					
Renting products, machinery, or equipment	**8.0**	NA	4.3	7.7	No stat. sign. differences
Full-service contracts	**32.0**	17.2	22.9	30.3	No stat. sign. differences
Operation of products at customer site for the customer	**19.2**	6.3	5.7	14.2	No stat. sign. differences
Taking over the management of maintenance activities	**12.0**	1.6	4.3	10.3	No stat. sign. differences

In this chapter, we analyzed whether the provision of services is contingent on the size, industry, and type of the product development process. The results reveal that the industry and the extent of the product mix flexibility are the most critical contingency variables. The infusion of products with services does not differ significantly in organizations characterized by different sizes.

Table 5.12 The difference in the provision of services across different types of design and development processes

Types of services	According to the customer's specification (1), %	As a standardized basic program incorporating customer-specific options (2), %	For a standard program from which the customer can choose options (3), %	Difference
Product supports				
Installation, start-up	**30.3**	15.9	16.9	1 > 2,3
Maintenance and repair	**33.6**	26.1	21.1	1 > 3
Training	**18.3**	14.8	14.1	No stat. sign. differences
Remote support for clients	34.9	**44.3**	27.5	2 > 3
Design, consulting, project planning	**33.2**	23.9	21.1	1 > 3
Software development	**11.6**	8.0	7.7	No stat. sign. differences
Revamping or modernization	17.8	**18.2**	14.1	No stat. Sign. Differences
Take-back services	17.8	**21.6**	14.1	No stat. Sign. Differences
Customer support services				
Online training, documentation, error description	**17.0**	12.5	14.8	No stat. sign. differences
Web services product configuration or product design	**19.1**	5.7	9.2	1 > 2, 3
Remote monitoring of operating status	**12.9**	5.7	7.7	No stat. sign. differences
Mobile devices for diagnosis, repair, or consultancy	**12.0**	3.4	11.3	No stat. sign. differences
Data-based services based on big data analysis	1.7	NA	**2.1**	No stat. sign. differences

(continued)

Table 5.12 (continued)

Types of services	According to the customer's specification (1), %	As a standardized basic program incorporating customer-specific options (2), %	For a standard program from which the customer can choose options (3), %	Difference
Result-oriented services				
Renting products, machinery, or equipment	**8.7**	2.3	3.5	No stat. sign. differences
Full-service contracts	**40.2**	17.0	18.3	1 > 2,3
Operation of products at customer's site for the customer	**16.2**	12.5	12.7	No stat. sign. differences
Taking over the management of maintenance activities	**10.8**	6.8	7.7	No stat. sign. differences

A comparison of the proportions of different sector companies providing services revealed that engineering companies tend to provide more services than companies from other sectors. Companies from the engineering sector lead in absolute numbers across all the 17 services that were analyzed in this survey. In addition, our analysis reveals that the companies that customize products tend to provide more product and customer support services and adopt result-oriented business models. These findings inform our knowledge about the diffusion of services. The findings show that big companies do not have an advantage in servitization. Advantage starts around engineering companies and the companies that customize products to their customers' demands—thus, they diffuse innovations to other sectors.

5.6.4 Relationships of Service Practices

The relationships among service practices in Lithuanian manufacturing companies are provided in Table 5.13. The relationships are characterized by a correlation coefficient and presented below.

Product support services are highly interrelated. Customer support services are relatively highly interrelated, except for data-based services that have lower correlations with other services. Result-oriented services are two times less interrelated among themselves. Full-service contracts with a defined scope to maintain products are related to most result-oriented services.

Table 5.13 The relationship between service practices (biserial correlation coef., $N = 500$)

		1	2	3	4	5	6	7	8	1	2	3	4	5	1	2	3	4
Product support services	1. Installation, start-up	1	0.640**	0.539**	0.489**	0.544**	0.498**	0.521**	0.417**	0.242**	0.246**	0.295**	0.288**	0.084	0.132**	0.374**	0.237**	0.170**
	2. Maintenance and repair	0.640**	1	0.518**	0.521**	0.534**	0.476**	0.573**	0.435**	0.229**	0.160**	0.239**	0.263**	0.100*	0.094*	0.368**	0.241**	0.246**
	3. Training	0.539**	0.518**	1	0.507**	0.474**	0.612**	0.574**	0.475**	0.356**	0.273**	0.361**	0.318**	0.120**	0.088*	0.318**	0.189**	0.236**
	4. Remote support for clients	0.489**	0.521**	0.507**	1	0.499**	0.411**	0.408**	0.470**	0.308**	0.268**	0.287**	0.252**	0.112*	0.040	0.317**	0.215**	0.179**
	5. Design, consulting, project planning	0.544**	0.534**	0.474**	0.499**	1	0.491**	0.481**	0.514**	0.257**	0.281**	0.282**	0.306**	0.177**	0.121**	0.330**	0.216**	0.180**
	6. Software development	0.498**	0.476**	0.612**	0.411**	0.491**	1	0.682**	0.548**	0.268**	0.242**	0.407**	0.332**	0.177**	0.112*	0.204**	0.087	0.178**
	7. Revamping or modernization	0.521**	0.573**	0.574**	0.408**	0.481**	0.682**	1	0.514**	0.244**	0.237**	0.358**	0.333**	0.118**	0.176**	0.240**	0.138**	0.215**
	8. Take-back services	0.417**	0.435**	0.475**	0.470**	0.514**	0.548**	0.514**	1	0.227**	0.173**	0.250**	0.227**	0.027	0.121**	0.218**	0.155**	0.164**
Customer support services	1. Online training, documentation, error description	0.242**	0.229**	0.356**	0.308**	0.257**	0.268**	0.244**	0.227**	1	0.520**	0.510**	0.521**	0.259**	0.096*	0.190**	0.153**	0.229**
	2. Web services product configuration or product design	0.246**	0.160**	0.273**	0.268**	0.281**	0.242**	0.237**	0.173**	0.520**	1	0.581**	0.553**	0.188**	0.069	0.148**	0.187**	0.181**
	3. Remote monitoring of operating status	0.295**	0.239**	0.361**	0.287**	0.282**	0.407**	0.358**	0.250**	0.510**	0.581**	1	0.715**	0.229**	0.137**	0.213**	0.103*	0.174**
	4. Mobile devices for diagnosis, repair or consultancy	0.288**	0.263**	0.318**	0.252**	0.306**	0.332**	0.333**	0.227**	0.521**	0.553**	0.715**	1	0.333**	0.051	0.206**	0.138**	0.193**
	5. Data-based services based on big data analysis	0.084	0.100*	0.120**	0.112*	0.177**	0.177**	0.118**	0.027	0.259**	0.188**	0.229**	0.333**	1	0.032	0.095*	0.040	0.123**
Result-oriented services	1. Renting products, machinery, or equipment	0.132**	0.094*	0.088*	0.040	0.121**	0.112*	0.176**	0.121**	0.096*	0.069	0.137**	0.051	0.032	1	0.195**	0.177**	0.168**
	2. Full-service contracts	0.374**	0.368**	0.318**	0.317**	0.330**	0.204**	0.240**	0.218**	0.190**	0.148**	0.213**	0.206**	0.095*	0.195**	1	0.265**	0.264**

	3. Operation of products at customer site for the customer	0.237**	0.241**	0.189**	0.215**	0.216**	0.087	0.138**	0.155**	0.153**	0.187**	0.103*	0.138**	0.040	0.177**	0.265**	1	0.285**
	4. Taking over the management of maintenance activities	0.170**	0.246**	0.236**	0.179**	0.180**	0.178**	0.215**	0.164**	0.229**	0.181**	0.174**	0.193**	0.123**	0.168**	0.264**	0.285**	1

** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed)

5.6.5 *Effect of Services, Digital Manufacturing Innovations, and Lean Methods on Service and Digitalization Performance Dimensions*

Path analysis using the partial squares structural equation modeling approach is used to determine which services, digital manufacturing innovations, and Lean practices affect service and digitalization performance. Two groups of models were explored. The first group of models estimates the influence of services, digital innovations, and lean methods on service performance. The second group of models analyzes the influence of services, digital innovations, and lean methods on digitalization performance.

Our analysis reveals that maintenance and repair, remote support for clients, take-back services, online training, taking over the management of maintenance activities, and Full-service contracts contribute to service performance (Table 5.14). Interestingly, maintenance and repair, and Full-service contracts with a defined scope to maintain products hurt service performance. Full-service contracts with a defined scope to maintain products are complex services requiring the competence of outcome-based sales and well-planned service infrastructure (Kumar et al. 2004; Iansiti and Lakhani 2014). Companies providing these services may struggle with the execution, resulting in a negative perception of the company's service performance. Contrary to the expectations, we could not find any effects of digital innovations on service performance. The services that are provided online and

Table 5.14 Effects of services, digital innovations, and lean practices on service performance

Model/methods	Model 1: Services -> Service performance		Model 2: Digital innovations -> Service performance		Model 3: Lean methods -> Service performance	
Effects	Path estimate*	*p* values	Path estimate	*p* values	Path estimate	*p* values
Maintenance and repair	0.216	0.041	–	–	–	–
Remote support for clients	0.388	0.001	–	–	–	–
Take-back services	−0.219	0.02	–	–	–	–
Online training, documentation, error description	0.257	0.037	–	–	–	–
Taking over the management of maintenance activities	0.173	0.049	–	–	–	–
Full-service contracts	−0.146	0.028	–	–	–	–
Development of suppliers	–	–	–	–	0.214	0.024
Total productive/preventive maintenance	–	–	–	–	0,221	0.029
R^2	0.307		–		0.226	
R^2_{adj}	0.235		–		0.143	
N	170		67		158	

Table 5.15 Effects of services, digital innovations, and lean practices on digitalization performance

Model/methods	Model 1: Services -> Digitalization		Model 2: Digital innovations -> Digitalization		Model 3: Lean methods -> Digitalization	
Effects	Path estimate*	*p* values	Path estimate	Path estimate	*p* values	*p* values
Design, consulting, project planning	0.224	0.02	–	–	–	–
Software development	−0.25	0.018	–	–	–	–
Taking over the management of maintenance activities	0.181	0.009	–	–	–	–
Setup time reduction	–	–	–	–	0.168	0.044
Visual management	–	–	–	–	0.16	0.036
Integration of tasks	–	–	–	–	0.201	0.018
R^2	0.161		–		0.231	
R^2_{adj}	0.086		–		0.162	
N	194		80		185	

result-oriented services models rely heavily on digital innovations (Iansiti and Lakhani 2014; Siggelkow and Terwiesch 2019). The questionnaire may reveal manufacturing companies' back-end digitalization practices more extensively than front-end digitalization practices that enable customer support and result-oriented services. ERP, MES, Warehouse management systems, industrial robots, and 3D printing constitute digital manufacturing innovations that do not strongly affect service performance.

Service practices, as expected, have the highest contribution to the variation of service performance (30.7%), followed by the lean methods (22.6%). Contrary to our expectations, digital innovations do not contribute to service performance. All the methods account for 53.3% performance variation of the service performance.

Further, we predicted the effects of different types of services, digital innovations, and lean methods on digitalization performance (Table 5.15). Modeling the effects of service practices, digital innovations, and lean methods raises more questions than provides answers. The lean methods have the highest contribution to digitalization performance. Setup time reduction, visual management techniques, and integration of tasks positively affect digitalization performance. Visual management tools, such as display boards in the production sector aimed to illustrate work processes status, may be manual, but they may also be based on digital solutions. Setup time reduction techniques may also be based on video analysis techniques which help to analyze and improve the setup and changeover times.

We also found that such services as design, consulting, project planning, software development, and managing maintenance activities affect digitalization performance. However, software development services negatively influence digitalization performance. This finding is counter-intuitive. A possible way of explanation is as follows. If a company starts developing product software, it reserves IT resources for this task. At the same time, they are stripped from the activities increasing the digitalization capability, e.g., developing software to augment processes, integrate processes, and automate routine tasks. Even more challenging to explain the diminishing effects of digital innovations on digitalization performance. The non-extensive use of digital innovations in the sample organizations may contribute to the situation where we cannot locate weak effects within the required alpha level.

Lean methods are denoted by the highest contribution to the variation of digitalization performance (23.1%), followed by services (16.1%). We were unable to confirm the effects of digital manufacturing innovations on digitalization performance. All the methods account for a 39.2% variation in the digitalization performance.

In this section, we aimed to explore which services, digital innovations, and lean practices are related to service and digitalization performance. Our investigated methods were able to predict 53.3% performance variation of the services performance and 39.2% of the variation of digitalization performance.

5.7 Summary

In conclusion, the analysis of the diffusion of services revealed that manufacturing companies are experimenting with various services. However, companies treat services as product complements.

The empirical analysis reveals that only 2.4% of companies compete on services competitive priority. Even more, only 17.2% of organizations indicate that services are an important competitive priority. Such findings reveal that companies do not use servitization as a differentiation strategy.

The results reveal that most companies are offering services, but most of them are merely product support services where customer and result-oriented services are less prevalent.

Further, we investigated whether servitization of the companies is contingent on the size, industry, and extent of customization of the products. The size was positively related to the extent of lean methods and digital innovations usage. However, the infusion of products with services does not differ significantly in organizations characterized by different sizes. Our analysis revealed that the industry and the extent of the product mix flexibility are the most critical contingency variables influencing the decision to infuse products with services. Engineering companies tend to provide more services compared with companies from other sectors. In addition, our analysis revealed that the companies that customize products tend to provide more product support and customer support services; on top of that, they also adopt result-oriented services. These findings complement our understanding of the diffusion of services.

We determined that the three groups of services explained 30.7% of the variance in the service performance. Our service performance measure indicates how companies perceive their service performance in relation to competitors. While it does not reveal the effect of services on financial performance directly, it hints at which services are perceived positively and negatively in terms of service performance. The results reveal that a mix of services contributes to service performance. Maintenance and repair, remote support for clients, online training, and taking over the management of maintenance activities are positively associated with service performance, while Full-service contracts and take-back services hurt service performance.

We also discovered that the digitalization performance in manufacturing companies is not very well predicted by services, digital innovations, and lean methods. These practices explain 23.1% of digitalization competitive performance variance. Interestingly, lean methods contribute to digitalization performance more extensively than digital innovations and services. As indicated later, manufacturing companies are the least confident with their service and digitalization performance compared to the quality, cost, flexibility, delivery, and innovation performance.

Annex 5.1 Measurement Scales [1]

Measurement of Competitive Priorities

Please rank the following competitive factors in order of significance to distinguish your factory positively from competitors.

Please rank from 1 to 6, 1 indicating "the most important." Please do not assign equal importance to any factors.

– Product price
– Product quality
– Innovative products
– Customization to customers' demands
– Delivering on schedule/short delivery times
– Services

Measurement of Organizational Characteristics

Which of the following characteristics best describes your main product or line of products?

[1] European manufacturing survey scales (EMS 2022).

Product Development

- According to customers' specification
- As a standardized basic program incorporating customer-specific options.
- For a standard program from which the customer can choose options.
- Does not exist in this factory.

Batch or Lot Size

- Single unit production
- Small or medium batch/lot
- Large batch/lot

Manufacturing Process

- Upon receipt of customer's order, i.e., made-to-order.
- Final assembly of the product is carried out upon receipt of customer's order, i.e., assembly-to-order.
- To stock (before customer's order).
- Does not exist in this factory.

Product Complexity

- Simple products
- Products with medium complexity
- Complex products

Measures of Lean Methods

Which of the following organizational concepts are currently used in your factory? 0—No; 1—Yes.

If Yes, what is the extent of the used potential of the method? 1—Low; 2—Medium; 3—High.

(Extent of the used potential—Extent of actual utilization compared to the most reasonable maximum potential utilization in your factory: Extent of the utilized potential "low" for an initial attempt to utilize, "medium" for partly utilized, and "high" for extensive utilization.)

- Standardized and detailed work instructions (e.g., standard operation procedures, SOP; MOST).
- Measures to improve internal logistics (e.g., Value Stream Mapping/Design, changed spatial arrangements of production steps).
- Fixed process flows to reduce setup time or optimize changeover time (e.g., SMED, QCO).
- KANBAN, Internal zero-buffer principle.
- Customer- or product-oriented lines/cells in the factory (instead of task-/operation-structured shop floors).
- Detailed regulations on the arrangement and setting of the work equipment and storage of intermediary products (e.g., Method of 5S).
- Decreasing the time of equipment downtime (Total Productive/ Preventive Maintenance).
- SPC, process capability analysis.
- Display boards in production to illustrate work processes and work status (e.g., Visual Management).
- Involvement of employees into improvement (e.g., A3, KAIZEN, and PDCA).
- Integration of tasks (planning, operating, or controlling functions with the machine operator).
- Involvement of customers into production (e.g., sharing demand information and joint product development).
- Inventory managed by suppliers, exchange of cost structure information.
- Collecting supplier feedback (e.g., sharing information on quality and delivery problems).

Measures of Digital Manufacturing Innovations

Which of the following technologies are currently used in your factory? 0—No; 1—Yes.

If Yes, What is the extent of the used potential of the method? 1—Low; 2—Medium; 3—High. The extent of used potential—Extent of actual utilization compared to the most reasonable maximum potential utilization in your factory: Extent of utilized potential "low" for an initial attempt to utilize, "medium" for partly utilized, and "high" for extensive utilization.

- Mobile/wireless devices for programming and controlling facilities and machinery (e.g., tablets).
- Digital solutions to provide drawings, work schedules, or work instructions directly on the shop floor.
- Software for production planning and scheduling (e.g., ERP system).

- Digital Exchange of product/process data with suppliers/customers (Electronic Data Interchange EDI).
- Near real-time production control system (e.g., Systems of centralized operating and machine data acquisition, and MES).
- Systems for automation and management of internal logistics (e.g., Warehouse management systems, and RFID).
- Virtual Reality or simulation for product design or product development (e.g., FEM, Digital Prototyping, and computer models).
- Industrial robots for manufacturing processes (e.g., welding, painting, and cutting).
- Industrial robots for handling processes (e.g., depositing, assembling, sorting, packing processes, and AGV).
- 3D printing technologies for prototyping (prototypes, demonstration models, and 0 series).
- 3D printing technologies for manufacturing of products, components and forms, tools, etc.

Measures of Services

Which of the following product-related Services do you offer your customers? 0—No; 1—Yes.

- Installation, start-up
- Maintenance and repair
- Training
- Remote support for clients (e.g., User Helpdesk, web platform)
- Design, consulting, project planning (incl. R&D for customers)
- Software development (e.g., software customization)
- Revamping or modernization (incl. enhancement of functions and software extensions).
- Take-back Services (e.g., recycling, disposal, and taking back).

Which of the following digital solutions do you offer as part of your Service portfolio? 0—No; 1—Yes.

- Web-based offers for product utilization (online training, documentation, and error description).
- Web-based Services for customized product configuration or product design (development).
- Digital (remote) monitoring of operating status (e.g., condition monitoring).
- Mobile devices for diagnosis, repair, or consultancy (e.g., digital camera, smartphone, and tablets).
- Data-based Services based on big data analysis.

Which of the following business models do you offer your customers? 0—No; 1—Yes.

- Renting products, machinery, or equipment.
- Full-service contracts with a defined scope to maintain your products.
- Operation of your own products at customer site/for the customer (e.g., pay on production).
- Taking over the management of maintenance activities for the customer in order to guarantee availability or costs.

Measurement of Operational Performance

Indicate how well your factory performed compared to its competition within your industry along these different performance dimensions, 1—Much worse, 2—Somewhat worse, 3—About the same, 4—Somewhat better, 5—Much better, 6—I don't know.

Quality

- Product overall quality performance
- Product reliability
- Product features
- Product conformance
- Product durability

Cost

- Unit cost
- Manufacturing overhead cost
- Inventory turnover

Flexibility

- Ability to adjust production volumes
- Ability to respond to changes in delivery requirements
- Ability to customize products

- Ability to produce a range of products
- Speed of new product introduction into the plant

Delivery

- Delivery accuracy
- Delivery dependability
- Delivery quality
- Delivery availability
- Delivery speed

Innovation

- Lead time to introduce new products
- Number of new products introduced each year
- The extent of innovativeness of products

Service

- Regular products support services
- Online product support services
- Advanced service provision models
- Data-driven services

Digitalization

- Digitalization of production data
- Connection production system elements
- Autonomous production data collection and analysis
- Automation of production processes

Measures of Financial Performance

Please characterize your factory:

– Annual turnover

  In 2017 XX million €
  In 2015 XX million €

– Number of employees

  In 2015 XX number
  In 2015 XX number

– Return on sales (before tax, 2017)

  Negative
  0 up to 2%
  >2 up to 5%
  >5 up to 10%
  >10%

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Chapter 6
Performance Implications of the Fit Between Lean and Agile: Organizational Ambidexterity Perspective

Abstract Long-standing debates about whether pursuing both lean and agile templates concurrently can be a performance-enhancing solution have become even more relevant for businesses operating in an increasingly uncertain environment. Based on the theoretical premise of performance enhancing-organizational ambidexterity, we tested the hypothesis that improved performance results from the fit between agile and lean capabilities. The deviation score approach (matching perspective) and fit as profile deviation were used to examine the performance-enhancing fit of lean (quality and delivery) and agile (flexibility and innovation)-related capabilities. The deviation score method did not reveal a significant relationship between misfit and profit. In contrast, the misfit and sales revenue growth rates were positively and significantly related, albeit not in the expected direction. The profile deviation strategic fit perspective revealed a nonsignificant negative relationship between non-adherence to the ideal profile and profit within the specific range of profile deviation. The current study relied on fit as matching and profile deviation, which denotes the combining approach of ambidexterity. Further research may thus broaden our understanding of the performance implications of lean-agile template compatibility, most notably conceptualizing the fit as an ambidexterity-related balancing approach in the pursuit of optimal levels of lean and agile capability configurations.

6.1 Introduction

The growing uncertainty of the business environment generates challenges for organizations as the conventional methods and the already existing resources are no longer viable and efficient in ensuring organizational prosperity or survival. The strategic fit perspective posits that superior performance stems from the fit or the co-alignment between environment and strategy (Venkatraman 1989). The attainment of fit becomes much more complicated when the environment is highly volatile and technologically dynamic. The routines and capabilities fitting stable environment may fail to provide expected outcomes when the degree of environmental turbulence is high. Thus, the responsiveness and capability to adjust to a changing

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environment become the prerequisite competency for sustainable improvement to be attained. It has been well-documented that leanness and agility rely on different capabilities. Leanness is more inside-oriented, focusing on cost efficiency, whereas agility refers to the outward-oriented approach best summarized as excellence achieved in flexibility and innovativeness. The distinction between the two strategies is most noticeable in the goals assigned to the lean and agile-oriented templates (Pache and Santos 2010). The stark disparity in goals and competitive priorities would imply that agile and lean templates are incompatible. Such an approach receives considerable support in the lean and agile compatibility literature (Bruce et al. 2004; Krishnamurthy and Yauch 2007; Hallgren and Olhager 2009). However, a closer examination of the lean and agile templates-related practices reveals a certain degree of overlap (Shah and Ward 2003). The similarities in practices raise the question of whether organizations can follow both templates simultaneously and how templates compatibility affects organizational performance.

The distinct nature of performance capabilities implies that the appropriateness of each strategy should be contingent upon the degree of the business environment variability. Leanness is assumed to be the most effective in a stable environment, whereas agility is more applicable in a dynamic setting. However, both lean- (Ghobakhloo and Hong 2014; Yang et al. 2011) and agile-based strategies are reported to be predictors of enhanced performance among manufacturers. Moreover, literature (Inman et al. 2011; Narasimhan et al. 2006) suggests that the agile state is the more advanced one in its potential to enhance performance, therefore, presupposing that leanness may be the precursor to agility. The assumption that l*eanness precedes agility* suggests that the manufacturers which are high on both leanness and agility-related capabilities should outperform other organizations pursuing different configurations of capabilities. We may pose a number of research questions: What are the levels of leanness and agility that should be present for the performance to be enhanced? Are they mutually exclusive? What configurations of lean and agile-related capabilities determine performance improvements? All of these questions remain to be answered. Grounding on the concept of organizational ambidexterity, we propose that superior performance stems from the appropriate combination or the fit between agile and lean capabilities. This hypothesis is further tested by adopting two approaches of strategic fit.

The current study adds to the literature on the compatibility of lean and agile templates. Using the theory of organizational ambidexterity as a foundation, the present study conceptualizes the compatibility of lean and agile templates as a strategic fit and investigates its performance outcomes.

6.2 Theoretical Framework: Resource-Based View and Dynamic Capabilities

A resource-based approach treats an organization as a unique set of accumulated tangible and intangible resources (Barney 1991). Organizations use these resources to achieve their strategic goals. According to Morgan et al. (2012), lately, the resource-based view approach is opposed to the Structure-Conduct-Performance (SCP) perspective, arguing that the competitive advantage and performance of companies are affected more by company-specific resources rather than by market characteristics. This theory emphasizes the importance of company-controlled resources and capabilities for company performance because they determine the potential return on the company's strategy (Barney 2014). The resource-based approach is based on two main assumptions. The first assumption relates to the heterogeneity of companies suggesting that resources and capabilities may vary significantly across different companies. Another assumption emphasizes the "immobility" of resources stating that the differences in resources between companies can remain stable (Barney and Hesterly 2006). According to this theory, companies are characterized as combinations of exceptional resources (technological, financial, and organizational) and capabilities (Young et al. 2014). Resources are conceptualized as internal organizational attributes including tangible assets, specific internal capabilities, and business routines (Barney 1991). Exceptional resources and capabilities, while properly transformed into a value offer, create the conditions for competitive advantage (Morgan et al. 2004). It is noted that companies gain a competitive advantage only when they are able to convert resources to capabilities (Day 1994; Teece et al. 1997). Resources are valuable insofar as they have the potential to provide competitive differentiation and value for the customer.

The resource-based approach tends to focus on the company's internal environment in order to explore and find its own valuable rare resources and capabilities to be replicated at a high cost, and only thereafter they look for markets where these resources could be used (Young et al. 2014). According to this theory, it is precise that the heterogeneity of corporate resources and capabilities make it possible to explain the differences in the performance of companies (Barney and Hesterly 2006).

Scientific literature based on the resource-based view (RBV) refers to unique or specialized resources generating economic rent, such as trademarks, the accumulated technological know-how, and qualified personnel (Mosakowski 1993). These latter sources of differentiation are the most commonly used to differentiate company's goods. According to Aulakh et al. (2000), companies pursuing the differentiation strategy seek to create a product or a service unique from the customer's point of view. The uniqueness of the offer can be based on a positive brand image, exceptional technology, services, or innovative products. The aim of the companies applying the differentiation strategy is to increase consumer loyalty and create entry barriers for potential new market participants. Reduced in terms of demand in respect of price as a result of loyalty, elasticity leads to higher profit margins.

The resource-based approach was the starting point for developing the dynamic capability perspective emphasizing the evolving nature of capabilities in a competitive environment. Teece et al. (1997, p. 516) describe dynamic capabilities as follows: "the firm's ability to integrate, build and reconfigure internal and external competencies to address rapidly changing environments." From the perspective of dynamic capabilities, the company's competitiveness is characterized by the timely response, rapid and flexible strategies, and managerial capability to effectively coordinate and reallocate internal and relationship-based resources (Teece et al. 1997). Dynamic capabilities are manifested when organizations successfully adopt a strategic combination of resources to unique market characteristics (Eisenhardt and Martin 2000). The potential of resources to increase competitiveness remains latent until resources get configured to dynamic capabilities that respond to the market needs (Amit and Schoemaker 1993). The relationship between resources, capabilities, and performance reflects an evolving process, i.e., resources determine capabilities, which, in turn, influence the company's performance (Chang and Gotcher 2007). Thus, dynamic capabilities can be defined as the constantly ongoing modification of combinations of resources and capabilities (Eisenhardt and Martin 2000; Teece et al. 1997).

6.3 Concept of Organizational Ambidexterity: Exploration and Exploitation

Organizational ambidexterity (OA) has been a relevant topic of research for over 15 years. This phenomenon explains how organizations are able to reconcile seemingly difficult and often competing/incompatible goals. Organizational ambidexterity is most commonly analyzed within the theoretical framework of dynamic capabilities (O'Reilly and Tushman 2013).

The prevailing view is that the long-term success of an organization depends on its capability to exploit its current capabilities by exploring new competencies in parallel (Raisch et al. 2009; Tushman and O'Reilly 1996). The key challenge for organizations is how to conduct sufficient exploitation in order to ensure the current vitality of the organization, while maintaining few allocating sufficient capacities for exploration activities thus ensuring the company's continuity and vitality in the future (Levinthal and March 1993). Since these activities are based on different knowledge-processing capabilities of people (Floyd and Lane 2000), there is constant organizational tension overachieving professionalism in both areas (exploration and exploitation). Researchers note that there is a paradoxical relationship between the two components of ambidexterity (Andriopoulos and Lewis 2010; Raisch and Zimmermann 2017) originating from the different structures, processes, strategies, and capabilities required to carry out these activities (Chang et al. 2009).

Recently, there has been a consensus that activities previously considered difficult to reconcile can, in principle, take place simultaneously, i.e., under certain circumstances, organizations are able to exploit their available competencies while exploring new business opportunities and maintaining the necessary level of adaptivity in a turbulent environment. Despite the tension, exploitation and exploration are said to complement and reinforce each other when executed simultaneously for extended periods (Raisch et al. 2009). The high level of synergies between exploitation and exploration, by exploiting their complementarity, enables the company to enhance its competitiveness in the market (Birkinshaw and Gibson 2004). Thus, organizational ambidexterity refers to a company's strategic focus on resource exploitation while simultaneously exploring new resources to avoid dysfunctional rigidity (O'Reilly and Tushman 2004). According to O'Reilly and Tushman (2013), the application of the organizational ambidexterity concept in broader contexts has recently been observed while using more generalized concepts such as "alignment" and "adaptability." The aforementioned authors point out that such departure from the original conceptualization of the organizational ambidexterity, i.e., organizational ambidexterity as a capability to overcome organizational tensions, is flawed by conceptual confusion and less focused academic discussion. Nevertheless, the concept of ambidexterity is used to describe not only the control of the tension between exploration and management, but also the capability of the organization to handle the entire range of other kinds of dualities that occur in such contexts as: integration and responsiveness (Gulati and Puranam 2009), low cost and differentiation strategy (Porter 1980), efficiency, and flexibility (Adler et al. 1999), among many others. According to Markides (2013), the logic of ambidexterity can help to solve the leadership dilemma of differentiation versus cost in the context of business models.

According to Peng and Lin (2019), if companies focus only on one of the two forces, the tension between the latter grows, i.e., the ignored power can suppress the power of the organization that has enjoyed the attention. Ultimately, this imbalance leads to frustration among the organization members and can provoke defensive reactions. The problem of the constant tension arising from the contradictory nature of the individual components of ambidexterity is difficult to solve. According to Andriopoulos and Lewis (2009), it is possible to eliminate this type of tension by means of integrating or differentiating principles. The integrative approach emphasizes the interdependence of conflicting activities and requires coordination, whereas the differential approach emphasizes only the explorative or only the exploitative aspects of the organization's activities (Tushman and O'Reilly 1996).

Scientific literature highlights two different approaches to conceptualizing the phenomenon of organizational ambidexterity. As Junni et al. (2013) note, the key difference is whether organizational ambidexterity involves the attempt for the optimal balance between exploitation and exploration, or whether it combines both high-level exploitation and high-level exploration (Cao et al. 2009). March (1991), for example, emphasize the importance of balance, stating that maintaining a proper balance between exploitation and exploration is a prerequisite for the company's survival in the market. This perspective indicates that organizational ambidexterity should be defined as the optimum point in the continuum where extreme points are represented by exploitation and exploration (Simsek et al. 2009). The need for balancing should be particularly relevant for companies which lack sufficient internal resources and have limited access to external resources. In the case of the combination perspective, both exploration and exploitation are considered independent activities while assuming that a high level of organizational ambidexterity is only possible when the maximum level of both activities has been achieved (Cao et al. 2009; Simsek et al. 2009). In the case of combination, it is assumed that a high level of efficiency of the current activities must be maintained, while at the same time new opportunities are identified and exploited in parallel at the same intensity and at a high level, thus seeking to avoid organizational inertia and the negative consequences of path dependence (Simsek et al. 2009).

There are three types of ambidexterity identified in the scientific literature: sequential, simultaneous or structural, and contextual (Raisch et al. 2009; Simsek et al. 2009). Sequential ambidexterity means that the organization performs its activities one after another. Initially, it focuses on any one of the competing goals and then moves on to the next. Simultaneous or structural ambidexterity means that an organization distributes different tasks to different departments. Contextual ambidexterity is defined as a situation in which each member of the organization can move between competing tasks—jumping from exploration to exploitation whenever the need arises or new opportunities emerge. Thus, contextual ambidexterity contains an element of dynamism in itself (Raisch et al. 2009).

Exploitation and Exploration High levels of environmental turbulence and technological uncertainty require organizations to be more adaptive in pursuit of long-term success. The challenge is how to balance efficiency and flexibility. The controversy of the latter aims is illustrated by exploitation and exploration. “Exploitation is about efficiency, increasing productivity, control, certainty and variance reduction. Exploration is about search, discovery, autonomy, innovation and embracing variation” (O’Reilly and Tushman 2008, p. 189). Both exploration and exploitation capabilities are considered dynamic capabilities, given that the purpose of dynamic capabilities is to transform existing resources into new functional competencies that better match the business environment (Eisenhardt and Martin 2000).

According to Kauppila (2010), strategies of mechanistic nature used by the companies focused on short-term profits usually encourage exploitation thus assisting the company to thrive in a stable business environment. Meanwhile, the volatile business environment creates an increased need for the organization’s adaptivity manifesting through innovation-oriented strategies thus contributing to exploration activities. Cao et al. (2009) argue that exploration and exploitation support each other and utilize each other’s strengths to make up for their shortcomings. A high level of exploitation can enhance the exploration activities of a company aimed at finding new knowledge and helping to develop the resources needed to create new products and new markets. According to Peng and Lin (2019), exploration is an ongoing learning process that aims to exploit implicit knowledge through the process of externalizing and integrating knowledge and thus developing new technologies and new markets. In the case of exploitation, however, the focus is on using explicit knowledge through the processes of internalization and integration of knowledge that allow for gradual improvement of manufacture, products, technologies, and processes while maintaining a competitive position in the marketplace. The exploration strategy is characterized by actively searching for new opportunities, engaging in risk-taking, and achieving innovation. The exploitation strategy involves improvement of the already existing practices, increasing efficiency, and the utilization of the already existing knowledge.

6.4 Organizational Ambidexterity and Performance

Most research shows a positive relationship between organizational ambidexterity and company performance (Gibson and Birkinshaw 2004; Lubatkin et al. 2006; Tamayo-Torres et al. 2017). Empirical research confirms that, when markets and technologies are characterized by high uncertainty, organizational ambidexterity has a positive impact on the company's performance. Organizational ambidexterity has been found to be positively related to sales growth (He and Wong 2004), company growth (Geerts et al. 2010), innovation (Atuahene-Gima 2005), and the capability of companies to survive in the market (Piao 2010). A study by Goossen et al. (2012) revealed that companies with more advanced technological capabilities benefit more from organizational ambidexterity. A study by Peng and Lin (2019) showed that organizational ambidexterity helps to reduce the negative effect of organizational tension, which, in turn, improves the performance of the company. Within the context of service innovation, Bustinza et al. (2020) found that the interplay between exploitation and exploration leads to enhanced performance where exploitation precedes exploration.

Organizational ambidexterity is particularly successful in a high degree of environmental uncertainty (Kafetzopoulos 2021). Meanwhile, in the short term, ambidexterity is ineffective as it requires duplication of effort and waste of resources for innovation, not all of which will be justified in the short term (O'Reilly and Tushman 2013). For example, a study by Menguc and Auh (2008) revealed a negative relationship between organizational ambidexterity and performance.

However, studies show that the company effort focused on both *balancing* and a *combination* of both efforts is associated with superior performance if compared to the companies that focus on only one component of ambidexterity (Raisch and Birkinshaw 2008). Excessive focus on exploiting the current competencies at the expense of exploration may lead to organizational inertia that prevents the organization from appropriately adapting to the changing environmental conditions with the resultant inefficiency over the long term (Smith and Tushman 2005). Equally, overemphasis on exploration has a negative impact on performance in the sense that innovations are replaced too quickly with new innovations and with underdeveloped ideas without giving enough time for companies to pay off and generate sufficient revenue (Levinthal and March 1993).

Meta-analysis performed by Junni et al. (2013) revealed that organizational ambidexterity is positively and statistically significantly related to performance. The results of the meta-analysis also showed that exploration was mainly related to growth, while exploitation was related to the company profits. It should be noted that there are several studies that theorized about the existence of a negative relationship between the organizational ambidexterity and performance (Menguc and Auh 2008; Partanen et al. 2020). Contrary to expectations, Menguc and Auh (2008) did not find that organizational ambidexterity has any negative effect on the performance of a firm.

When it comes to the different forms of ambidexterity, balancing-based ambidexterity showed a positive but weaker relationship with performance than combination-based ambidexterity. Meta-analysis performed by Junni et al. (2013) argues that this kind of connection is likely to be determined by the nature of ambidexterity. For example, ambidexterity based on balancing may represent equal levels of exploitation and exploration, but the latter may be of a sufficiently low level.

An overview of research on the organizational ambidexterity-performance relationship is presented in Table 6.1.

To conclude, organizational ambidexterity in the majority of cases is found to be positively related to performance. However, the nature and the magnitude of the ambidexterity-performance relationship depends on the boundary conditions of various contextual factors.

6.5 Conceptual Domains of Lean and Agile

Lean Approach Analysis of scientific literature reveals that both the *lean* and the a*gile* approaches to production can be treated as paradigms of production and as capabilities of performance. According to Narasimhan et al. (2006) within the context of paradigms, the l*ean* and the a*gile* production are described as systems of certain practices and the elements of corporate philosophy, values, and culture. At a more abstract level, it is difficult to identify the differences between the two approaches to production. The conceptual distinction between these phenomena at the paradigm level is difficult due to confusing definitions that include both performance and characteristic production practices (Narasimhan et al. 2006). A more precise definition of both phenomena is possible by conceptually distinguishing between l*eanness* and a*gility* as performance capabilities and the corresponding practices associated with the l*ean* and a*gile* production systems.

One of the key dynamic capabilities representing the optimal productivity of business processes and enhancing the capability of a company to meet market needs is l*ean* (Cavusgil et al. 2007). Leanness, via its capability to minimize the cost of delivering production and value to customers, generates sustainable competitive advantage. An essential aspect of leanness is the efficient use of resources through minimization of waste and profusion. Lean manufacturing focuses on reducing

Table 6.1 Performance outcomes of organizational ambidexterity-performance link

The nature of the relationship	Authors	Research design	Context	Form of ambidexterity	Findings
Positive relationship	Gibson and Birkinshaw 2004	Survey, 4195 respondents of 41 business units	Multinational firms	Combination (both exploitation and exploration are at high levels); both are non-substitutable and interdependent	Contextual ambidexterity relates positively to performance
	He and Wong 2004	Survey, 206 manufacturing firms	Technological innovation	Combination (both exploitation and exploration are at high levels)	Organizational ambidexterity has a positive effect on sales growth (interaction of exploitation and exploration) Relative imbalance of exploitation and exploration relates negatively to sales growth
	Lubatkin et al. 2006	Survey, 139 SMEs	SMEs	Combination (both exploitation and exploration are at high levels)	Highest levels of performance are achieved when both exploration and exploitation are at their highest degrees
	Jansen et al. 2012	Survey, company records			Unit level ambidexterity is positively related to unit financial performance
	Boumgarden et al. 2012	In-depth case analysis	Case studies of *Hewlett-Packard* and *USA Today*	Balance of exploration and exploitation	Organizational ambidexterity is beneficial to performance
	Patel et al. 2013	Survey, 215 firms	High-tech small to medium-sized enterprises (SMEs). Within the context of HR practices	Balance of exploration and exploitation (ambidexterity congruence)	High-performance work system utilization is positively related to organizational ambidexterity, which in turn positively affects firm growth

(continued)

Table 6.1 (continued)

The nature of the relationship	Authors	Research design	Context	Form of ambidexterity	Findings
	Monferrer Tirado et al. 2019	Survey, 384 bank branch managers	Banking sector, bank branches		Exploration leads to enhanced performance through exploitation
Negative relationship	Partanen et al. (2020)	Survey, 200 manufacturing SMEs	Equipment manufacturing SMEs	Combination (both exploitation and exploration are at high levels)	Supply chain ambidexterity negatively affects small firm profit performance
Zero relationship	Menguc and Auh 2008	Survey, 260 manufacturing firms	Various industries	Combination (both exploitation and exploration are at high levels)	Negative relationship assumption was not supported. Organizational ambidexterity does not have a negative effect on firm performance

resource wastage and various activities not creating value. Some authors (Hopp and Spearman 2004; de Treville and Antonakis 2006) identify “obvious profusion,” such as unnecessary processes, excessive setup times, unreliable machines, repeating procedures, and “less obvious” waste associated with volatility as methods for reducing waste. Fluctuations in the processing time, delivery time, profitability, the number of employees, the level of demand, and others create buffer costs. Lean operations allow to eliminate obvious wastage, reduce volatility, and enable the replacement of expensive buffers (such as stocks) with cheaper ones (such as capacity). Ultimately, this has a positive impact on the company’s performance in terms of cost efficiency, compliance quality, delivery speed, and reliability. Performance improvement is the consequence of higher resource productivity and utilization, lower overheads, lower stock (buffering) levels, faster cycle times, and throughput times.

Shah and Ward (2003) describe the lean manufacturing as a set of practices that work synergistically to create a streamlined, high-quality system that enables the production of finished products at the pace of the customer demand and with minimal or even zero waste. The practices characterizing lean manufacturing include procedures enabling the JIT (*just in time*) flow, human resource development and empowerment practices, facility management and preventive maintenance, and various quality control practices (McLachlin 1997; Negrão et al. 2017; Shah and Ward 2003). Analysis of scientific literature reveals that lean manufacturing is described in a similar manner by various authors. According to Narasimhan et al. (2006), manufacturing is considered to be lean if it is performed with minimal wastage due to unnecessary, inefficient operations, or excessive buffering in operations. Thus, in terms of the concept of leanness, it is considered to be a production-based approach that includes a set of operational tools to help identify and reduce or eliminate waste and value-adding activities, reduce costs and improve efficiency and effectiveness of manufacturing processes (Centobelli et al. 2019). This perspective underlines the need to increase the efficiency of the already existing production processes and reduce costs in order to achieve short-term goals as a prerequisite for enhancing the competitiveness of the company.

Agile Approach While the conceptualization of agile manufacturing is less developed, it obviously emphasizes other aspects. Agility reveals the capability to effectively change business specifics when taking into account highly uncertain and changing market conditions (Fliedner and Vokurka 1997). Agility encompasses a wide range of flexibility and the capability to engage in unplanned, new activities in response to unexpected market changes or unique customer requests (Brown and Bessant 2003; Prince and Kay 2003; Sharifi and Zhang 2001). Agile production programs emphasize areas of performance improvement of these activities—more adequate response, product adaptation, reduced lead times for the development of new products, reduced system switching times and costs, as well as efficient scaling-up and scaling-down of operations. Manufacturing practices related to agility emphasize the use of advanced manufacturing technologies, utilization of vendor alliances, understanding of training, highly qualified staff and customer needs, and practices for management of sales staff relationships with customers in the organization (Brown and Bessant 2003; Prince and Kay 2003). According to Narasimhan et al. (2006), the manufacturer is agile if it efficiently changes the states of operations in response to the undefined and changing requirements placed upon it.

The differences between the two approaches at the paradigmatic level emerge when analyzing their expression in the supply chain. According to Naylor et al. (1999), agility requires the use of knowledge of the market and a virtual architecture of the organization in order to enable an organization to take advantage of the opportunities offered by the rapidly changing market. Meanwhile, leanness requires elimination of all forms of waste, including time, and requires the implementation of constant production level schedules. The key difference between the two approaches is the importance attached to flexibility in responding to market needs. The agile system places more emphasis on rapid reconfiguration and reliability, while the lean system focuses more on a well-established, predictable production schedule. Flexibility is a key feature of an agile organization. The scientific literature maintains that the two paradigms are different but overlap in their content—they can coexist (Christopher and Towill 2001). Leanness is characterized by improved quality, level of service, and lead time, but the most prominent feature is its higher cost efficiency.

Agility, meanwhile, is characterized by better service level achievements, but also by positive changes in cost, quality, and lead times. Thus, while lean and agile manufacturers share the same priorities in terms of production competitiveness (cost, quality, lead time, service level), the importance attached to them is different. The results of the empirical research of Narasimhan et al. (2006) confirmed that manufacturing companies with strong lean practices have well-developed capabilities that emphasize cost efficiency, quality control, and reliability. Therefore, leanness has the greatest impact on cost-effectiveness (Christopher and Towill 2001; Shah and Ward 2003). Meanwhile, companies oriented toward agile practices are characterized by an emphasis on achievement in service capabilities.

Summarizing the analysis of scientific literature, it can be argued that leanness and agility are different performance capabilities explaining the essential differences in the manufacturing performance. However, the analysis of scientific literature also shows that both lean and agile manufacturers share certain commonalities that occur through the same applied manufacturing practices. The results of empirical research (Narasimhan et al. 2006) show that agile manufacturing companies outperform lean companies in all the dimensions of performance outcomes, except for cost efficiency.

Although the two phenomena are obviously linked, there is no unanimous consensus in the scientific literature as to which is the precursor to it. Although, at the theoretical level, assumptions are made that manufacturing companies follow a certain evolutionary path while going from one level of achievement to the other (Hormozi 2001), such assumptions still lack theoretical and empirical justification. The sequence of implementing the lean and agile manufacturing practices, their impact on the manufacturing performance, and how the level of digitization and digitization capabilities affect this sequence and performance, are relevant and require further research and articulation of the scientific problem.

Leanness and Performance Analysis of scientific literature shows that various lean aspects are positively related to operational performance (Ghobakhloo and Hong 2014). For example, stocks managed according to the lean principle allow simplifying and elimination of excess stocks in the system (Eroglu and Hofer 2014). Lean manufacturing processes have a positive impact on the production quality and productivity thus allowing to simplify the demand flow management (Prajogo et al. 2016). The lean-based strategy of introducing the new product in the market reduces the necessary stock level, errors, and defects, and reduces the lead time for orders (Calantone and Di Benedetto 2012). Leanness improves organizational processes and is positively related to cost efficiencies (Fullerton et al. 2014).

Agility and Performance Agility is found to be positively related to sales turnover, overall performance, and market share (Yusuf and Adeleye 2002). Literature indicates that agility has the potential to increase product differentiation (Hallgren and Olhager 2009). Ghobakhloo and Azar (2018) found that agile manufacturing leads to enhanced marketing and financial performance within the automobile manufacturing settings. Overall, agility is suggested to be leading to higher performance gains when the environment is highly unpredictable and is characterized by the changing demand.

6.6 Conceptual Proximity of Leanness and Agility Versus Exploitation and Exploration

The literature review shows that the key features of exploration and leanness obviously share a certain degree of conceptual proximity. Definitions of both exploitation and leanness refer to the notion of efficiency and effectiveness. In a similar vein, the conceptual overlap of exploration and agility is revealed through flexibility, market responsiveness, and, consequently, innovations (see Table 6.2). Exploration activities favor flexibility and organic structures, whereby exploitation is mostly achieved by efficiency and rigid organizational practices (Ghemawat and Ricart Costa 1993).

Based on the conceptual proximities shown in the table above, leanness is regarded as the proxy to exploitation, whereas agility is assumed to be a representation of exploration-related capability. This study defines lean capabilities as encompassing cost and quality dimensions. Meanwhile, capabilities reflecting the agile pattern include flexibility and innovation dimensions. In the first chapter, we argued that quality was an amorphous concept. Companies would agree that quality is essential despite their chosen template. To avoid this bias, we use cost performance capability as a characteristic performance capability of a lean template.

Table 6.2 Characteristics of leanness, agility, exploitation, and exploration

Concept	Descriptive characteristics	Conceptual commonalities
Exploitation	Cost leadership, cost control, economies of scale, capacity utilization, efficiency, increasing productivity, certainty, and variance reduction	Cost-effectiveness and efficiency, reliability (quality and delivery)
Leanness	Cost-effectiveness and efficiency, efficient use of resources (minimization of waste and profusion), quality control and reliability, compliance quality, delivery speed, and reliability	
Exploration	Innovation differentiation, growth, R&D, search, discovery, autonomy, embracing variation	Flexibility (market responsiveness), innovations, services
Agility	Flexibility and responsiveness to unexpected market changes or unique customer requirements, reduced lead times for development of new products, knowledge of the market and capabilities to capitalize on the emerging market opportunities, emphasis on services	

6.7 Effect of Fit Between Agile and Lean Capabilities on Organizational Performance

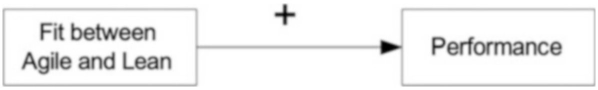
6.7.1 Hypothesis, Measures, and Methods

6.7.1.1 Hypothesis

The performance-enhancing effect of ambidexterity is well-documented in the literature (Junni et al. 2013; O'Reilly and Tushman 2013). The organizational capability to simultaneously pursue exploitation and exploration at a high degree leads to enhanced performance outcomes. Fine-tuned and aligned exploitation activities result in cost efficiency and produce short-term performance benefits in terms of profitability and stable incomes. Exploration manifested as the increased adaptability to turbulent environment permits to capitalize on the emerging market opportunities, therefore inducing innovations and growth of the firm. Exploitation provides resources and enables long-term benefits producing exploration activities. Exploration, on the other hand, prevents organizations from organizational rigidity and dangerous path dependence while operating in turbulent and uncertain environments. Both activities support each other and create synergies while employed simultaneously in a balanced and combined way. Literature suggests that the combination of both capabilities in pursuing both exploitation and exploration activities congruently should result in enhanced performance.

The conceptual proximity between exploitation and leanness, and between exploration and agility suggests that the companies which score high on both agile and lean capabilities should outperform the organizations featuring other forms of agile-lean configurations. Organizational ambidexterity posits that exploration and exploitation are non-substitutable in their positive effect on performance. Given that the

Fig. 6.1 Effect of fit between agile and lean on performance



reasonable extrapolation is that the highest level of performance is achieved when both agile and lean capabilities are at their highest degree. The interdependence and non-substitutability premise suggest that performance enhancement requires the fit between the degree of agile and Lean capabilities. Thus, we hypothesize that the fit between agile and lean levels leads to enhanced performance.

H1: The fit between agile and lean capabilities is positively related to performance.

More specifically:

H1a: Superior performance stems from the fit between the degree of agile and the degree of lean capabilities.

H1b: Organizations that are high on both lean and agile capabilities exhibit higher levels of performance.

Conceptual depiction of the assumed relationship is shown in Fig. 6.1.

6.7.1.2 Measures

Lean capabilities were measured through *cost*, *quality*, *and delivery* dimensions. Agile capabilities were captured through the dimensions of *flexibility and innovation*. We utilized the available reflective five-point scales to measure different facets of agile and lean capabilities. Flexibility was measured with five items (adapted from Narasimhan et al. 2006; Schroeder et al. 2011; Singh et al. 2015). Cost capabilities were captured by three items (Narasimhan et al. 2006). To measure innovation capabilities, we used three items adapted from Henderson and Clark (1990); Shan et al. (2016); Janger et al. (2017). Quality and delivery dimensions were operationalized by using five and five items, respectively (Narasimhan et al. 2006). Table 6.3 shows dimensions (constructs) and corresponding items.

Validity and Reliability

We used a confirmatory factor analysis (CFA) to investigate the psychometric properties of our measurement scales. Item loadings and other statistics are calculated in CFA framework using R package Lavaan and semTools. FIML estimator was used with bootstrapping to account for non-normal variables and to calculate robust standard errors. The measurement properties of the constructs used in this chapter are reported in Table 6.3. All factor loadings were statistically significant, ranging from 0.834 to 0.988. The average variance extracted (AVE) ranged from 0.785 to 0.980, indicating acceptable convergent validity (Bagozzi and Yi 1988). Finally, internal consistency as measured by Cronbach alphas were higher than the commonly recommended threshold of 0.7 (Nunnally and Bernstein 1994), with the range 0.785–0.924.

Table 6.3 Measures of the constructs used in the chapter

Performance capabilities (dimensions)	AVE	Omega	Cronbach alpha	Items	Loading	*p*, loadings
Quality	0.857	0.968	0.857	Product overall quality performance	0.94	0.000
				Product reliability	0.939	0.000
				Product features	0.935	0.000
				Product conformance	0.91	0.000
				Product durability	0.904	0.000
Delivery	0.822	0.958	0.822	Delivery accuracy	0.898	0.000
				Delivery dependability	0.925	0.000
				Delivery quality	0.911	0.000
				Delivery availability	0.902	0.000
				Delivery speed	0.898	0.000
Cost	0.828	0.935	0.828	Unit cost	0.931	0.000
				Manufacturing overhead cost	0.953	0.000
				Inventory turnover	0.834	0.000
Flexibility	0.785	0.948	0.785	Ability to adjust production volumes	0.877	0.000
				Ability to respond to changes in delivery requirements	0.9	0.000
				Ability to customize products	0.865	0.000
				Ability to produce a range of products	0.888	0.000
				Speed on new product introduction into the plant	0.901	0.000
Innovation	0.884	0.958	0.884	Lead time to introduce new products	0.945	0.000
				Number of new products introduced each year	0.966	0.000
				Level of products innovativeness	0.908	0.000

Note: AVE—Average variance extracted

Performance To estimate the level of performance, we used the self-reported measures of profitability and derived a measure of the sales growth rate. The profit variable was measured by using a categorical scale. The EMS survey contains a question asking to report the net profit before taxes (year 2017) in percentage by utilizing the categories “negative,” “0 to 2%,” “2 to 5%,” “5 to 10,” “more than 10%,” respectively. The categorical scale was recoded into the five-point ordinary scale to capture the variability in the relative profit level. The EMS questionnaire also contains a question asking to indicate the production site's annual revenues (millions of EUR) in the year 2015 and in the year 2017, respectively. In order to estimate the sales revenue growth rate, we created a new variable by calculating the percentage change in reported revenues from 2015 to 2017.

The performance-enhancing fit was estimated by employing different methodological approaches documented by Venkatraman (1989). In this study, following the recommendations (Venkatraman 1989), we used two approaches to test the hypothesis. We tested performance-enhancing fit with *Fit as matching: deviation score approach* and *Fit as profile deviation*. By adopting a matching perspective, the fit is derived independently without reference to performance (Venkatraman 1989). The profile deviation approach considers "fit" as a degree of adherence to the specified ideal pattern. This perspective examines how deviation from the specified profile affects performance.

6.7.1.3 Description of Data

Table 6.4 reports the descriptive statistics for all the variables. The strongest capabilities of organizations within the sample appear to be flexibility ($M = 3.75$), quality ($M = 3.64$), and delivery ($M = 3.58$). The quality, delivery, and cost dimensions theoretically manifest leanness. Flexibility and innovation represent agility. The quality and delivery capabilities are slightly more developed than the cost-related skills. Flexibility is the most prominent capability of the agility domain and is also the most prominent in general. In comparison, innovation-related skills are relatively somewhat less developed. The revenues growth rate ranges from −66.67% to 104,551.16%.

To characterize the sample, we calculated the percentage of organizations that reported a relatively high degree of lean and agile-assigned capabilities. Before that, ordinal variables—cost, flexibility, delivery, quality, and innovation, respectively—were recoded into low and high-scoring groups by using the middle point of the scale split. In addition, the median-split and the mean-split were performed for comparison. The scale we used captures how well the capabilities are developed in comparison with those of the competitors. The middle point of the scale (3, respectively) refers to the same level as that of competitors. Therefore, in order to ensure comparability, the middle point was chosen as a base for the split into the groups of low and high-scoring capabilities.

Roughly two-thirds (66.7%) of the organizations in our sample reported that their flexibility-assigned capabilities are better than those of their competitors (see the top part of Table 6.5). Slightly more than a half of the organizations indicated that they outperform competitors along the quality (54.6%) and delivery dimensions (53.6%). Meanwhile, only one-third of all the organizations are characterized by high levels of innovation (32.1%) and cost (29.6%).

Next, we inspected the distribution of the scores of capabilities for low, medium, and high-performing organizations. For that purpose, the two performance variables

Table 6.4 Descriptive statistics of all variables

	Quality	Cost	Flexibility	Delivery	Innovation	Sales revenues growth rate	Sales revenues growth rate[a]	Profit
Mean	3.64	3.23	3.76	3.58	3.25	530.25	72.01	3.22
Median	3.4	3.00	4.00	3.40	3.00	14.75	14.29	3.00
SD	0.72	0.59	0.72	0.68	0.76	6923.31	236.14	1.29
Minimum	2.00	2.00	2.00	2.00	1.00	−66.67	−66.67	1.00
Maximum	5.00	5.00	5.00	5.00	5.00	104551.2	2900	5.00
N valid	460	348	403	429	361	228	227	292
N missing	39	151	96	70	138	271	271	207

[a] w/o extreme outlier ID2120

Table 6.5 Frequency of organizations with low and high levels of agile and lean-assigned capabilities

Group	*N*	%	Group	*N*	%	Group	*N*	%	Group	*N*	%	Group	*N*	%
Cost middle point-split (Binned)			Flexibility middle point-split (Binned)			Delivery middle point-split (Binned)			Quality middle point-split (Binned)			Innovation middle point-split (Binned)		
<= 3.00	245	70.4	<= 3.00	134	33.3	<= 3.00	199	46.4	<= 3.00	209	45.4	<= 3.00	245	67.9
3.01+	103	**29.6**	3.01+	269	**66.7**	3.01+	230	**53.6**	3.01+	251	**54.6**	3.01+	116	**32.1**
Total	348	100.0	Total	403	100.0	Total	429	100.0	Total	460	100.0	Total	361	100.0
Cost (median spilt) (Binned)			Flexibility (median split) (Binned)			Delivery (median split) (Binned)			Quality (median split) (Binned)			Innovation (median split) (Binned)		
<= 3.00	245	70.4	<= 4.00	315	78.2	<= 3.40	221	51.5	<= 3.40	232	50.4	<= 3.00	245	67.9
3.01+	103	**29.6**	4.01+	88	**21.8**	3.41+	208	**48.5**	3.41+	228	**49.6**	3.01+	116	**32.1**
Total	348	100	Total	403	100	Total	429	100	Total	460	100	Total	361	100
Cost (mean-split) (Binned)			Flexibility (mean-split) (Binned)			Delivery (mean-split) (Binned)			Quality (mean-split) (Binned)			Innovation (mean-split) (Binned)		
<= 3.23	245	70.4	<= 3.76	181	44.9	<= 3.58	229	53.4	<= 3.64	243	52.8	<= 3.25	245	67.9
3.24+	103	**29.6**	3.77+	222	**55.1**	3.59+	200	**46.6**	3.65+	217	**47.2**	3.26+	116	**32.1**
Total	348	100.0	Total	403	100.0	Total	429	100.0	Total	460	100.0	Total	361	100.0

(sales revenue growth rate and profit) were collapsed into groups by using the Visual Binning SPSS function. Performance variables were broken into three nearly equal groups each. New categorical variables have three values corresponding to the three sales revenue growth rates and profit ranges. Since performance may be conditional upon the size of the organization, we included the variable “2017 number of employees” as a proxy for the organization size into the analysis. The variable “2017 number of employees” was similarly recorded into the categorical variable of the three groups representing three approximately equal ranges of the organization size.

The series of the bar graphs presented in Fig. 6.2 shows the differences in cost, quality, flexibility, delivery, and innovation capabilities scores (means) among low, medium, and high-performing organizations in terms of sales revenues growth rate.

We used a similar graphical exploration to assess the mean differences in cost, quality, flexibility, delivery, and innovation among low, medium, and high-profit performers of different sizes (Fig. 6.3). The bar graphs above suggest that the higher profit performers appear to feature slightly higher levels of flexibility. However, this difference across the profit groups is pronounced only within the group of small organizations. Similarly, within the subsample of the small organizations, the degree of innovation is higher for the higher profit performers. The results presented in Fig. 6.3 suggest that the degree of cost, quality, and delivery levels does not increase with an increase in profit regardless of the size of the organization.

Correlations among the variables are presented in Table 6.6. Neither lean nor agile-related capabilities relate to profit as a performance indicator. However, certain lean (quality and delivery) and agile (flexibility and innovation) linked capabilities are found to be associated with the revenue growth rate. As expected, the relationship is positive and significant. The more developed are the capabilities of quality, delivery, flexibility, and innovation, the higher the performance outcomes in terms of the revenue growth rate. The strongest association is observed between innovation and the revenue growth rate ($r_s = 0.304$, $p < 0.01$). Conversely, the capabilities of cost show significant association neither with profit nor with the revenue growth rate.

To sum up, the inspected correlations are positive and significant only with one performance indicator, a derived measure of revenue growth rate.

6.7.2 *Results of Testing the Effect of Various Types of Fit on Organizational Performance*

Fit as Matching: Deviation Score Approach We analyzed the data with *R* software. Regression analysis was used to test the hypothesis. The deviation score approach within the matching perspective conveys that the absolute difference in standardized scores of two variables indicates misfit between the variables of the domain of interest. Then, the performance variable is regressed on misfit in order to test the performance implications of the misfit between agile and lean capabilities.

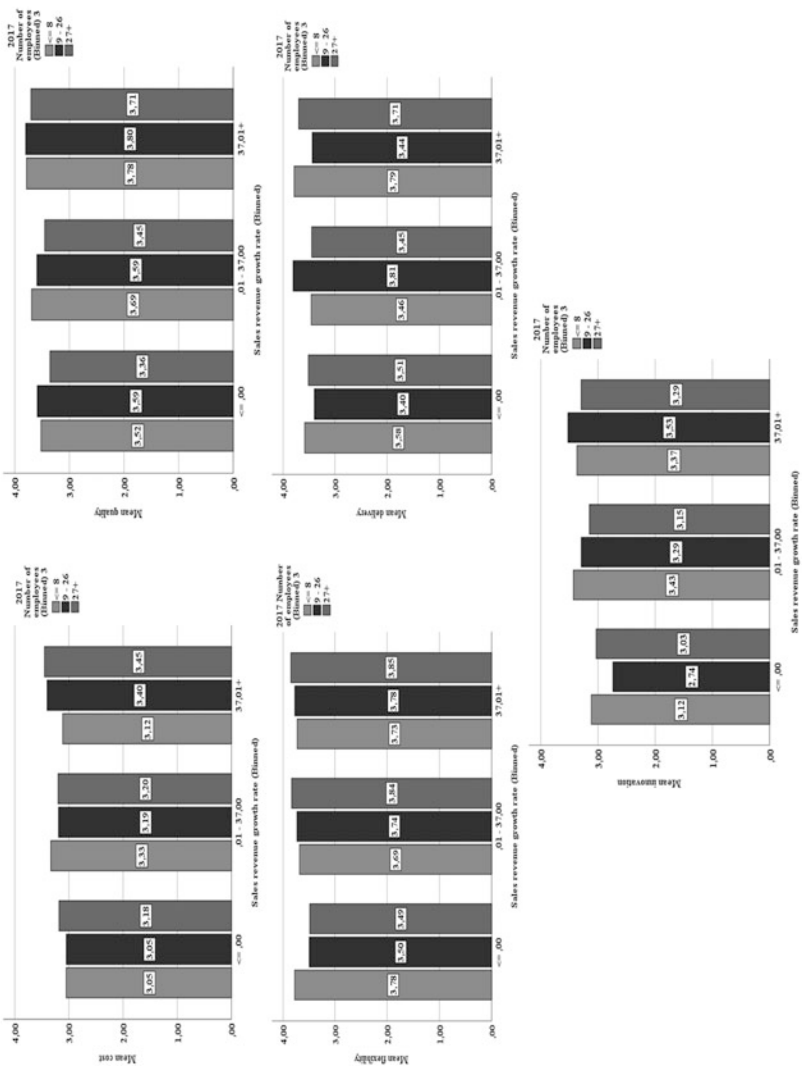


Fig. 6.2 Mean scores of agile and lean-attributed capabilities along with different groups of the sales revenue growth rate and organization size

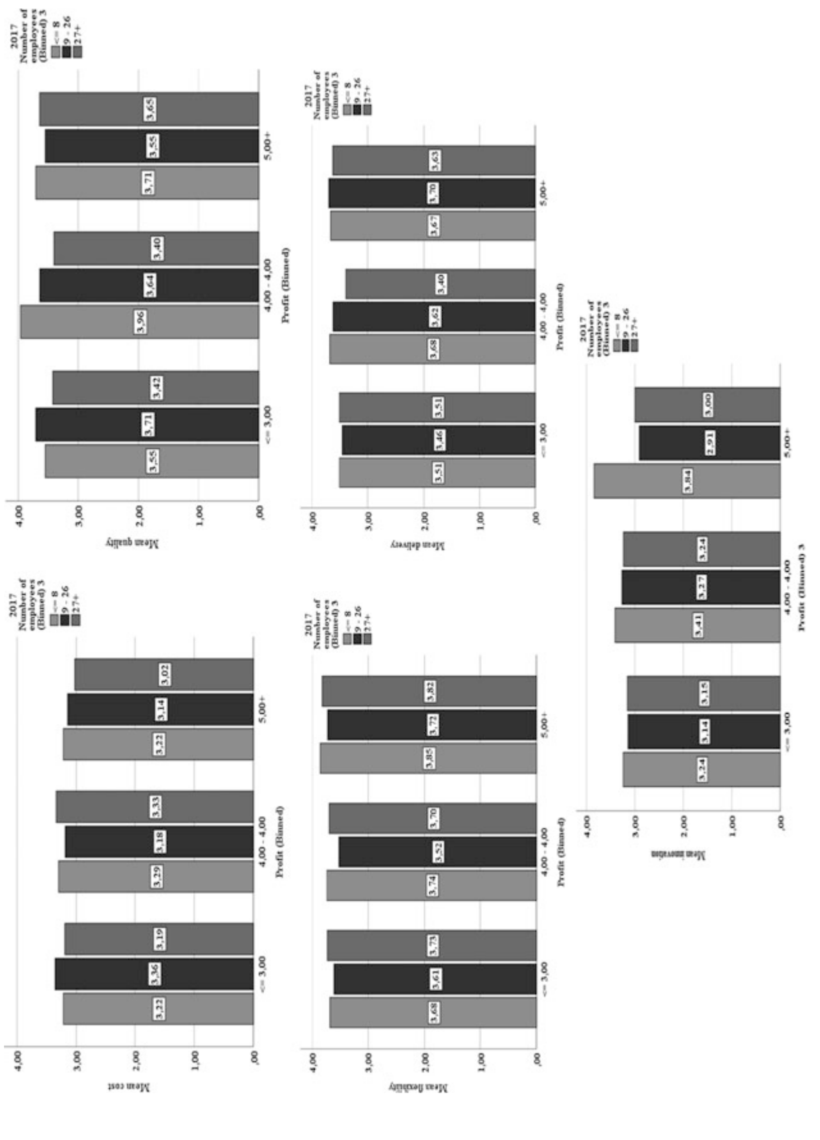


Fig. 6.3 Mean scores of agile and lean-attributed capabilities along different groups of the profit levels and organization size

Table 6.6 Correlations among variables

		Profit	Revenue growth rate	Quality	Cost	Flexibility	Delivery	Innovation
Profit		**1.000**						
	N	292						
Revenue growth rate		**0.113**	**1.000**					
	N	186	228					
Quality		**0.069**	**0.175***	**1.000**				
	N	273	214	460				
Cost		**–0.054**	**0.145**	**0.265****	**1.000**			
	N	219	173	343	348			
Flexibility		**0.032**	**0.170***	**0.388****	**0.298****	**1.000**		
	N	247	193	396	340	403		
Delivery		**0.102**	**0.153***	**0.482****	**0.347****	**0.392****	**1.000**	
	N	260	203	420	343	392	429	
Innovation		**0.067**	**0.304****	**0.404****	**0.414****	**0.426****	**0.345****	**1.000**
	N	225	179	355	305	350	352	361

Spearman's rho. * Correlation is significant at 0.05 level (2-tailed). ** Correlation is significant at 0.01 level (2-tailed)

We used the regression equation which was adapted based on the works of Naman and Slevin (1993) and Hultman et al. (2009):

$$\text{Performance} = f(\text{misfit}) = C_0 + C_1\text{misfit} + \varepsilon,$$

where $c_1 < 0$.

Misfit = $|X1\text{-}X2| + |X1\text{-}X3|$, where

$X1$ = cost

$X2$ = innovation

$X3$ = flexibility

Based on theoretical reasoning, the misfit has to be negatively related to performance. The lean capability in this model is represented by the cost dimension. Agile capabilities include innovation, and flexibility. The absolute difference between lean and agile capabilities indicates the degree of mismatch, which shows the poor balance between exploration and exploitation. The imbalance of these capabilities should theoretically result in poor performance outcomes.

The data shows a poor fit to the linear regression model with profit as the dependent variable. We do not observe any linear relationship between misfit and profit as performance variables (see Fig. 6.4).

Contrary to expectations, we cannot conclude that the match between the degree of lean and agile capabilities is linked to profit (Fig. 6.4).

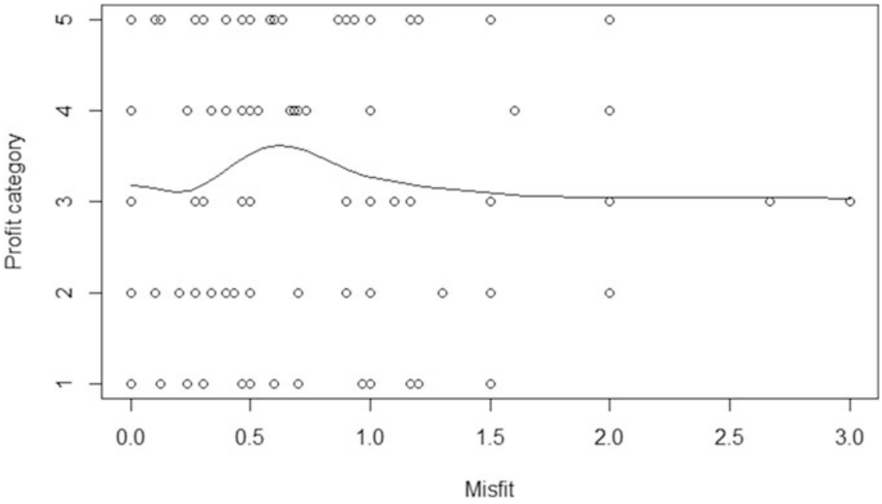


Fig. 6.4 Relationship between misfit and profit ($N = 216$) (scale: theoretical min = 0, max = 12)

Table 6.7 Regression analysis testing for misfit effect on sales revenue growth rate

	Outcome			
	Y (sales revenue growth rate)			
Predictor	Coeff. *B*	*SE*	*T value*	*p*
Intercept	41.12	13.48	3.051	0.00265***
X (misfit)	34.24	17.09	2.003	**0.04675***

$R^2 = 0.023$ adjusted $R^2 = 0.017$
$F = (1, 169) = 4.013$, $p = 0.0468$*
$N = 155$, *** if $p < 0.0001$, * if $p < 0.05$

Sales revenue growth rate was regressed on misfit (see Table 6.7). Contrary to expectations, misfit was found to be positively and significantly related to the sales revenue growth rate ($B = 34.24$, $p < 0.05$). Our findings suggest that the higher the degree of mismatch between lean and agile-assigned capabilities, the better are the performance outcomes. The opposite direction of the relationship implies that compensation for the underdevelopment of one set of activities by the other (lean or agile) may positively affect performance outcomes. Ultimately, hypothesis H1a is not supported within our sample.

Fit as a Profile Deviation The underlying hypothesis is that the organizations which exhibit high levels of lean (cost) and agile (innovation, flexibility) simultaneously demonstrate better performance outcomes. The degree of adherence to a specified profile (the high level of all the listed agile and lean capabilities) has a significant effect on performance. We took 10% of the organizations with the highest revenue growth rate and calculated their average scores on cost, innovation, and flexibility. The same was done for the highest profit category. It was not possible to select 10% in this case. We were forced to choose the highest revenue category as a

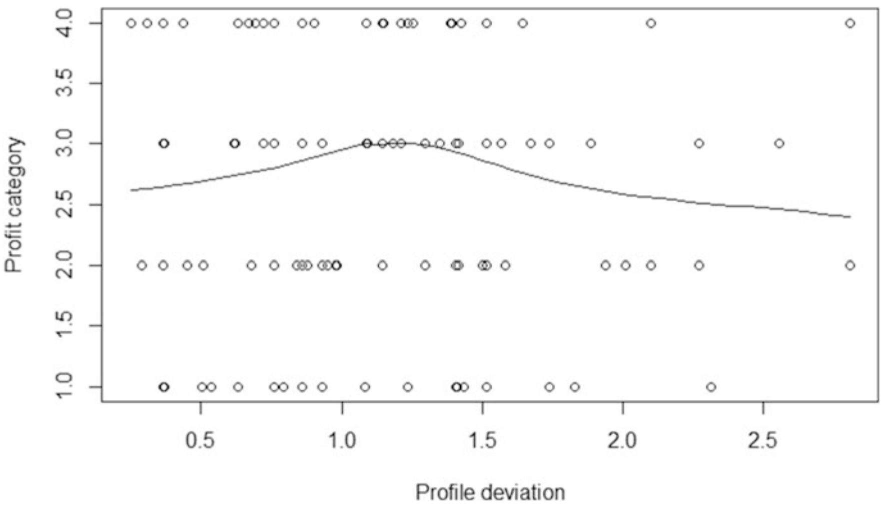


Fig. 6.5 Relationship between misfit and sales revenue growth rate ($N = 171$)

calibration sample. The fifth revenue category had 57 entries that made up 19.5% of the valid cases and 11.4% of the overall sample. The missing values ($N = 154$) were excluded from the sample of $N = 499$. For the rest of the sample for both performance variables, the deviations (Euclidean differences) from the calibration sample means were calculated, squared, summated, and square rooted. The new variable (deviation from the high-performance profile) was thus computed.

The data shows a poor fit to the linear regression model with profit as the dependent variable. With the highest performing companies excluded from the data, the linear regression showed that the profile deviation regression coefficient is negative, however, insignificant. The relationship between profile deviation and profit is depicted in Fig. 6.5.

Within the specific range of profile deviation (see Fig. 6.5), there is a negative relationship between nonadherence to the ideal profile and profit. The graphical representation of the relationship suggests that, upon reaching a certain level of deviation, the further profile deviation results in decreased performance outcomes (profit, respectively). The observed nature of the relationship is partially in line with the predicted direction. However, the insignificant linear relationship does not let us conclude that H1a hypothesis obtained support within the profile deviation perspective.

Our data do not show a significant relationship between profile deviation and sales revenue growth rate (Fig. 6.6). Contrary to our expectations, our data does not support the performance-enhancing fit based on the profile deviation perspective. Therefore, H1b is not supported.

We further conducted a comparison of the mean statistics of the high-performing category and the low-performing category (see Table 6.8). The highest profit-earning group mean scores for innovation and flexibility (agility) are slightly above the mean

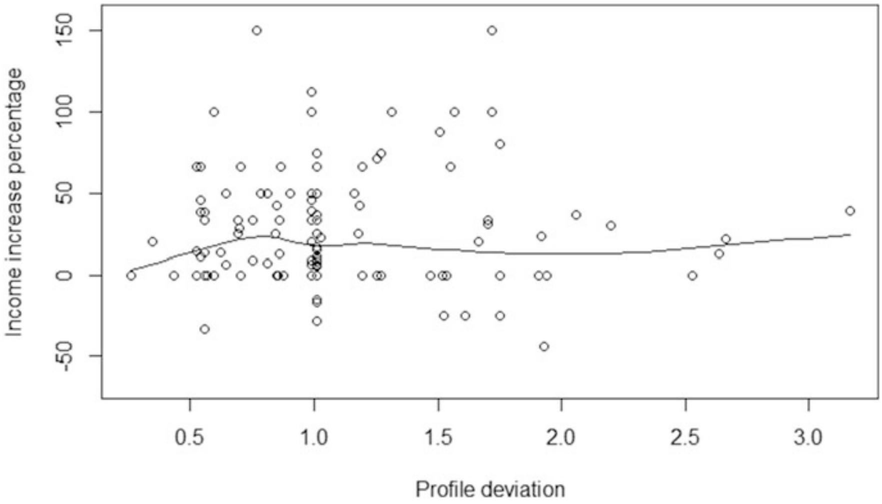


Fig. 6.6 Relationship between profile deviation and profit

Table 6.8 Comparison of the means of the high-performing group and the rest of the sample group along with agile and lean performance capabilities

	Highest profit category	Other profit categories	10% highest sales revenues growth rate category	Other sales revenue growth rate values
Cost	3.133	3.258	3.148	3.198
Innovation	3.277	3.224	3.519	3.146
Flexibility	3.803	3.665	3.853	3.683
N	57	235	23	203

scores of the rest of the sample group. Surprisingly, the organizations belonging to the lower profit group were found to be exceeding high performers on the cost (leanness) dimension.

What concerns the sales revenue growth rate, as expected, the mean scores of the high performers for innovation and flexibility are higher than the mean scores of the rest of the sample group. The organizations which outperform others on the sales revenue growth rate appear to exhibit a relatively higher degree of developed capabilities in the domain of agility-related capabilities (innovation and flexibility, respectively). However, similarly to the profit outcomes, the high performers are weaker on cost capability (leanness).

Next, we tested the mean differences of the agile and lean capabilities within two subsamples—high performers and low performers—respectively. To split the sample into high and low performers in terms of profit, we combined the categories of "negative," "0 to 2%," "2 to 5%" into the new "low performers' category ($N = 159$),

Table 6.9 *T*-tests for high and low performers

DV	*p*-Value	*t* Statistics	df	Means in group 0, 1[a]	Method
By H-L profit category					
quality_mean	0.402873	−0.83782	271	3.56723, 3.6384	Two sample *t*-test
delivery_mean	0.184444	−1.33076	258	3.493124, 3.605271	Two sample *t*-test
cost_mean	0.567785	0.57219	217	3.253501, 3.206667	Two sample *t*-test
flexibility_mean	0.606638	−0.51554	245	3.671554, 3.71886	Two sample *t*-test
innovation_mean	0.340761	−0.9547	223	3.188525, 3.289644	Two sample *t*-test
By H-L revenue growth rate					
quality_mean	0.058846	−1.89958	212	3.513208, 3.68642	Two sample *t*-test
delivery_mean	0.171663	−1.37177	201	3.510891, 3.637255	Two sample *t*-test
cost_mean	0.145751	−1.46149	167.8449	3.130522, 3.251852	Welch two sample *t*-test
flexibility_mean	0.095569	−1.67501	191	3.616489, 3.77963	Two sample *t*-test
innovation_mean	**0.002474**	−3.07252	169.2803	3.019841, 3.333333	Welch two sample *t*-test

[a] 0—low performers, 1—high performers

while the two latter categories (“5 to 10%,” “more than 10%,” respectively) were attributed to the high performers’ group ($N = 133$). Based on the revenue growth rate, high ($N = 114$) and low ($N = 114$) performers were calculated with the median split (Mdn = 13.96%). The mean values of quality, delivery, cost, flexibility, and innovation indicators were calculated, and t-test calculation was performed in order to test whether statistically significant differences exist within the two subsamples (see Table 6.9).

The first half of Table 6.9 indicates that high performers in the profit category exceed the low performers across all the capabilities except for cost. However, these differences are not statistically significant. The second half of Table 6.9 shows the differences between high performers and low performers in terms of the revenue growth rate. While the results are consistent with the expected differences, they are largely insignificant. There are no significant differences detected within the subsamples of high and low performers along with all the agile and lean capabilities, except for the innovation capability. *T*-tests show that the high performers score higher on the innovation capability than the low performers with respect to the revenue growth rate. Overall, the T-test results do not provide support for the assumption that the high performers should exhibit higher degrees of all the agile and lean capabilities in order to outperform the low performers with respect to their capabilities.

6.8 Summary

Literature review revealed that leanness and exploitation similarly to agility and exploration exhibit a certain degree of conceptual overlap. The latter conceptual proximities suggest that the combination and balancing of leanness and agility should improve the performance outcomes as is the case with the ability to reconcile exploitation and exploration simultaneously, which refers to the concept of organizational ambidexterity. Relying on the premise that organizational ambidexterity leads to enhanced performance, this study tested the hypothesis that enhanced performance is the result of the fit between agile and lean capabilities. The fit between lean and agile capabilities was tested by applying the strategic fit perspectives. More specifically, the fit as matching (the deviation score approach) and the fit as profile deviation were employed to examine the performance-enhancing fit hypothesis.

Descriptive statistics showed that the sample organizations excel at flexibility and fall behind on costs. Neither lean nor agile-attributed capabilities were related to profit as a performance indicator. However, in line with our prediction, individual lean-related capabilities, such as quality and delivery, and agile-related capabilities—flexibility and innovation—respectively, show positive and significant association with the revenue growth rate. These findings are in line with those of Prajogo et al. (2016), Calantone and Di Benedetto (2012), Yusuf and Adeleye (2002), Ghobakhloo and Azar (2018) who found that leanness and agility are positively related to various performance metrics.

The deviation score approach within the matching perspective did not indicate a significant relationship between misfit and profit, whereas a misfit in terms of the sales revenue growth rate was found to be positively and significantly related. However, the opposite direction of the relationship between misfit and the sales revenue growth rate prevents us from drawing the conclusion that matching agile and lean leads to improved performance outcomes. The positive relationship between misfit and performance implies that a combination rather than balancing might be the performance-enhancing driver. Higher mismatch refers to the higher differences between the levels of agile and lean-assigned capabilities. Therefore, the positive relationship may suggest that the high degree of one capability may compensate for the deficiencies in another capability. However, these speculations require more thorough theoretical justification and different methodological approaches, thus highlighting the direction for further investigation.

The profile deviation strategic fit perspective revealed that, within the particular range of profile deviation, there is a negative relationship between nonadherence to the ideal profile and profit. However, the observed nature of the relationship is non-significant. Thus, we did not find support for the assumption that superior performance stems from the fit between agile and lean capabilities within the profile deviation perspective.

Consistent with theoretical reasoning, the organizations which outperform others in terms of the profit and revenue growth rate were found to be scoring higher on all the capabilities except for cost. However, the detected differences were statistically significant only in the case of innovation capability and in the group of high performers with respect to the sales revenue growth rate.

The current study adds to the literature on the performance consequences of agile and lean-ascribed template compatibility within the theory of organizational ambidexterity. The lack of empirical support does not allow us to claim the positive performance outcomes resulting from the compatibility of lean and agile ascribed templates. The empirical results of manufacturers corroborate the notion that ambidexterity is rare and difficult to maintain (Tushman and O'Reilly 1996). Our results also align with the premise that balancing the agile-lean templates is less relevant for manufacturing firms (Junni et al. 2013). Such findings also echo those of other authors (Hughes 2018), pointing out that the complex template compatibility–performance relationship may be sensitive to the range of boundary conditions. Because the compatibility of the agile and lean templates from the perspective of strategic fit is susceptible to various conceptualizations and measurement perspectives, further research should test the current hypothesis from different methodological avenues.

Annex 6.1 Measurement Scales

Measurement of Performance Capabilities

Indicate how well your factory performed compared to its competition within your industry along these different performance dimensions, 1—Much worse, 2—Somewhat worse, 3—About the same, 4—Somewhat better, 5—Much better, 6—I don't know.

Quality

– Product overall quality performance
– Product reliability
– Product features
– Product conformance
– Product durability

Cost

– Unit cost
– Manufacturing overhead cost
– Inventory turnover

Flexibility

– Ability to adjust production volumes
– Ability to respond to changes in delivery requirements
– Ability to customize products
– Ability to produce a range of products
– Speed of new product introduction into the plant

Delivery

– Delivery accuracy
– Delivery dependability
– Delivery quality
– Delivery availability
– Delivery speed

Innovation

– Lead time to introduce new products
– Number of new products introduced each year
– The extent of innovativeness of products

Measures of Financial Performance

Please characterize your factory:

– Annual turnover

  In 2017 XX million €
  In 2015 XX million €

– Number of employees:

  In 2015 XX number
  In 2015 XX number

– Return on sales (before tax, 2017)

  Negative
  0 up to 2%

>2 up to 5%
>5 up to 10%
>10%

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Chapter 7
Factors Affecting Trade-Off, Cumulative Capability, and Alternative Models of Operation Strategy

Abstract A framework of competitive capabilities connects intentions, actions, and performance at the organization's strategic level. The decision about the sequence of obtaining capabilities is the question for the selection of operation strategy. This research explores four competitive dimensions: quality, cost, flexibility, and delivery in various sequences, i.e., trade-off, cumulative capabilities, non-competitive, and multiple models. We assume that factors such as competitive priority, manufacturing capacity utilization, product complexity, and others influence a particular sequence model. The survey results represent 500 Lithuanian manufacturing companies, according to the methodology of the European Manufacturing Survey. Our research confirmed all four operation strategy models in Lithuanian manufacturing organizations. The main results have shown that implementing the trade-off model and developing only one capability means the loss of innovations. On the contrary, the cumulative way of developing capabilities is positively associated with innovations, cooperation, digitalization in manufacturing, and better utilization of manufacturing capabilities. Organizations that embrace the multiple capabilities model mainly benefit from the main product customization and are the next ones in innovation. Non-competitive model organizations have been found to have low innovations and low digitalization. Furthermore, factor analysis has shown additional differences and similarities between the operation strategies.

7.1 Introduction

Operation strategies and their selection are essential for the future development of organizations. A competitive capabilities framework joins intentions, actions, and performance at the strategic level (Skinner 1969; Porter 1985; Hayes et al. 1988). Operation strategies of organizations are widely discussed in the literature proposing different approaches to how organizations are developing their competing capabilities for manufacturing. The two main operation strategies are described by the trade-off model (Narasimhan et al. 2006; Rosenzweig and Easton 2010), and by the cumulative capabilities model (Ferdows and De Meyer 1990).

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According to the classical Skinner's trade-off model, the organization makes a strategic choice in emphasizing one competitive dimension against the other dimensions. Organizations cannot perform well across all the dimensions as the improvement in one dimension results in some deterioration in another one. The model includes four competitive dimensions, specifically, quality, cost, flexibility, and time (Safizadeh et al. 2000), while time is replaced by delivery in later research (Boyer and Lewis 2002; Narasimhan et al. 2006). The idea that manufacturing organizations should follow the trade-off model and focus on one capability in order to maintain and foster competitiveness has been strongly supported by many researchers (e.g., Boyer and Lewis 2002; Nand et al. 2013). However, empirical evidence does not always support the existence of the trade-off model. Upon exploring 1438 research plants, Singh et al. (2015) found none to be following this model.

Based on the previous research, Ferdows and De Meyer (1990) claim that empirical evidence from manufacturing companies in North America, Europe, and Japan proved that all the four competitive dimensions as organizational capabilities can be built upon each other, i.e., outperformed simultaneously. They present a sand cone model known widely as the cumulative capabilities model. The logic of the cumulative capabilities model is based on the sequential obtaining of capabilities with the cumulative effect. First, quality is obtained, then delivery, flexibility, and costs. Empirical evidence provided by Narasimhan and Schoenherr (2013), Singh et al. (2015), Boon-itt and Wong (2016) confirmed the sequence of cumulative capabilities. Manufacturing organizations develop strong capabilities in a particular order along multiple dimensions (Singh et al. 2015).

At the same time, Narasimhan and Schoenherr (2013) report similar or better results on other sequences of capabilities and operation strategies. Alternative paths are related to the split of the sequence after delivery. Hallgren et al. (2011) found that cost and flexibility are developed simultaneously rather than sequentially. Also, their results reject the link between cost and flexibility. Therefore, alternative models might be possible. The call for additional ones (Hallgren et al. 2011) is still relevant due to existing contradictions (Frynn and Frynn 2004) or current models' lack of explanatory power.

Discussions about the relationship between the trade-off and cumulative capabilities models resulted in the development of other models. Instead of a single cumulative capabilities model, Schroeder et al. (2011) found a high variance of capabilities sequences and claimed alternative ways to high performance. According to them, it also depends on the selected strategy of operation. Singh et al. (2015) tested alternative models, such as the "threshold model," "average model," "non-competitive model," and "multiple models," and validated them empirically. The threshold model is described with one high capability, whereas others are at the average levels, while the average model consists of all the capabilities at the average level. Two additional models were identified. All the low capabilities represented a non-competitive model, which was also confirmed in a small yet significant amount of the researched plants. Various combinations of capabilities received support from the empirical data and were summarized into multiple models.

Our further research of sequence models of the operation strategy is based on the need for empirical data that describes practical situations and contributes to the understanding of fundamental concepts (Sarmiento et al. 2016). As additional information for investment and development of operational capabilities is needed for organizations (Scarpin and Brito 2018), analysis of the factors influencing one or another model of the operation strategy shall contribute to the strategic decision-making and assigning resources for implementation.

7.2 Factors of Operation Strategies

In an open and complex business environment, multiple possible ways to develop organizations coexist. Our next step is to explore the factors of operation strategies that impact sequence models. Schroeder et al. (2011) believe that different strategic goals may lead to different sequences. The leading manufacturing organizations cannot be an efficient frontier but may instead lead differently.

The classical competitive priorities are short and on-time delivery, quality, flexibility, and low costs (Boyer and Lewis 2002). Flexibility reflects the organization's ability to behave in a more responsive way to its customers' needs, therefore, becoming advanced in customization. Accordingly, low costs create a possibility for organizations to provide products at a lower price. Although researchers mainly point out these four main competitive priorities, others highlight additional competitive priorities, such as innovations (Diaz-Garrido et al. 2011) and customer services (Corbett and Van Wassenhove 1993; Da Silveira et al. 2001). Thus, we further research six main competitive priorities, specifically, price, quality, customization, delivery, innovation, and services. As soon as the competitive priorities that the management considers to be important have been selected (Safizadeh et al. 2000), focus on the manufacturing operations follows next (Skinner 1974).

Despite the amount of manufacturing capacity, organizations differ in their utilization. Maximum performance in manufacturing by an organization can be limited by the plant's capacity (Schmenner and Swink 1998). However, organizations do not always utilize their manufacturing capability at the most providing another possible factor that might be related to the possibility of implementing one or another sequence model. Internal organizational settings may also limit the flexibility and organizational capability to cope with the customers' needs. Such restrictions reflect the operational decisions regarding the method of manufacturing. The organization might manufacture products to the stock, make final assembly upon customer order, or may start manufacturing only upon the order of the customer.

Building competitive advantage on capabilities development differs according to the external organizational environment. The specific industry might limit the application or provide opportunities for one or another sequence model. Advanced manufacturing technologies might contribute to building cumulative capabilities in smaller organizations but not in building multiple capabilities in larger organizations. Liu et al. (2011) state that, in such a case, organizations trade-off cumulative capabilities with regard to low costs even though, in the same industry, some organizations might still perform two times better than others (Syverson 2004). Thus, such factors as the industry and the company size might impact the sequence model and should be researched further.

The complexity of manufacturing and the product itself might also impact the sequence model. In general, larger organizations implement higher complexity (Choi et al. 2001). Advanced manufacturing technologies related to manufacturing complexity contribute higher to developing cumulative capabilities in small organizations than in large ones (Liu et al. 2011). In the case of the trade-off model, Sarmiento et al. (2016) draw attention to the competitive aspects of the product. Such positively accepted aspects as the user experience might be less competitive than the price of the product. However, the relationship between the sequence model and the specific aspects of the product calls for empirical evidence.

A set of factors of sequence models is assigned to innovations and digitalization. In the discussion among the researchers of sequence models, sometimes, innovations appear as one of the capabilities and are included in the sequence (Noble 1995; Peng et al. 2008; Narasimhan and Schoenherr 2013). Still, the latest research of innovations in sequence models by Vilkas et al. (2021) shows that innovations are developed not in sequence with other capabilities but simultaneously. Thus, innovations can be a factor for sequences as well. Development of innovations is also related to other activities in organizations like research and development, cooperation, customization, environmental features in new products, etc. While many researchers confirm the link between R&D and innovations, cooperation contributes positively to this link (Berchicci 2013; Rojas et al. 2018). Moreover, Radicic and Balavac (2019) confirmed the importance of cooperative partners on the joint impact of internal and external R&D activities on innovations.

In addition, product manufacturing innovations include customers' participation in the product development process. Sarmiento et al. (2016) highlight customers' interests in environmentally conscious manufacturing. Environmental care fostered by customers is also visible in the final product(s). In general, environmental features in manufacturing and products and their role in the sequence models have been gaining the attention of various researchers (Harrison et al. 2005; Avella et al. 2011; Sarmiento et al. 2016), even considering environmental features as one of the main competitive priority (Diaz-Garrido 2011). Moreover, customers may actively participate in the new product development by contributing to new ideas, features, or environmental approaches (Papageorgiou et al. 2017; Morgan et al. 2019).

The increasing demand from customers fosters organizations to seek various possible competitive advantages (Westerman et al. 2011). For this, Bharadwaj (2000) identifies such a possibility in digitalization. It helps to optimize organizational processes with the aim of operational excellence through data-based workflows (Lederer et al. 2017) and by using the technology to radically improve the performance or reach of enterprises (Westerman et al. 2011). Digital manufacturing and its features are already implemented in manufacturing organizations (Klotzer et al. 2017; De Carolis et al. 2017; Nadeem et al. 2018). As digitalization is a relatively new research area, regarding sequence models, it has already been established that digital manufacturing companies develop their cumulative capabilities differently from traditional manufacturing ones (Kulkarni et al. 2019).

Besides strategic, operational, and technical decisions in organizations, human resources play a role in exploring and exploiting new knowledge. Liu et al. (2011) point out the performance of human and technological resources. In agile organizations, attention is paid to the employees' competencies, education, team building, and other human resource-related features to ensure innovations and cooperation inside and outside organizations (Yusuf et al. 1999). By contrast, organizations face low performance and represent all of their low capabilities, possibly because of the lack of employees' skills, capital, or inability to act (Singh et al. 2015).

The continuous need for empirical evidence and discussions regarding knowledge of the operation strategies fostered our analysis of manufacturing companies with regard to competitive capabilities, their sequential models, and factors. Presently, we seek to outline the findings of the survey of 500 manufacturing companies while describing and discussing four models of operation strategies, i.e., trade-off, cumulative capabilities, non-competitive, and multiple models.

7.3 Operations Strategy Models in Lithuanian Manufacturing Companies

7.3.1 Model, Measures, and Methods

Our empirical research of sequence models of operation strategy is based on the need for empirical data (Sarmiento et al. 2016) that describes practical situations and contributes to understanding fundamental concepts. Due to the lack of knowledge about organizations with specific operation strategies, we state the first research question *what are organizations that follow a particular sequence model of operation strategy?*

As additional information for investment and development of operational capabilities is needed for organizations (Scarpin and Brito 2018), analysis of factors influencing one or another model of operation strategy will contribute to the strategic decision making and assigning resources for implementation. Therefore, we state a second research question as *what are the factors that influence a particular model of operation strategy?*

Based on theoretical analysis, we assume that such factors as a competitive priority, utilization of manufacturing capacity, product complexity, innovations, cooperation, new products with environment-friendly features, customization of new products, digitalization, and characteristics of human resources influence a particular sequence model of operation strategy in the organization (see Fig. 7.1).

The industry and size of organizations are set as descriptive measures for further analysis of each sequence model of operation strategy; therefore, they are not

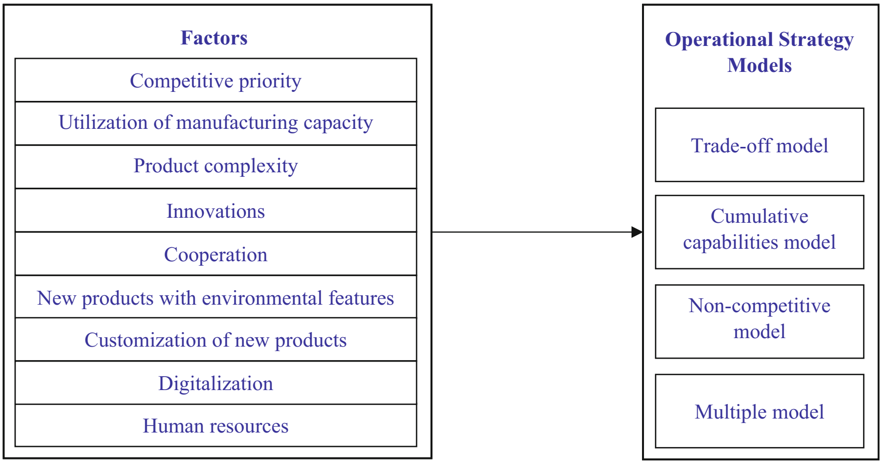

Fig. 7.1 The model of operation strategy models in organizations

included in the model. The description of the constructs of the model follows in the following paragraphs.

In line with such measures as a competitive priority, innovations, and digital manufacturing, as used in the other chapters (see Annex 7.1), specific ones were employed to analyze operation strategy models. Single measures were used for the utilization of manufacturing capacity (variable "k20h_cat"), product complexity (variable "P_complex"), and development of the main product (variable "Main_product") as ordinal ranks coded from binary questions related to each category (for categories, see Tables 7.3 and 7.4).

Variables for measuring cooperation, improved environmental impact in new products, and features of digital manufacturing were calculated by summing the "yes" answers to the sets of binary questions to each particular variable (Table 7.1). Cooperation was coded in the range from *1* (none was used) to *6* (all of the mentioned were used). Improved environmental impact in the new products was coded in the range from *1* (1 feature was improved) to *6* (all of the mentioned features were improved). The variable of digital features in manufacturing was coded in the range from *1* (none of the mentioned digital features was currently being used) to *7* (7 and more features from the list mentioned were currently used).

Two measures were used for human resources in manufacturing organizations. The first one referred to the main level of human resources education (variable "HR_EduN"). It was coded into five categories according to the answers to the questions about each education category (variables from *k09a1* to *k09a5*; for categories, see Table 7.6). The second measure referred to the main working field of human resources in a manufacturing organization (variable "HR_FieldN"). It was coded into six categories according to the answers to the questions about each working field (variables from *k09b1* to *k09b5*; for categories, see Table 7.6). The last category for the variable about the working field was calculated using all of the

Table 7.1 Additional measures and variables used for the analysis of operation strategy models

Measure (Variable)	Variable	Item
Cooperation (Cooperation)	k07a	Purchasing cooperation [joint or collaborative purchase]
	k07b	Production cooperation (e.g., for capacity compensation or for joint utilization of machinery)
	k07c	Sales/distribution cooperation
	k07d	Service cooperation
	k07e	R&D cooperation with customers or suppliers
	k07f	R&D cooperation with other companies (excluding customers or suppliers)
	k07g	R&D cooperation with research organizations or research entities (e.g., universities and institutes)
Improved environmental impact on new products (Envir_impact)	k14f1	Reduced health risk during use
	k14f4	Extended product lifetime
	k14f2	Reduced energy consumption during use
	k14f5	Reduced environmental pollution during use
	k14f3	Easier to maintain or retrofit
	k14f6	Improved recycling, take-back or disposal properties
Features of digital manufacturing (D_MFeatures)	k10a1	Mobile/wireless devices for programming and controlling facilities and machinery
	k10b1	Digital solutions to provide drawings, work schedules, or work instructions directly on the shop floor
	k10c1	Software for production planning and scheduling
	k10d1	Digital Exchange of product/process data with suppliers/customers
	k10e1	Near real-time production control system
	k10f1	Systems for automation and management of internal logistics
	k10g1	Virtual Reality or simulation for product design or product development
	k10h1	Industrial robots for manufacturing processes
	k10i1	Industrial robots for manufacturing processes
	k10k1	Industrial robots for handling processes
	k10l1	3D printing technologies for prototyping
	k10m1	3D printing technologies for manufacturing
	k10p1	Used mobile industrial robots
	k10p2	Used collaborating industrial robots
	k10p3	Used autonomous industrial robots

questions of this group and reflected the organizations where human resources were shared equally among at least four working fields.

Several methods of statistical analysis were applied. For descriptive analysis, in order to compare organizations of different sizes, the Pearson chi-square test was used. Kruskal Wallis chi-square test was applied for multiple group comparison with regard to different factors. Mann–Whitney U test contributed to the comparison of factors with regard to each of the two operation strategy models. Finally, binary regression analysis was used to measure each factor's impact on operation strategies' models. All the further discussed results are significant in terms of the *p* level of at least 0.05.

7.3.2 Diffusion of Operations Strategy Models Among Organizations

Based on the reported competitive capabilities, organizations were classified into 16 groups according to their scores of quality, delivery, flexibility, and costs in comparison to the competitors. The results were used to classify companies into groups according to their sequences. To be precise, the main classification criteria were the fit to a particular theoretical model, i.e., cumulative capabilities or the trade-off one. Due to the comparatively big size, the non-competitive nature, and the overlap with the cumulative capabilities model, organizations with a non-competitive sequence (which scored low for all the competitive capabilities) were classified into a group corresponding to the non-competitive model. The additional group consisted of organizations that had two high competitive capabilities. This group of organizations was assigned as the ones following the multiple model, as reported by Singh et al. (2015). Moreover, two types of organizations were revealed in this group. The first one reflects the organizations with two high and two low competitive capabilities thus corresponding to the 2H2L multiple model. The second one describes organizations with a set of three high and one low competitive capabilities (the 3H1L multiple model). The distribution of organizations according to sequences in different groups is presented in Table 7.2.

Groups of organizations for further analysis consisted of 102–171 research units. Organizations with a link to a multiple model were analyzed separately in each type and in a joint group for the identification of their specifics if such were present.

7.3.3 Trade-off Model with Declining Innovations

Description of organizations whose operational strategy corresponds to the trade-off model is presented with respect to their size (see Table 7.3). The size was calculated according to the *European Commission* (ec.europa.eu/eurostat) from the number of employees and the annual turnover of 2017 reported in the survey. The largest group

Table 7.2 Distribution of organizations according to sequences and fit to the models

No.	Sequence	Models of operation strategy			
		Trade-off	Cumulative capabilities	Non-competitive	Multiple
1	LLLL	N	Y[a]	Y	N
2	HLLL	Y	Y	N	N
3	LHLL	Y	N	N	N
4	LLHL	Y	N	N	N
5	LLLH	Y	N	N	N
6	HHLL	N	Y	N	N
7	HLHL	N	N	N	Y1[b]
8	HLLH	N	N	N	Y1
9	LHHL	N	N	N	Y1
10	LHLH	N	N	N	Y1
11	LLHH	N	N	N	Y1
12	LHHH	N	N	N	Y2[b]
13	HLHH	N	N	N	Y2
14	HHLH	N	N	N	Y2
15	HHHL	N	Y	N	Y2
16	HHHH	N	Y	N	N
N		102 (Y) 369 (N)	171 (Y) 300 (N)	127 (Y) 344 (N)	154 (Y) 396 (N)
		471			

Notes: Y—model fit, N—no model fit
[a] Excluded from this group and moved into a group associated with the non-competitive model
[b] Y1 means that the group is associated with the 2H2L multiple model. Y2 means that the group is associated with 3H1L multiple model

of organizations was that of micro and small size (77.5%). Organizations of medium size made up almost 20% of this group. Only three organizations were large (3%).

The largest amount of organizations in this group were operating in the wood and paper industry, together with organizations in the engineering industry representing more than half of this group. Only a few organizations in these groups were of the large size. Quality was stated to be the main competitive priority for 46% of organizations followed by customization with an additional 23% of organizations. In addition, products of medium or high complexity were the most common; also, most of the trade-off model organizations utilize their manufacturing capacity at more than 60%. Yet the largest part of low utilized manufacturing capacity (40%) was also observed in the trade-off model organizations. The main manufacturing method was already conducting production upon receipt of a customer's order. As the potential for manufacturing capacity was still visible, customization is another area for developing competitive advantage. No significant correlation was confirmed with regard to the relationship between industry, competitive priority, and utilization of manufacturing capacity.

Compared to competitors, the trade-off model organizations rated their own innovations at a similar level (a 5-point scale was used for the measurement) and

Table 7.3 Description of trade-off model organizations

Characteristic	Category	Size of an organization (count)				
		Micro	Small	Medium	Large	*N*
Industry	Engineering	17	6	4	1	28
	Food	2	3	4	2	11
	Textile	5	7	2	0	14
	Wood and paper	13	16	8	0	37
	Chemicals and chemistry	0	0	0	0	0
	Other	6	4	2	0	12
Competitive priority	Price	6	5	3	0	14
	Quality	20	19	7	1	47
	Innovation	3	1	2	1	7
	Customization	10	7	6	1	24
	Delivery	3	4	2	0	9
	Services	1	0	0	0	1
Product complexity	Simple products	8	10	3	0	8
	Products with medium complexity	20	20	13	3	20
	Complex products	12	6	4	0	12
	Missing					3
Method of main manufacturing	To stock	3	9	6	1	19
	Final assembly upon customer's order	2	1	1	0	4
	Upon customer's order only	37	25	13	2	77
	Does not exist or is missing		1			2
Manufacturing capacity utilization	Low (up to 70%)	18	13	4	1	36
	Medium (71–90%)	7	12	8	1	28
	High (91% and more)	12	9	4	1	26
	Missing					12
N		43	36	20	3	102

digitalization at a lower level despite the size of the organizations (see Table 7.4). Only large organizations rated digitalization at the same level as their competitors. However, at least 13% of them consider environmental impact features in new products. Growing the size of the organization corresponded to growing its R&D activities. While there were no reported R&D activities in micro organizations, some of them were already present in small organizations. 6 out of 20 medium organizations and 2 out of 3 large organizations reported occasionally or continuously running R&D activities. With regard to competitive priority, organizations with a different competitive priority also differ in R&D activities (Pearson chi-square = 15.702, df = 8, $p = 0.047$) and the development of the main product (Pearson chi-square = 39.364, df = 15, $p = 0.001$).

Table 7.4 Innovations and digitalization in trade-off model organizations

Characteristic	Category/Measure	Size of organization				*N*/ Mean
		Micro	Small	Medium	Large	
Innovations	Mean	3.01	3.09	2.96	3.33	3.04
Positive environmental impact features in new products	Count of organizations (*at least 1 used*)	7	5	3	1	16
R&D activities	Count of organizations (*R&D used occasionally or continuously*)	0	2	6	2	9
Cooperation	Count of organizations (*at least 1 type used*)	0	18	14	2	34
Digital services	Mean	2.02	2.64	2.43	3.00	2.30
Digital manufacturing	Mean	2.57	2.77	2.68	3.17	2.68
Digital features in manufacturing	Count of organizations (*at least 1 used*)	0	18	12	3	33
Development of the main product	A standard program from which the customer can choose options	4	15	9	2	30
	A standardized basic program incorporating customer-specific options	7	5	4	0	16
	According to customers' specification	29	14	7	1	51
	Does not exist or missing	2	1	0	0	5
N		43	36	20	3	102

Cooperation with other organizations was also considered to be an important activity for larger organizations only. It was not visible in micro organizations, yet, more than half of small to large organizations were cooperating with others in manufacturing, supply, sales, or R&D activities. Also, micro organizations did not use digital features of manufacturing, but half of the small organizations were already implementing them. The number of organizations using them was growing with the size of an organization, in particular, 60% of medium organizations and all the three large organizations implemented at least one digital feature in manufacturing.

Correlation analysis revealed a positive relationship between the type of the main product development and the method of the main manufacturing (see Table 7.5). Additional positive correlations were found between innovations, digitalization in manufacturing, and digitalization in services. Types of cooperation were also positively associated with innovations and digital features used in manufacturing. Cooperation with other organizations might contribute to employing different competencies, therefore, contributing to innovations and advanced technologies in an organization.

Table 7.5 Significant correlations between factors in trade-off model organizations

Factors	Kendall's tau-b correlation coefficient (*p*-value)				
	Cooperation	Digital services	Digital manufacturing	Digital features in manufacturing	Development of the main product
Innovations	0.270 (0.044)	–	0.248 (0.023)	–	–
Cooperation		–	–	0.292 (0.031)	–
Digital services			0.320 (0.017)	–	–
Digital manufacturing				–	0.368 (<0.001)

Operation strategies and decisions regarding them also concern organizational human resources due to their role in the success of strategies and decisions implementation. University or college degree graduates were the main groups of employees in organizations that followed the trade-off model, whereas the organizations with the main group of technicians and skilled workers were the third largest group (see Table 7.6). The main working field in the organizations that followed the trade-off model was in the area of construction, configuration, and design despite the size of the organization.

As regards the relationship between the characteristics of human resources and other factors in organizations that followed the trade-off model, a significant difference was found regarding education and product complexity (Kruskal Wallis chi-square = 15.062, df = 4, $p = 0.005$). Technical/industrial or commercial apprentices were involved only in manufacturing complex products, whereas balanced human resources (equal groups or only one missing) were used only for medium or highly complex products.

Regression analysis showed that for the organizations that conform to the trade-off model only the factor of innovations was confirmed (Wald = 8.946, df = 1, $p = 0.003$). The beta coefficient was negative ($\beta = -0.520$), thus implicating the finding that innovations impact organizations to follow the trade-off model of the operation strategy negatively (see Fig. 7.2).

The impact is small (Nagelkerke R square = 0.039), but the regression model correctly predicts 73.6% of the selection of the trade-off model of operation strategy. Nevertheless, additional factors should be considered to be involved in the regression model for higher predictability.

7.3.4 Cumulative Capabilities Model in the Mix of Factors

The largest group of organizations, according to models of the operation strategy, was following the cumulative capabilities model (see Table 7.1). Most organizations in this group were micro and small (80%). Together with medium organizations,

Table 7.6 Characteristics of human resources in trade-off model organizations

Characteristic	Category/Measure	Size of organization				
		Micro	Small	Medium	Large	*N*
The largest group of employees by education in categories	University/college degree, graduates	22	17	9	2	50
	Technicians, skilled workers	8	11	5	0	24
	Employees with commercial or technical/industrial training	6	3	4	0	13
	Semi-skilled and unskilled workers	0	0	0	0	0
	Technical/industrial or commercial apprentices	4	0	0	0	4
	All equal (or 0 in one) groups	2	1	0	0	3
	Several large groups or missing					8
The largest group of employees by working field in categories	R&D	2	1	0	0	3
	Construction, configuration, design	32	31	20	2	85
	Manufacturing and assembly	0	1	0	0	1
	Customer service	1	1	0	0	2
	Other	2	0	0	0	2
	All equal (or 0 in one) groups	2	0	0	0	2
	Several large groups or missing					7
N		43	36	20	3	102

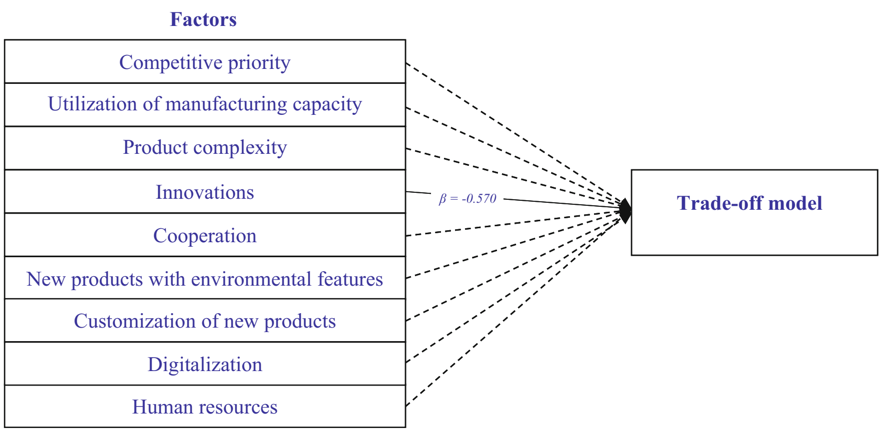

Fig. 7.2 Results on factors of trade-off model

Table 7.7 Description of cumulative capabilities model organizations

Characteristic	Category	Size of the organization (count)				N
		Micro	Small	Medium	Large	
Industry	Engineering	16	10	8	0	34
	Food	10	9	5	3	27
	Textile	9	15	6	0	30
	Wood and paper	23	17	6	2	48
	Chemicals and chemistry	2	4	1	0	7
	Other	16	6	1	2	25
Competitive priority	Price	4	1	0	0	5
	Quality	40	34	16	6	96
	Innovation	5	3	0	1	9
	Customization	16	15	7	0	38
	Delivery	9	8	4	0	21
	Services	2	0	0	0	2
Product complexity	Simple products	13	13	2	0	28
	Products with medium complexity	33	31	17	5	86
	Complex products	27	13	8	2	50
	Missing	3	4	0	0	7
Method of the main manufacturing	To stock	14	11	8	3	36
	Final assembly upon customer's order	4	3	2	0	9
	Upon customer's order only	58	46	17	4	125
	Does not exist or missing					1
Manufacturing capacity utilization	Low (up to 70%)	22	18	4	2	46
	Medium (71–90%)	19	15	11	3	48
	High (91% and more)	25	21	8	2	56
	Missing					21
N		76	61	27	7	171

SMEs organizations following this model constituted almost 96%. The description of the characteristics of the cumulative capabilities model organizations with respect to their size is presented in Table 7.7.

The dispersion of cumulative capabilities model organizations among the industry sectors was similar to the trade-off model organizations. The largest part of their competitive priority was also similar. More than a half of the cumulative capabilities model organizations stated quality as their competitive priority. Customization is the second option, also similar to the previous group of the organization. However, the third selection was delivery (12%) to be compared with the price in the trade-off model organizations (almost 13%).

Regarding product complexity, the main emphasis of the cumulative capabilities model organizations was on medium complex products (more than 50% in total) in all sizes of organizations. Complex products were reported by almost 30% of

Table 7.8 Innovations and digitalization in cumulative capabilities model organizations

Characteristic	Category/Measure	Size of organization				
		Micro	Small	Medium	Large	*N*/ Mean
Innovations	Mean	3.56	3.46	3.46	3.94	3.53
Positive environmental impact features in new products	Count of organizations (at least 1 used)	20	12	9	3	44
R&D activities	Count of organizations (R&D used occasionally or continuously)	0	8	4	4	16
Cooperation	Count of organizations (at least 1 type used)	3	27	21	6	57
Digital services	Mean	2.45	2.47	2.54	3.94	2.53
Digital manufacturing	Mean	2.82	2.97	3.05	4.07	2.99
Digital features in manufacturing	Count of organizations (at least 1 used)	1	22	19	5	47
Development of the main product	A standard program from which the customer can choose options	16	18	9	5	48
	A standardized basic program incorporating customer-specific options	9	11	9	1	30
	According to customers' specification	48	26	7	0	81
	Does not exist or missing	2	5	1	0	12
N		76	61	27	7	171

organizations. Compared with the organizations that followed the trade-off model, their main emphasis was on simple products (almost 55%). Complex products were the smallest share of their production. The most popular method of manufacturing in the cumulative capabilities model organization was similar to that of the trade-off model organizations, i.e., manufacturing only upon the receipt of its customers' order. Thus manufacturing capacity utilization was better in the cumulative capabilities model organizations.

When comparing their own innovations with competitors, the cumulative capabilities model organizations rated them at a similar or almost higher level (see Table 7.8). Larger organizations tended to rate them higher than smaller organizations. At least one improved feature of a new product was reported by more than 25% of organizations, including all sizes of organizations. Innovations were supported by R&D activities, but their amount did not differ from the trade-off model organizations; thus, the tendencies were similar.

The growing size of an organization corresponded to growing its R&D activities. Also, similarly to the trade-off model organizations, there were no reported R&D activities in micro organizations, while some of them were already present in small organizations. A percentage of organizations was found to be growing in terms of size. With regard to competitive priority, organizations with different competitive priorities differed in their R&D activities (Pearson chi-square = 13.549, df = 6, $p = 0.035$) and the development of the main product (Pearson chi-square = 27.090, df = 15, $p = 0.028$) as well. The differences were revealed as follows:

– R&D activities were performed more continuously in organizations with priorities of innovation and quality.
– The development of the main product had a more customized approach in organizations with the priorities of customization and price.
– Organizations with the priorities of services and quality reported higher utilization of their manufacturing capacity.

Cooperation with other organizations was growing together with the size of the cumulative capabilities model organizations only. It was not visible in micro organizations (only 4% of them), but almost half of small (44%) and most of the medium (78%) to large (86%) organizations were cooperating with other organizations. It might be the key to innovations in the cumulative capabilities model organizations as the measurement of cooperation also included R&D activities.

The lower rating of one's own digital services in comparison to competitors was reported by micro and small cumulative capabilities model organizations, but it scored the same level in medium and even higher rating by the large organizations. The rating of digital manufacturing was higher in comparison to digital services across all sizes of organizations. Large organizations even rated their digital manufacturing better than their competitors. Only one micro organization was using digital features in its manufacturing, while there were many more organizations of a bigger size using them (36, 70, and 76%, respectively).

Similar to the trade-off model organizations, correlation analysis in the cumulative capabilities model organizations revealed a positive relationship between the type of the main product development and the method of the main manufacturing and product complexity (see Table 7.9). Product complexity was positively related to the utilization of the manufacturing capacity. Additional positive correlations were found between digital manufacturing and innovations, R&D, and digital services. However, the types of cooperation were not associated with innovations and digital features used in manufacturing, but a negative correlation with digital services was found. Thus less cooperation appeared together with more digital services. It is supposed that digital services were provided while using the internal capabilities of organizations rather than joint capabilities with other organizations through cooperation.

The largest group of employees in the cumulative capabilities model organizations was composed of university or college degree graduates (see Table 7.10), similarly to the corresponding figures in the trade-off model organizations. Yet, in the current group of organizations, the number of employees attaining this education level was greater, i.e., 57% (in comparison with 49% in the trade-off model organizations). As regards the working field in the organizations, construction,

Table 7.9 Significant correlations between factors in cumulative capabilities model organizations

Factors	Kendall's tau-b correlation coefficient (*p*-value)							
	Method of the main manufacturing	Manufacturing capacity utilization	Product complexity	Innovations	R&D activities	Cooperation	Digital Services	Digital manufacturing
Development of the main product	0.372 (<0.001)	–	0.217 (0.002)	–	–	–	–	–
Method of the main manufacturing		–	0.194 (0.006)	–	–	–	–	–
Manufacturing capacity utilization			0.158 (0.030)	–	–	–	–	–
Innovations					–	–	–	0.379 (<0.001)
R&D activities						–	–	0.407 (0.025)
Cooperation							−0.398 (0.005)	–
Digital services								0.535 (<0.001)

Table 7.10 Characteristics of human resources in cumulative capabilities model organizations

Characteristics	Category/Measure	Size of organization				
		Micro	Small	Medium	Large	*N*
The largest group of employees by education in categories	University/college degree, graduates	39	37	12	3	91
	Technicians, skilled workers	10	14	6	2	32
	Employees with commercial or technical/industrial training	13	4	1	0	18
	Semi-skilled and unskilled workers	2	0	0	0	2
	Technical/industrial or commercial apprentices	7	0	1	0	8
	All equal (or 0 in one) groups	2	2	3	0	7
	Several large groups or missing					13
The largest group of employees by working field in categories	R&D	3	3	2	0	8
	Construction, configuration, design	55	52	22	5	134
	Manufacturing and assembly	3	2	0	0	5
	Customer service	2	1	0	0	3
	Other	4	1	0	0	5
	All equal (or 0 in one) groups	5	0	0	0	5
	Several large groups or missing					11
N		76	61	27	7	171

configuration, and design were the main fields in the cumulative capabilities model organizations at the same percentage as in the trade-off model organizations.

Analysis of the possible relationship between the characteristics of human resources and other factors in the cumulative capabilities model organizations revealed similarities between product complexity and such education categories as university or college graduates, semiskilled and unskilled workers, and technical/industrial or commercial apprentices. This group of employees was more involved in manufacturing products of medium to high complexity than others.

Regression analysis revealed the impact of many research factors to support the cumulative capabilities model of the operation strategy. The utilization of the manufacturing capacity (β varied from -0.682 to -0.597, Wald $= 8.198$, df $= 2$, $p = 0.017$), digital features of manufacturing ($\beta = 0.385$, Wald $= 7.917$, df $= 1$, $p = 0.005$) as well as innovations ($\beta = 0.824$, Wald $= 25.077$, $d = 1$, $p < 0.001$) were found to be important for the cumulative capabilities model organizations (see Fig. 7.3).

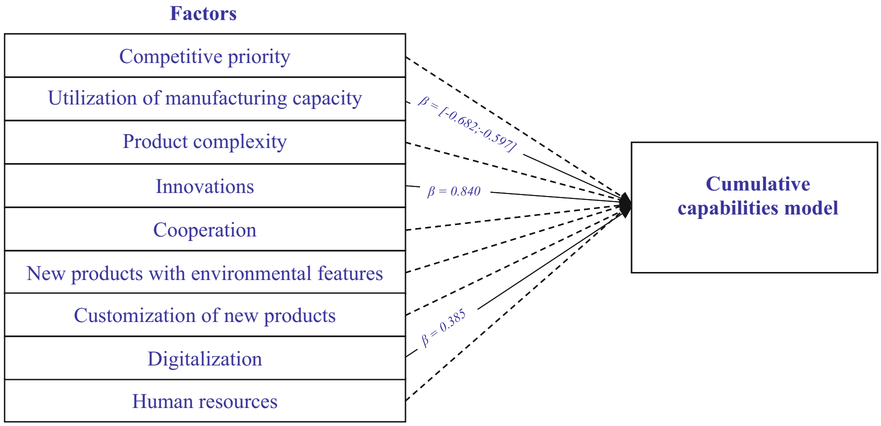

Fig. 7.3 Results on factors of cumulative capabilities model

The impact of innovations on the cumulative capabilities model is positive and much higher (Nagelkerke R square = 0.107) than on the trade-off model. In addition, the results have confirmed the impact of utilization of manufacturing capacity (Nagelkerke R square = 0.028) and digital features of manufacturing (Nagelkerke R square = 0.067) on the cumulative capabilities model of operation strategy. The regression models predict correctly from 62.2 to 68.9% of the selection of the cumulative capabilities model, suggesting the higher predictability in case of the joint impact of the factors for this model.

For other factors, one or some categories were significant. The positive impact was found regarding:

- Competitive priority (general model)
- Medium and high cooperation ($\beta = 1.289$ and $\beta = 1.471$, respectively)

The negative impact was found regarding:

- Low and high product complexity ($\beta = -0.630$ for high complexity).
- Three features of better environmental impact in new products ($\beta = -1.946$).
- One or four digital features in manufacturing ($\beta = -2.140$ and $\beta = -1.861$, respectively).
- Technical and professional employees, in particular, technicians, skilled workers ($\beta = -1.425$), employees with commercial or technical/industrial training ($\beta = -1.519$), and technical/industrial or commercial apprentices ($\beta = -1.658$).

7.3.5 Non-Competitive Model and Competitive Priorities

Singh et al. (2015) identified the non-competitive model as an additional one which was confirmed in a small number of organizations. In our case, the group of

Table 7.11 Description of non-competitive model organizations

Characteristic	Category	Size of an organization (count)				*N*
		Micro	Small	Medium	Large	
Industry	Engineering	8	17	1	0	26
	Food	9	6	0	0	15
	Textile	5	7	1	0	13
	Wood and paper	30	12	2	2	46
	Chemicals and chemistry	1	2	0	0	3
	Other	15	6	3	0	24
Competitive priority	Price	12	6	1	1	20
	Quality	29	21	4	1	55
	Innovation	3	1	0	0	4
	Customization	10	12	1	0	23
	Delivery	9	9	1	0	19
	Services	5	1	0	0	6
Product complexity	Simple products	15	6	0	0	21
	Products with medium complexity	43	36	3	2	84
	Complex products	8	7	4	0	19
	Missing	2	1	0	0	3
Method of main manufacturing	To stock	12	5	0	0	17
	Final assembly upon customer's order	1	0	0	0	1
	Upon customer's order only	54	45	6	2	107
	Does not exist or missing	1	0	1	0	2
Manufacturing capacity utilization	Low (up to 70%)	17	15	2	0	34
	Medium (71–90%)	24	18	2	2	46
	High (91% and more)	6	9	2	0	17
	Missing					30
N		68	50	7	2	127

organizations that followed the non-competitive model was large, the second in the sample according to the size. More than half of the non-competitive model organizations were operating in the wood and paper industry (36%) and engineering (20%; see Table 7.11). Organizations differ significantly in terms of industry sectors with respect to their size (Kruskal Wallis chi-square = 10.009, df = 3, $p = 0.018$). The main industry for small organizations was engineering rather than wood and paper. Also, the main activities of 18% of non-competitive model organizations were reported to be "other industries"; this also was the second option for micro organizations.

Quality was reported to be the main competitive priority by the largest share of all sizes of organizations. The price scored second place in micro organizations, while customization was the second priority for small organizations. In general, quality scored similarly as in the cumulative capabilities model organizations, and the price scored similarly as in the trade-off model organizations.

Most of the products produced by non-competitive model organizations were of medium complexity. Non-competitive model organizations differ in terms of product complexity (Kruskal Wallis chi-square = 9.473, df = 3, $p = 0.024$). Medium and large organizations did not produce simple products. None of the large organizations produced complex products. Still, only two large organizations of the whole sample were classified as representing the non-competitive model.

The majority (84%) of the non-competitive model organizations manufactured their products mainly upon order from the customers. The final assembly upon the receipt of the order from the customers was almost not applicable. Only one micro organization reported the implementation of this manufacturing method. Manufacturing directly to stock was not common, either; it was less than both cumulative capabilities and trade-off models organizations.

The non-competitive model organizations did not fully utilize the manufacturing capacity. The main level of their utilization was medium only (45%). Moreover, many micro and small organizations reported low-level utilization of their manufacturing capacity (about 36% in each group). In the comparison of manufacturing capacity according to the size of organizations, utilization was growing together with the size of the organization, except for the large ones. In general, a better manufacturing capacity utilization was available in medium organizations. In particular, it was dispersed equally among all the levels.

To compare the non-competitive model organizations with regard to innovations, the scores were lower than those of their competitors, only medium organizations saw their innovations at a similar level as those of their competitors (see Table 7.12). The large organizations did not report their innovation scores at all. At least one improved environmental feature was implemented in new products at 10% of the non-competitive model organizations. Also, none of them was found in medium or large organizations.

Two supporting innovation activities, such as R&D and cooperation, were run even in non-competitive model organizations (11%) and in those which did not report any innovations. Differently from the trade-off or the cumulative capabilities models organizations, R&D activities were run in the micro organizations that followed the non-competitive model. The proportion of R&D activities in a group regarding the organization's size was growing together with the size. A similar growing tendency was observed with regard to cooperation. However, no linkage with the competitive priority in the non-competitive model organizations was found. This might reflect the non-competitive operation strategy model.

Regarding digitalization, digital services and digital manufacturing were also rated lower by the non-competitive model organizations in comparison to their competitors. Only medium size organizations scored their digital manufacturing at the same level as their competitors. Digitalization in services and features of digital manufacturing were growing together with the size of organizations. This finding is limited to large organizations because of different scores and a very small count of organizations. To compare with the other models of operation strategy, digital

Table 7.12 Innovations and digitalization in non-competitive model organizations

Characteristic	Category/Measure	Size of organization				
		Micro	Small	Medium	Large	*N*/ Mean
Innovations	Mean	2.90	2.82	3.00	–	2.87
Positive environmental impact features in new products	Count of organizations (*at least 1 used*)	10	3	0	0	13
R&D activities	Count of organizations (*R&D used occasionally or continuously*)	2	8	3	1	14
Cooperation	Count of organizations (*at least 1 type used*)	3	23	6	2	34
Digital services	Mean	2.04	1.90	2.33	1.00	1.98
Digital manufacturing	Mean	2.47	2.52	3.00	2.00	2.50
Digital features in manufacturing	Count of organizations (*at least 1 used*)	2	15	2	2	21
Development of main product	A standard program from which the customer can choose options	20	13	2	1	36
	A standardized basic program incorporating customer-specific options	11	4	0	0	15
	According to customers' specification	33	30	4	1	68
	Does not exist or missing	2	1	1	0	8
N		68	50	7	2	127

features in manufacturing were used more rarely than in the trade-off or cumulative capabilities models of organizations.

Correlation analysis of the factors in the non-competitive model organizations revealed positive relationships between the main manufacturing methods and two other factors, i.e., the type of the main product development and product complexity (see Table 7.13). The development of the main product was more customized, manufacturing was more adjusted to the customer needs, and the product was more complex. Although the relationship was not direct, with the method of manufacturing, the correlation was medium strong, while with the product complexity, it was weak.

Additional relationships were found with regard to digitalization. Cooperation of the non-competitive model organizations with other organizations was negatively related to digital services and digital manufacturing, while digital manufacturing was positively related to R&D activities.

Human resources in non-competitive model organizations did not differ significantly with regard to the size of organizations. The distribution of employees according to their education was also similar to that of organizations of the other

Table 7.13 Significant correlations between factors in non-competitive model organizations

Factors	Kendall's tau-b correlation coefficient (p-value)						
	Type of manufacturing process	Product complexity	R&D activities	Cooperation	Digital services	Digital manufacturing	Digital features in manufacturing
Development of main product	0.446 (<0.001)	–	–	–	–	–	–
Type of manufacturing process		0.177 (0.035)	–	–	–	–	–
R&D activities				–	–	–	0.434 (0.008)
Cooperation					–	−0.546 (0.043)	−0.287 (0.048)
Digital services						0.594 (<0.001)	–

Table 7.14 Characteristics of human resources in non-competitive model organizations

Characteristic	Category/Measure	Size of organization				
		Micro	Small	Medium	Large	*N*
The largest group of employees by education in categories	University/college degree, graduates	28	22	4	0	54
	Technicians, skilled workers	15	14	1	1	31
	Employees with commercial or technical/ industrial training	14	10	0	0	24
	Semi-skilled and unskilled workers	1	1	0	0	2
	Technical/industrial or commercial apprentices	10	1	0	0	11
	Several large groups or missing					5
The largest group of employees by working field in categories	R&D	2	2	0	0	4
	Construction, configuration, design	53	42	5	2	102
	Manufacturing and assembly	2	1	0	0	3
	Customer service	1	0	0	0	1
	Other	2	1	0	0	3
	All equal (or 0 in one) groups	7	1	0	0	8
	Several large groups or missing					6
N		68	50	7	2	127

operation strategy models. The largest group was university or college degree graduates (see Table 7.14), but it was smaller than the levels of organizations in the other models. However, only this group and technicians with skilled workers were reported as the largest part of employees in medium organizations, and university or college degree employees were the only group reported by large organizations. Regarding the working field in the organizations, construction, configuration, and design were the major group in non-competitive model organizations, which was larger than in the cumulative capabilities or trade-off models organizations.

A comparison of non-competitive model organizations according to their employees' education revealed the relationship between university or college degree graduates and improved environmental features in new products (Kruskal Wallis chi-square $= 8.002$, df $= 3$, $p = 0.046$). The organizations with this main group of employees implemented more improved environmental features in new products than the organizations with other main groups of employees with regard to education. No relationship was found with regard to employees in the main working fields and other factors.

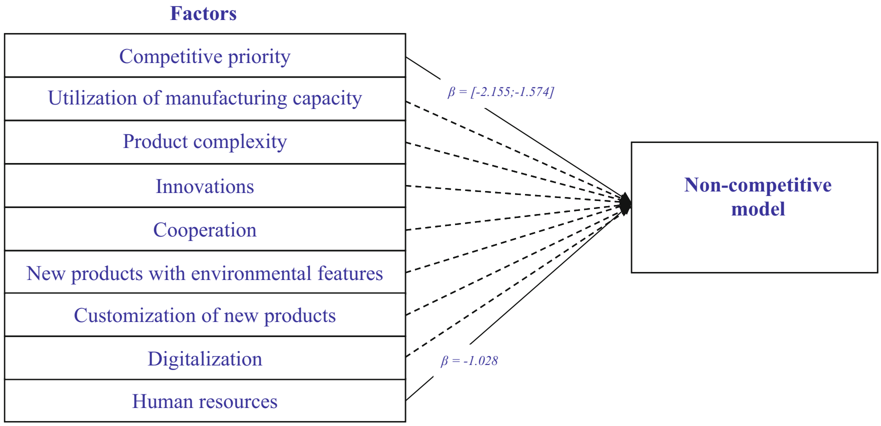

Fig. 7.4 Results on factors of the non-competitive model

Regression analysis confirmed the impact of such competitive priorities as quality ($\beta = -1.580$, Wald = 5.667, df = 1, $p = 0.017$), innovation ($\beta = -2.155$, Wald = 6.538, df = 1, $p = 0.011$), and customization ($\beta = -1.574$, Wald = 5.231, df = 1, $p = 0.022$) as well as employees working in construction, configuration, and design field ($\beta = -1.028$, Wald = 4.010, df = 1, $p = 0.045$) in organizations, following the non-competitive model of operation strategy (see Fig. 7.4).

All the beta coefficients were negative thus confirming a minor but negative impact of the above-mentioned factors (Nagelkerke $R = 0.048$ in the case of competitive priorities and 0.013 in the case of the working field of employees). By using the competitive priority and the working field of employees, the correct forecast percentage was 73.5 and 72.8%, respectively.

7.3.6 Multiple Models and Customization in Manufacturing

The final group of the sample consisted of those organizations which had one or two low capabilities with high others and did not fit into the sequences of previous models. This group was following the multiple models of operation strategies and was assigned to the multiple model organizations.

Multiple model organizations were operating in the wood and paper as well as engineering industries (see Table 7.15). The majority of micro and small companies were operating in the wood and paper industry, they were mostly following other models of operation strategies, but the main industry of the medium size organizations was engineering. None of the three large organizations were operating in these industries. Instead of that, they were representing food, textile, and other industries. Other industries were also common in the micro and small organizations (20 and 15% in their groups, respectively).

Table 7.15 Description of multiple model organizations

Characteristic	Category	Size of an organization (count)				N
		Micro	Small	Medium	Large	
Industry	Engineering	17	13	9	0	39
	Food	8	8	6	1	23
	Textile	10	3	4	1	18
	Wood and paper	24	17	4	0	45
	Chemicals and chemistry	1	2	0	0	3
	Other	15	8	2	1	26
Competitive priority	Price	8	4	0	0	12
	Quality	35	21	13	2	71
	Innovation	7	4	2	0	13
	Customization	13	15	6	0	34
	Delivery	12	6	4	1	23
	Services	0	1	0	0	1
Product complexity	Simple products	13	9	3	0	25
	Products with medium complexity	41	29	15	2	89
	Complex products	20	13	6	1	40
	Missing	1	0	1	0	2
Type or manufacturing process	To stock	11	8	7	1	27
	Final assembly upon customer's order	5	1	3	0	9
	Upon customer's order only	59	42	15	2	118
Manufacturing capacity utilization	Low (up to 70%)	29	14	3	0	46
	Medium (71–90%)	20	14	13	2	49
	High (91% and more)	16	17	6	1	40
	Missing					19
N		75	51	25	3	154

The top three main competitive priorities of the multiple model organizations were quality (46%), customization (22%), and delivery (14%). Quality was reported mostly by all sizes of organizations. Small organizations were prioritizing customization more than organizations of the other sizes. Priorities of the large organizations were given to quality and delivery only. No significant relationship was found between the competitive priorities and other descriptive characteristics in the multiple model organizations.

Multiple model organizations mainly (56%) produced products of medium complexity, similarly to the organizations of the other operation strategy models. However, all the sizes of multiple model organizations also produced complex products, which was similar to the cumulative capabilities model organizations. The method of main manufacturing was similar to that of the trade-off model organizations, i.e., manufacturing upon the receipt of the customer's order only (76%). A larger

Table 7.16 Innovations and digitalization in multiple model organizations

Characteristic	Category/Measure	Size of organization				
		Micro	Small	Medium	Large	*N*/ Mean
Innovations	Mean	3.41	3.29	3.11	3.78	3.32
Positive environ-mental impact fea-tures in new products	Count of organizations (*at least 1 used*)	15	8	5	1	29
R&D activities	Count of organizations (*R&D used occasionally or continuously*)	0	4	4	2	10
Cooperation	Count of organizations (*at least 1 type used*)	2	19	15	3	39
Digital services	Mean	2.30	2.31	2.09	3.00	2.28
Digital manufacturing	Mean	2.52	2.74	2.76	3.33	2.64
Digital features in manufacturing	Count of organizations (*at least 1 used*)	4	14	17	0	35
Development of the main product	A standard program from which the customer can choose options	21	16	6	2	46
	A standardized basic pro-gram incorporating customer-specific options	15	13	9	0	37
	According to customers' specification	36	21	8	0	65
	Does not exist or missing	2	1	1	0	6
N		62	42	20	2	126

proportion of such manufacturing was observed in small organizations, while the final assembly of the product carried out upon receipt of the customer's order was the least common method of manufacturing in multiple model organizations if disregarding their size (from 0 to 12% only).

The largest part of the multiple model organizations was utilizing their manufacturing capacity on a medium scale. However, about 34% of the multiple model organizations utilized their manufacturing capacity on the lower level. In comparison to the other models of the operation strategy, low utilization in multiple model organizations was similar to the non-competitive model organizations, while the proportion of the medium utilization was similar to the cumulative capabilities and the trade-off models organizations that followed with regard to this criterion. With the high utilization of manufacturing capacity, the multiple model organizations were mostly similar to the trade-off model organizations.

Multiple model organizations reported the same level of innovations if compared with their competitors (see Table 7.16). In large organizations, this level was even higher. Innovations were the factor that scored differently according to the competitive priority of the multiple model organizations (Kruskal Wallis chi-square = 19.201, df = 5, $p = 0.002$). The highest scoring innovations were observed in the organizations with innovation priority (mean rank 92.62), followed by delivery priority (mean rank 78.16). The lowest scoring innovations were found in the organizations with the priority of services (mean rank 46.00).

Improved environmental impact in new products was implemented in 29 multiple model organizations (18%), which is less than in the cumulative capabilities model organizations but more than in the trade-off model organizations and much more than in the non-competitive model organizations. With regard to the size of the multiple model organizations, the largest percentage of environmentally improved new products was found in micro organizations, which was decreasing with the growth of organizations.

With the growing size of organizations, the R&D activities were also growing. None of the R&D activities were implemented in micro organizations. In small organizations, this value reached 7%, and all of them were being run in the occasional mode. The continuous model appeared in medium organizations. Sixteen percent of R&D was conducted there in the occasional and continuous mode equally.

To compare the R&D activities in the organizations following different models of operation strategies, the multiple model organizations were the least involved in these activities as well as in cooperation with other organizations. Yet, the percentage of cooperation was continuously increasing with the growth of organizations.

As regards digitalization, multiple model organizations of all sizes scored, on average, in terms of digital services and manufacturing at the same level as their competitors. The score of large organizations was even higher, but none of the large organizations reported digital features in manufacturing. It might be a case of full digital integration of the manufacturing process. Organizations of the other sizes scored for digital services and manufacturing lower than their competitors. However, they were implementing digital features in manufacturing, and the percentage of the features count was increasing with the size of the organizations.

The development of the main product was preceded in large part of organizations by customization (42%), but this feature was decreased with the increasing size of organizations. On the contrary, the usage of a standardized basic program with customer-specific options was increasing in all sizes of organizations, except for the large ones. All the three large organizations were using only a standard program, from which the customers could choose options. As the large organizations ranked their innovations better than their competitors, their innovations were based on R&D activities and cooperation, not on digitalization.

Correlation analysis of the factors of multiple model organizations revealed a positive relationship between the methods of main manufacturing, the types of the main product development, and product complexity (see Table 7.17). Customization in manufacturing and product development was increasing with an increase in product complexity. Product complexity had weak but positive and significant relations with innovations and digital services and medium strength positive relationship with digital features in manufacturing. Similarly, innovations were positively related to digital manufacturing. Digital features were also positively related to digital services. An additional relationship was found between the method of main

Table 7.17 Significant correlations between factors in multiple model organizations

Factors	Kendall's tau-b correlation coefficient (*p*-value)							
	Type of manufacturing process	Product complexity	Innovations	R&D activities	Cooperation	Digital Services	Digital manufacturing	Digital features in manufacturing
Development of the main product	0.370 (<0.001)	0.176 (0.016)	–	–	–	–	–	–
Type of manufacturing process		0.165 (0.028)	–	−0.345 (0.015)	−0.288 (0.017)	–	–	–
Product complexity			0.164 (0.037)	–	–	0.212 (0.033)	–	0.347 (0.008)
Innovations				–	–	–	0.247 (0.011)	–
Digital services							–	0.392 (<0.001)

Table 7.18 Characteristics of human resources in multiple model organizations

Characteristic	Category/Measure	Size of organization				
		Micro	Small	Medium	Large	*N*
The largest group of employees by education in categories	University/college degree, graduates	39	27	8	2	76
	Technicians, skilled workers	10	12	11	1	34
	Employees with commercial or technical/industrial training	7	9	3	0	19
	Semi-skilled and unskilled workers	2	0	0	0	2
	Technical/industrial or commercial apprentices	12	1	0	0	13
	All equal (or 0 in one) groups	1	1	2	0	4
	Several large groups or missing					6
The largest group of employees by working field in categories	R&D	1	1	1	0	3
	Construction, configuration, design	64	48	22	3	137
	Manufacturing and assembly	2	1	0	0	3
	Customer service	1	0	0	0	1
	Other	3	0	0	0	3
	All equal (or 0 in one) groups	2	1	1	0	4
	Several large groups or missing					3
N		75	51	25	3	154

manufacturing and R&D activities, but this relationship was negative. Interestingly, the less customization was applied in the main manufacturing, the more R&D activities were applied in the multiple model organizations.

The distribution of human resources according to education and the working field in various sizes of multiple model organizations was similar (see Table 7.18). The largest group of employees was the university or college degree graduates across all except for medium size organizations. Technicians and skilled workers were the largest groups there (44%). Comparison analysis of multiple model organizations according to their employees' education revealed differences between the employees' education and such factors as innovations (Kruskal Wallis chi-square = 15.295, df = 5, $p = 0.009$), R&D activities (Kruskal Wallis chi-square = 14.690, df = 4, $p = 0.005$), and the development of the main product (Kruskal Wallis chi-square = 11.986, df = 5, $p = 0.035$):

- Innovations were rated higher by the multiple model organizations where the main part of employees consisted of semiskilled and unskilled workers (mean

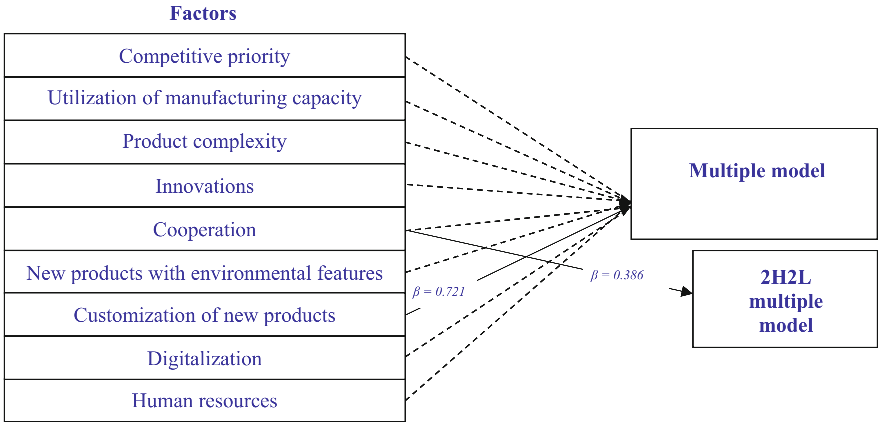

Fig. 7.5 Results on factors of multiple models

rank 103.25), while they were rated lower when the employees were technicians or skilled workers (mean rank 55.59), and university or college graduates (mean rank 54.73).

- R&D activities were performed more frequently in the organizations where the largest part of employees had a university or college degree (28.45), or were apprentices (mean rank 39.50) than in the other organizations (mean rank 18.50).
- Involvement of customers and customization in the development of the main product was the lowest in the organizations where semiskilled and unskilled workers (mean rank 47.75) were the largest part of employees. The highest involvement of customers in the development of the main product was reported by the organizations where education was balanced (all equal groups or all equal and one missing) in terms of human resources (mean rank 93.88) and where apprentices were the largest group of employees (mean rank 98.12).

As in most organizations, employees (88%) were working in construction, configuration, and design, comparison analysis was not run. Construction, configuration, and design was the major working field in the multiple model organizations. Overall, this sector was leading in the segment of organizations disregarding the model of operation strategy.

Regression analysis results for multiple models revealed no significant impact of factors for the 3H1L multiple model of the operation strategy. However, the impact of the main product specifics, particularly, the category of the products produced according to the customers' specification, was confirmed for the general multiple model that consisted of both types of multiple sequences strategy (see Fig. 7.5).

The impact of main product customization was significant for general multiple organizations ($\beta = 0.721$, Wald = 7.283, df = 1, $p = 0.007$). Regressions for the 2H2L multiple model showed that higher than medium cooperation (4th of 7 categories) impacted the sequence of 2H2L of the multiple model ($\beta = 0.386$, Wald = 3.942, df = 1, $p = 0.047$). All the impacts were positive but small ones.

The highest impact was of medium cooperation to 2H2L sequences of multiple model organizations (Nagelkerke $R = 0.138$, percentage correct 83.3). The impact of the main product customization also reveals high percentage correctness for forecasting the general multiple model (Nagelkerke $R = 0.023$, percentage correct 67.0).

7.4 Summary

Our research confirmed four models of operation strategies in Lithuanian manufacturing organizations. The trade-off and cumulative capabilities models were identified in 102 and 171 organizations, correspondingly. The non-competitive model was found in 127 organizations. One hundred fifty-four organizations were following the multiple models of operation strategy. Moreover, two types of multiple models were confirmed. The 2H2L multiple model with 2 high and 2 low characteristics was found in 79 organizations, and the 3H1L multiple model with 3 high and 1 low characteristics was found in 75 organizations.

The research results revealed the differences between organizations that followed different models of operation strategy. For the statistical analysis of the differences between the groups, we limited the sample by excluding the organizations that fit one model, but this fit was also available in the case of another model. Also, the general multiple model was included without splitting into types because of no differences found by comparative analysis in these groups.

Groups of organizations that fit a particular model of operation strategy were different in:

- Utilization of manufacturing capacities (Kruskal Wallis chi-square $= 9.400$, $df = 3$, $p = 0.024$)
- Innovations (Kruskal Wallis chi-square $= 78.543$, $df = 3$, $p < 0.001$)
- Digitalization in general (Kruskal Wallis chi-square $= 16.795$, $df = 3$, $p = 0.001$)
- Digital management (Kruskal Wallis chi-square $= 14.689$, $df = 3$, $p = 0.002$)
- Automatization and robotics in manufacturing (Kruskal Wallis chi-square $= 8.426$, $df = 3$, $p = 0.038$)
- Count of all the digital features used in manufacturing (Kruskal Wallis chi-square $= 15.222$, $df = 3$, $p = 0.002$)

Summary of organizations following a particular model of operation strategy is presented in Fig. 7.6.

The key feature of trade-off model organizations is low utilization of manufacturing capacity, which has been found in 40% of organizations following this model. Technical/industrial or commercial apprentices are involved only in manufacturing complex products. Balanced human resources have been used only for medium or highly complex products. Regarding the size of an organization, innovations have been scored highest in large organizations as well as digital services and digital manufacturing. Such features as R&D, cooperation, and digital features of manufacturing have been missed in micro organizations, following the trade-off

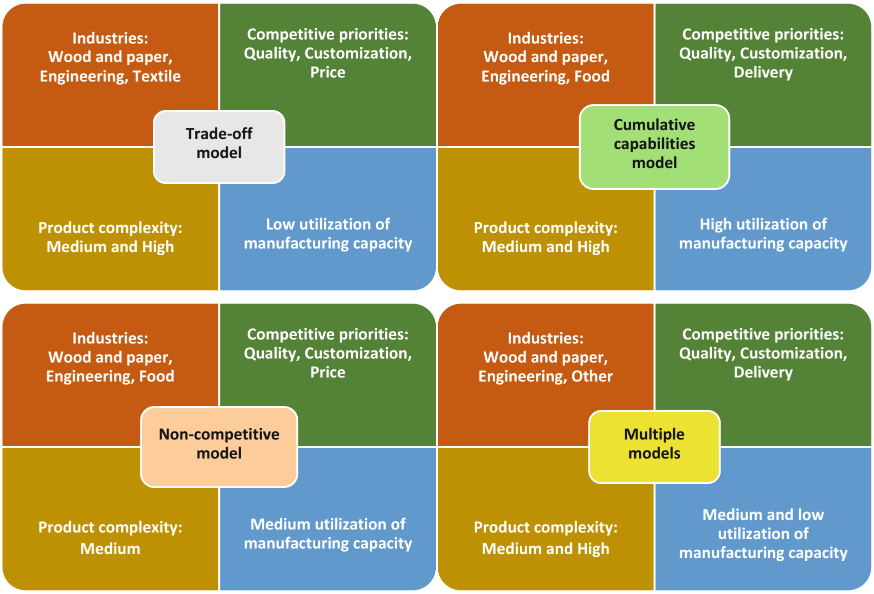

Fig. 7.6 Description of organizations that follow a particular sequence model of operation strategy

model. At the same time, heavy customization in the development of the main product has been found there.

Cumulative capabilities model organizations are similar to trade-off ones in regard to dispersion across industries, competitive priorities, and product complexity. However, in the third place, we see the food industry (instead of textile) and delivery competitive priorities (instead of price). Customization in main manufacturing is similarly high, but utilization of manufacturing capacity is higher here. Also, R&D activities have been performed more continuously in organizations with priorities of innovation and quality. The development of the main product had a more customized approach in organizations with priorities of customization and price. Moreover, organizations with priorities of services and quality reported higher utilization of manufacturing capacity. Finally, the percentage of organizations using R&D, cooperation, and digitalization was growing in regard to growing the size of organizations.

The similar dispersion of non-competitive model organizations to other model organizations is found in regard to industries. Most of the products produced by non-competitive organizations have been found to be of medium complexity. Interestingly, none of the medium or large organizations have been found to produce simple products. Most of the non-competitive model organizations have reported manufacturing their products mainly upon receipt from the customers, so they do have a high level of customization. However, manufacturing capacity is not fully utilized as the main level of their utilization has been found to be medium only. Moreover, many micro and small organizations (about 36% in each group) have reported low manufacturing capacity utilization. Also, non-competitive model organizations have been found to have low innovations and low digitalization.

The first two competitive priorities (quality and customization) of multiple model organizations are similar to other models organizations, but the third competitive priority, i.e., delivery, is the same as in cumulative capabilities model organizations. Multiple model organizations have been found to produce products of medium complexity mainly, similarly to organizations of other operation strategy models. However, multiple model organizations of all sizes have also been found to produce complex products but with medium or low manufacturing capacity utilization. In addition, as large organizations have ranked their innovations better than their competitors, their innovations seem to be based on R&D activities and cooperation, not digitalization.

Comparison analysis revealed the following differences that distinguished organizations within a particular model (see Annex 7.3):

- Cumulative capabilities model organizations utilized manufacturing capacity better than the organizations corresponding to the other models. Utilization in these organizations is better than in the trade-off model organizations (Mann–Whitney $U = 1888$, $p = 0.045$) and in the multiple model organizations (Mann–Whitney $U = 2723$, $p = 0.041$) as well as much better than in the non-competitive model organizations (Mann–Whitney U $= 27.12$, $p = 0.002$).
- Cumulative capabilities model organizations also innovated more than the organizations corresponding to the other models. They innovated more than the trade-off model organizations (Mann–Whitney U $= 723.5$, $p < 0.001$), multiple model organizations (Mann–Whitney U $= 1406.5$, $p < 0.001$), and non-competitive model organizations (Mann–Whitney U $= 622$, $p < 0.001$).
  - In addition, more innovations in multiple model organizations were found in the trade-off model organizations (Mann–Whitney U $= 2086.5$, $p < 0.040$) and non-competitive model organizations (Mann–Whitney U $= 2337$, $p < 0.001$).
  - No significant differences in innovations were found between the trade-off and non-competitive model organizations. Still, innovations were at the lowest in the non-competitive model organizations.
- Digitalization in manufacturing was implemented more by the cumulative capabilities model organizations than in the trade-off organizations (Mann–Whitney $U = 614$, $p = 0.006$), multiple (Mann–Whitney $U = 755$, $p = 0.002$) or non-competitive models (Mann–Whitney $U = 569$, $p < 0.001$) organizations.
- Analysis of digital management in the trade-off and non-competitive models organizations showed that the trade-off model organizations implemented more digital management features (Mann–Whitney $U = 284$, $p = 0.002$) as well as more automatization and robotics in manufacturing (Mann–Whitney $U = 500$, $p = 0.005$) than the non-competitive model organizations. The non-competitive model organizations also used less automatization and robotics than the multiple model organizations (Mann–Whitney $U = 631.5$, $p = 0.025$).

- The non-competitive model organizations were less digital in management than the cumulative capabilities model organizations (Mann–Whitney $U = 300.5$, $p = 0.001$) but similar to the trade-off model organizations.
- The trade-off, cumulative capabilities, and multiple model organizations were similar with regard to the general digital features used in manufacturing. Meanwhile, non-competitive model organizations were implementing digital features less than the trade-off organizations (Mann–Whitney $U = 233$, $p = 0.001$), cumulative capabilities organizations (Mann–Whitney $U = 266.5$, $p = 0.001$) or multiple model organizations (Mann–Whitney $U = 306$, $p = 0.020$).

To sum up, we described organizations according to the four models of operation strategies as outlined in the previous sections in terms of contributing to the knowledge about the characteristics and factors of organizations with regard to different models. Binary logistic regression was used for the analysis of factors that influence the sequences in organizations while following the particular model of operation strategy. In total, 26 factors were included in the analysis, and the impact of 11 of them was confirmed. Due to the scattered missing values in the data set, regression analysis was run separately for each factor. The total sample was used for calculations.

The impacts of the following factors were found for particular models:

- The negative impact of innovations was confirmed for the trade-off model.
- The positive impact of services as a competitive priority, innovations, medium, and high cooperation as well as the negative impact of low and high product complexity, improved environmental impact in new products, digital features in manufacturing, and education of human resources in the technical and professional areas were confirmed for the cumulative capabilities model.
- The negative impact of quality as a competitive priority, innovations, customization, and in the case of employees working in construction, configuration, and design fields was confirmed for the non-competitive model organizations.
- The positive impact of the main product customization was found for multiple model organizations in general. In addition, the positive impact of cooperation was confirmed for the 2H2L multiple model. None of the factors was confirmed for the 3H2L multiple model.

Some limitations should be considered. Regression models for all the sequence models had a good model fit and passed the test of Hosmer and Lemeshow. Due to binary logistic regression for each factor separately, the Nagelkerke R square was low (from 0.013 to 0.181) in all the cases. Thus, the forecasting power of factors would be higher when using them together. Still, it was not possible to test on the current data. The percentage of the correct forecast corresponded to the same issue. Yet, it varied from 62.2 to 68.9% in the case of the cumulative capabilities model, from 72.8 to 73.6% in the case of the trade-off, non-competitive, and multiple models. In the case of the 2H2L multiple model, it reached a higher percentage of correctness (83.3).

In addition, the research data is one source from each organization that might have a subjectivity bias in terms of referring to the information. Nevertheless, all the respondents were selected in accordance with their position in the organization and their knowledge about it. Also, the sample was composed using the random sampling method, thus ensuring the representation of all Lithuanian manufacturing companies.

For the managers of manufacturing organizations, some significant insights might be obtained. The implementation of the trade-off model and the development of only one capability means the loss of innovations. On the contrary, the cumulative way of developing capabilities is positively associated with innovations, cooperation, digitalization in manufacturing, and better utilization of manufacturing capabilities. In general, the cumulative capabilities model of operation strategy means the highest innovation compared to other models. Multiple model organizations are the next one in innovations. Still, some factors impacted the cumulative capabilities model negatively. Obtaining cumulative capabilities incurs the price of the environmental features in the new products, declines the number of employees with technical and professional education, or implements only a medium amount of digital features in manufacturing.

Organizations embracing the multiple capabilities model mainly gain from the main product customization. In the case of an organization that is developing two of its research capabilities, cooperation with other organizations is significant, while none of the researched factors was significant if the organization had high performance in three areas of capabilities. If an organization has three highly rated capabilities, checking the consistency of the cumulative capabilities model is needed. In the case of the positive match, previous insights for the cumulative capabilities model organizations are relevant.

Annex 7.1 Measurement Scales[1]

Measurement of Operational Performance

Indicate how well your factory performed compared to its competition within your industry along these different performance dimensions, 1—Much worse, 2—Somewhat worse, 3—About the same, 4—Somewhat better, 5—Much better, 6—I don't know.

[1] European manufacturing survey questionnaire scales (EMS 2022).

Quality

- Product overall quality performance
- Product reliability
- Product features
- Product conformance
- Product durability

Cost

- Unit cost
- Manufacturing overhead cost
- Inventory turnover

Flexibility

- Ability to adjust production volumes
- Ability to respond to changes in delivery requirements
- Ability to customize products
- Ability to produce a range of products
- Speed of new product introduction into the plant

Delivery

- Delivery accuracy
- Delivery dependability
- Delivery quality
- Delivery availability
- Delivery speed

Innovation

- Lead time to introduce new products
- Number of new products introduced each year
- The extent of innovativeness of products

Service

- Regular products support services
- Online product support services
- Advanced service provision models
- Data-driven services

Digitalization

- Digitalization of production data
- Connection production system elements
- Autonomous production data collection and analysis
- Automation of production processes

Measures of Financial Performance

Please characterize your factory:

- Annual turnover
- In 2017 XX million €
- In 2015 XX million €

- Number of employees
- In 2015 XX number
- In 2015 XX number

- Return on sales (before tax, 2017)
- Negative
- 0 up to 2%
- >2 up to 5%
- >5 up to 10%
- >10%

Annex 7.2 Results of Regression Analysis in Groups of Organizations According to Models of Sequences

Model	Variable	N	Regression model summary		Summary of variable						95% C.I. for Exp (B)	
			Nagelkerke R square	Percentage correct	Variables	B	S.E	Wald		Exp (B)	Lower	Upper
Trade-off	Innovations	360	0.039	73.6	Innovations	−0.520	0.174	8.946	**	0.594	0.423	0.836
					Constant	0.556	0.556	1.000		1.743		
Cumulative capabilities	Competitive priority	471	0.056	63.7	Comp_Priority			14.256	*			
					Constant	−1.386	0.791	3.075		0.250		
	Manufacturing capacity	397	0.028	62.2	k20h_cat			8.198	*			
					k20h_cat(1)	−0.597	0.261	5.240	*	0.551	0.330	0.918
					k20h_cat(2)	−0.682	0.256	7.082	**	0.506	0.306	0.836
					Constant	−0.052	0.187	0.078		0.949		
	Cooperation	174	0.090	67.8	Cooperation (3)	1.289	0.594	4.710	*	3.627	1.133	11.614
					Cooperation (6)	1.471	0.621	5.607	*	4.353	1.288	14.707
					Constant	−0.778	0.293	7.045	**	0,459		
	Innovations	360	0.104	68.9	Innovations	0.824	0.165	25.077	**	2.279	1.651	3.147
					Constant	−3.279	0.560	34.238	**	0.038		
	Environmental impact	84	0.181	65.5	Envir_impact (3)	−1.946	0.959	4.113	*	0.143	0.022	0.937
					Constant	1.099	0.667	2.716		3.000		
	Digital manufacturing	243	0.046	65.0	D_Manufact	0.385	0.137	7.917	**	1.470	1.124	1.922
					Constant	−1.626	0.413	15.498	**	0.197		
	Digital features of manufacturing	143	0.067	65.7	D_MFeatures (1)	−2.140	0.945	5.133	*	0.118	0.018	0.749
					D_MFeatures (4)	−1.861	0.936	3.952	*	0.156	0.025	0.974

(continued)

(continued)

Model	Variable	*N*	Regression model summary		Summary of variable						95% C.I. for Exp (*B*)	
			Nagelkerke *R* square	Percentage correct	Variables	*B*	S.E	Wald		Exp (*B*)	Lower	Upper
					Constant	1.099	0.816	1.810		3.000		
	Product complexity	471	0.026	63.9	P_complex			9.016	*			
					P_complex(3)	−0.630	0.234	7.258	**	0.533	0.337	0.842
					Constant	−0.131	0.194	0.457		0.877		
	HR education	446	0.034	65.2	HR_EduN(2)	−1.425	0.661	4.641	*	0.241	0.066	0.879
					HR_EduN(3)	−1.519	0.685	4.915	*	0.219	0.057	0.838
					HR_EduN(5)	−1.658	0.748	4.914	*	0.190	0.044	0.825
					Constant	0.560	0.627	0.797		1.750		
Non-competitive	Competitive priority	471	0.048	73.5	Comp_Priority (2)	−1.580	0.664	5.667	*	0.206	0.056	0.756
					Comp_Priority (3)	−2.155	0.843	6.538	*	0.116	0.022	0.605
					Comp_Priority (4)	−1.574	0.688	5.231	*	0.207	0.054	0.798
					Constant	0.405	0.645	0.395		1.500		
	HR field	445	0.013	72.8	HR_FieldN(2)	−1.028	0.513	4.010	*	0.358	0.131	0.978
					Constant	0.000	0.500	0.000		1.000		
Multiple	Main product	460	0.034	73.0	Main_product (3)	0.721	0.267	7.283	**	2.454	1.429	4.213
					Constant	−1.221	0.159	58.767	**	0.295		
Multiple 1	Cooperation	174	0.138	83.3	Cooperation (4)	1.386	0.698	3.942	*	4.000	1.018	15.717
					Constant	−2.079	0.433	23.062	**	0.038		

Note: * $p > 0.05$, ** $p > 0.01$. All presented regression models passed Hosmer and Lemeshow test for goodness of fit with $p > 0$

Annex 7.3 Differences Between Groups of Organizations According to Models of Sequences

Factors	Models	Trade-off	Cumulative capabilities	Non-competitive	Multiple	Mann–Whitney *U* test	
Utilization of manufacturing capacity	Trade-off	61.95	74.83			1888.000	*
	Cumulative capabilities		98.84	76.96		2712.000	**
	Cumulative capabilities		89.69		75.44	2723.000	*
Innovations	Trade-off	43.48	81.44			723.500	**
	Trade-off	65.12			78.24	2086.500	*
	Cumulative capabilities		105.13	50.32		622.000	**
	Cumulative capabilities		88.01		58.40	1409.500	**
	Non-competitive			70.49	97.15	2337.000	**
Digitalization in manufacturing	Trade-off	36.64	51.02			614.000	**
	Cumulative capabilities		58.12	37.16		569.000	**
	Cumulative capabilities		60.59		42.52	755.000	**
Digital management in manufacturing	Trade-off	39.84		25.61		284.000	**
	Cumulative capabilities		41.66	26.11		300.500	**
Automatization and robotics in manufacturing	Trade-off	42.85		33.20		500.000	**
	Non-competitive			36.40	43.88	631.500	*
Count of all digital features used in manufacturing	Trade-off	37.97		23.52		233.000	**
	Cumulative capabilities		39.92	24.60		266.500	**
	Non-competitive			25.87	36.30	306.000	*

Note: Mean ranks are given. Only significant differences are shown. * $p > 0.05$, ** $p > 0.01$

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Chapter 8
On Compatibility and Empirical Manifestation of Lean, Agile, and Service-Oriented Performers

Abstract In this last chapter, we summarize the findings and highlight the contribution of the research reported in this book. After characterizing the emerging service-oriented organizing template in relation to already established lean and agile templates, we suggest that the templates are characterized by a low degree of compatibility. The templates are constituted by contrasting goals, a partial overlap of practices and their adoption leads to unique competencies and performance capabilities. Further, our empirical research shows that lean template-related competitive priorities, practices and performance capabilities are diffused more extensively compared to agile and service-related ones. Finally, we reveal that lean, agile, and service-oriented practices and performance capabilities contribute to manufacturing firms' operational and financial performance. We provide empirical evidence revealing that quality and innovation performance capabilities positively influence revenue growth while digitalization capability positively relates to the productivity of industrial organizations. The findings contribute to the lean, agile, and servitization literature and longstanding debate on the compatibility and effects of popular organizational forms.

In this book, we focused on the trends of the shifting landscape of the global manufacturing field. At the heart of these changes are ubiquitous digital technologies and connectivity. Early adopters of digital manufacturing innovations find themselves immersed in digital transformation. The multidimensional and broad concept of digital transformation defines the overall effect of digital technologies and connectivity on an organization. We proposed that digital transformation enabled the emergence of a new service-oriented template of organizing for industrial companies. The service-oriented template of organizing complements two other popular templates used by industrial companies—lean and agile. We sought several objectives in this book. First, we aimed to characterize the emerging service-oriented organizing template in relation to already established lean and agile templates.

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Second, we sought to empirically assess how competitive orientations, practices, and competitive performance dimensions associated with lean, agile, and service-oriented organizations are distributed in an industrialized country. Finally, we intended to empirically assess how lean, agile, and service-oriented practices and performance capabilities contribute to manufacturing firms' operational and financial performance. Further, we summarize the main results and discuss the theoretical contribution of our findings.

8.1 The Interrelation of Lean, Agile, and Service-Oriented Templates of Organizing

To characterize the emerging Service-oriented organizing template in relation to already established lean and agile templates, we took a staged approach. In the beginning, we described each template, drawing on the neo-institutional theory. Later, we empirically identified companies adhering to the different templates in relation to each other. Following the neo-institutional theory, we defined templates of organizing as an institutionally relevant arrangement of goals and practices resulting in organizational competencies and differentiating competitive performance dimensions constituting an organization's core. Drawing on the definition, we described the lean, agile, and service-oriented templates of organizing in terms of goals, practices, competencies, and performance capabilities (Table 8.1).

The description of templates of organizing provided us with a set of alternatives to empirically identify organizations adhering to each template in relation to each other. We have chosen to identify the organizations adopting the templates by their differentiating performance dimensions. We hypothesized that a lean organization would excel in cost performance compared with Agile and Service-oriented organizations. Following the approach, we hypothesized that Agile organizations will be characterized by a superior flexibility performance, while Service-oriented organizations will be characterized by a superior service performance. The items that were used for the measurement of the performance dimensions may be found in Annex 8.1. Figure 8.1 summarizes the results of our empirical analysis.

The figure represents the standardized measures of performance dimensions of three clusters of organizations that we associate with lean, agile, and service-oriented organizations. We found that organizations that adhere to the lean template are not superior in cost performance compared to companies that adhere to agile and service-oriented templates. We found that companies that adopt agile templates are superior in flexibility performance compared with lean and service-oriented companies. Finally, we revealed that companies that adhere to a service-oriented template were characterized by far more advanced service performance than other companies. In summary, we provided a conceptual and empirical description of the companies adhering to lean, agile, and service-oriented templates in relation to each other. These findings allow us to make several contributions to lean, agile, and servitization

Table 8.1 Characteristics of the Service-oriented template of organizing in relation to the lean and agile templates

Dimensions	Lean	Agile	Service-oriented
Goal	Providing customers with goods and services characterized by high customer value in a low-cost manner through the elimination of waste (Womack and Jones 1996; Hines et al. 2004)	Providing customers with goods with enough variety and customization that nearly everyone finds exactly what they want (Pine 1993)	Providing customers with value by sharing risk; reducing the total cost of ownership of the product, and delivering new efficiencies and other benefits (Iansiti and Lakhani 2014)
Competitive priorities	– Cost***D – Quality***D – Delivery***; Flexibility**; Innovation** – Services*	– Flexibility***D; Innovation***D – Delivery***, Quality***; Services***, Cost***	– Services***D – Quality***; Flexibility***; – Innovation*** – Cost**; Delivery**
Practices	– Continuous flow – Customer involvement – Statistical process control – Total preventive maintenance – Supplier feedback – JIT delivery by suppliers – Supplier development – *Pull of production* – *Setup time reduction* – *Employee involvement*	– Design-product platforms – Concurrent engineering – Rapid prototyping – Modular product design – Design for manufacturing – Supply chain coordination – *Advanced manufacturing technologies* – *Pull of production* – *Employee empowerment* – *Setup time reduction*	– Product support services – Customer support services – Result-oriented services – Digital technologies – *Advanced manufacturing technologies*
Organizational competencies	– Customer-defined value – Integrated supply chain – Lead time compression – Waste elimination – Low variability of demand, processing time, and supply	– Solution space development for choice navigation – Integrated supply chain – Lead time compression – Rapid reconfiguration – Robust process design	– Intelligence – Connect – Analytic – Outcomes-based sales
Competitive performance dimensions[a]	– Cost***D – Quality	– Flexibility***D – Innovation – Fast delivery	Services***D

* Arbitrary importance; ** Secondary importance; *** Primary importance; ***D Differentiator
[a] The differentiating competitive performance dimension is identified because others tend to overlap (e.g., quality could be important in adhering to all templates; innovation could be important in adhering to service-oriented template)

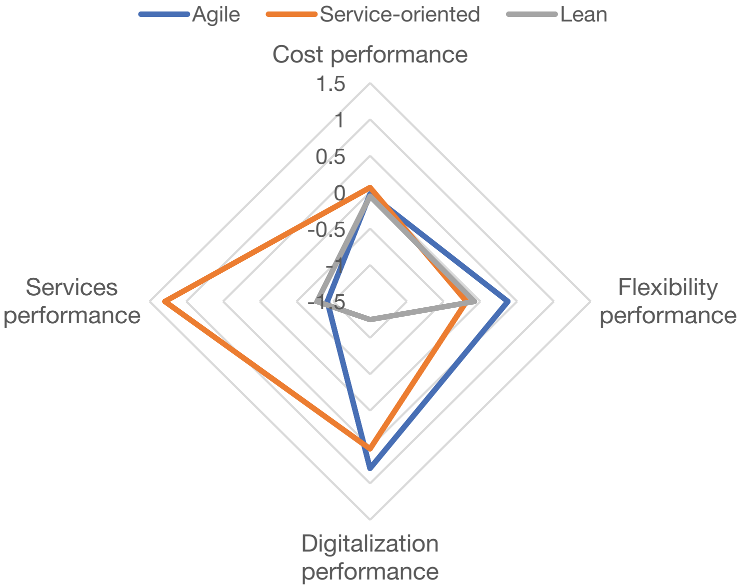

Fig. 8.1 Mean differences in performance capabilities of lean, agile, and service-oriented organizations (Vilkas et al. 2021a)

literature. First, we contribute to the discussion on the compatibility of the lean, agile, and service-oriented templates. Second, the study also offers insight into the sequential relation of the templates. In the following paragraphs, we elaborate on the contribution.

The research has implications for the longstanding debate on the level of compatibility of the lean and agile templates (Naylor et al. 1999; Naim and Gosling 2011). Some authors argue that there is a high overlap between the templates (Shah and Ward 2003; Krishnamurthy and Yauch 2007). Other scholars treat them as paradigmatically different (Naylor et al. 1999; Mason-Jones et al. 2000; van Hoek 2000; Aitken et al. 2002; Bruce et al. 2004; Hallgren and Olhager 2009). Our research provides additional evidence for the second group of scholars. First, the research based on the neo-institutional theory provided insights that the compatibility of the templates depends on the compatibility of the goals but not the means (Pache and Santos 2010; Greenwood et al. 2011). Conflicting goals reveal incompatibility and tend to mobilize legitimation of different stakeholders (Pache and Santos 2010). Our conceptual description of lean, agile, and service-oriented templates reveals fundamentally different goals of the templates.

Each template is grounded on a unique promise of increased returns. Lean template promises increased performance because of low production costs. Agile template draws on the trend of diversification of customers' needs. It enables to charge premiums because of individualized products and services. Finally, the Service-oriented template shifts attention from the products to sharing the risk, reducing the total cost of ownership, and delivering new efficiencies and other benefits through services. It allows capturing value by charging the customer a lower price than the total cost of ownership. While institutional theory argues that incompatibility of goals is the most consequential, our analysis reveals little overlap among other template elements. The templates are characterized by contrasting competitive priorities, a partial overlap of practices and nonidentical competencies and differentiating performance dimensions. Second, the template adoption initiates path-dependent dynamics. Thus, some choices because of the prior decisions become unavailable later. For example, the lean template is partially based on the critical values over the usage of IT technology. IT technology may result in over-automation, improper problem analysis, failure to consider the total cost of IT investment, and reinforcing silos, among others, from the perspective of the lean template (Orzen and Bell 2016). At the same time, IT and digital technologies constitute important means for customization of products and provision of customer support and result-oriented services for companies adopting Agile and Service-oriented templates (Gunasekaran et al. 2019; Iansiti and Lakhani 2014). In summary, conceptual analysis reveals the low compatibility of the templates. Adherence to templates may increase the symbolic performance of the adopters as they constitute the desired models of organizing by investment funds and public governance institutions. The incompatibility of the templates also means that shifting among templates could result in the loss of support of the constituents that subscribe to the particular template and the decrease of a symbolic performance—at least within a short timeframe.

This research also contributes to the debate on whether there is a sequential relationship between the templates. Some authors (Gunasekaran 1999; Narasimhan et al. 2006) propose that the lean template could be a precursor to the Agile template. The low compatibility of the templates contradicts the deliberate sequential adoption of the templates to develop additional capabilities. The templates promote conflicting goals. Thus, the templates are incompatible, and they are not sequentially related. The deliberate switching of templates is justifiable when adherence threatens the company's survival. It is challenging to imagine that a company that adheres to the lean template and seeks to develop superior flexibility or innovativeness performance announces to their stakeholders that they disband the lean template and continue with the Agile one. Adherence to the template requires longstanding continuity and coherence in managerial rhetoric and actions. The same arguments relate to lean, agile and service-oriented templates. According to our analysis, the propositions that the lean template is a precursor of agile and agile is a precursor of the service-oriented template are not well grounded looking from the neo-institutional theory perspective.

While deliberate template switching to develop new capabilities and competitive performance dimensions is not advisable, organizations may still choose to shift their subscription between the templates. It may happen because of the changes in the competitive situation or opportunistic exploitation of new possibilities. If the competitive position of an organization erodes, the change of the templates may provide a possibility for survival. Given that, which pairs of templates are characterized by a less effort-requiring switch? Our empirical findings of the organizations adhering to different templates can provide insight into this question. The empirical findings reveal the difference in the factor score means of performance dimensions among the clusters of organizations adhering to lean, agile, and service-oriented templates. If organizations belonging to different clusters exhibit only a slight difference in performance dimensions, switching from one template to another is more probable (Fig. 8.1). The data shows that if lean organizations ever decide to become agile organizations, they should advance on the flexibility performance, but the difference in the performance dimensions is not high. However, if lean organizations adopt the service-oriented template, they should considerably improve on the service performance dimension. Again, if agile organizations were willing to embrace the service-oriented template, they should enhance their service performance substantially. The digitalization performance of agile and service-oriented organizations is similar, whereas lean organizations lag far behind. Suppose the service-oriented and agile templates draw heavily on the digitalization capability. In that case, switching from the agile to a service-oriented template could be more comfortable than from the lean to the service-oriented template. It is possible to infer that it is easier to switch from the lean to the agile, and from the agile to the service-oriented template than from the lean to the service-oriented template.

8.2 An Empirical Assessment of Lean, Agile, and Service-Oriented Templates

This book sought to empirically identify the prevalence of lean, agile, and service-oriented templates by measuring the diffusion of competitive priorities, practices, and performance dimensions associated with each template. The prevalence of competitive priorities associated with lean, agile, and service-oriented templates is provided in Table 8.2. The most critical competitive priority indicates the company's strategic differentiator, which distinguishes it from its competitors. Such competitive priority could serve as an indicator of the template company subscribes. The results reveal that the competitive priority of quality associated with the lean template is the most popular differentiator. 49.5% of companies claim that product quality constitutes the most important strategic priority. The competitive priority of flexibility associated with the agile template follows. 20.8% of companies claim that product customization constitutes their strategic orientation. Finally, only 2.4% of companies claim that service competitive priority differentiates these companies.

The analysis of the overall importance of strategic priorities reveals several essential tendencies. First, innovative products do not constitute competitive importance for 73.6% of companies. Second, the overall importance of the services is also very low and stands only at 17.2%. The analysis reveals that manufacturing companies tend to differentiate using more traditional strategic priorities based on product quality and customization. After reviewing the prevalent strategic

Table 8.2 The prevalence of competitive priorities associated with lean, agile, and service-oriented templates ($N = 500$, %)

Competitive priorities/level of importance	Lean		Agile			Service-oriented
	Product price	Product quality	Innovative products	Product customization	Delivering on schedule/ fast delivery	Services
The most important	9.6	49.5	5.6	20.8	12	2.4
Important	14.2	24.8	8.6	20.2	26.7	5.4
Slightly important	19	11.8	12.2	24.0	23.4	9.4
Important (sum of above)	42.8	86.1	26.4	65.0	62.1	17.2
Not so much important	14	9.4	18.6	18.6	20.6	18.6
Not important	13.6	3	25.9	10.4	11.2	35.9
Not at all important	29.5	1.4	29.1	5.8	6	28.3
Not important (sum of above)	57.1	13.8	73.6	34.8	37.8	82.8

orientations, we concentrate on the diffusion of template-related organizational and technological practices in the following paragraphs.

The prevalence of organizational and technological practices associated with lean, agile, and service-oriented templates is provided in Table 8.3. The analysis reveals that lean methods are used very extensively among manufacturing organizations. Almost half of the methods are employed by more than 50% of organizations. The diffusion of digital manufacturing technologies related to the Agile template is relatively lower. ERP constitutes the most popular digital technology. 43.2% of manufacturing companies use such software for production planning and scheduling. Such numbers are low given the importance of ERP systems. Industrial robots are also less prevalent than one could expect. Finally, the service diffusion is the lowest compared with lean and agile practices. However, the extent of the provision of product and customer support services is high enough, considering that only 2.4% of companies tend to differentiate themselves by services. Such results indicate that services are not treated as a differentiator and are provided to increase product value.

The empirical assessment reveals extensive diffusion of lean methods in an industrialized country compared to digital technologies and services. After summarizing the diffusion of lean, agile, and service-oriented practices, we turn on the diffusion of template-related competitive performance dimensions in the next paragraphs.

The prevalence of performance dimensions associated with lean, agile, and service-oriented templates is provided in Table 8.4. Our analysis revealed that flexibility, quality, and delivery are the most prevalent performance dimensions,

Table 8.3 Prevalence of organizational and technological practices associated with lean, agile, and service-oriented templates ($N = 500$, %)

Lean		Agile		Service-oriented	
Title	Used, %	Title	Used, %	Title	Used, %
Supplier feedback	73.9	Software for production planning and scheduling	43.2	Product support services	
				Remote support for clients	33.4
Standardized work instructions	65.1	Mobile programming and controlling of facilities and machinery	35.7	Maintenance and repair	27.6
Just-in-time delivery	62.5	Digital solutions to provide documentation directly to the shop floor	35.2	Installation, start-up	22.6
Customer involvement	61.5	Near real-time production control systems	33.7	Take-back services	17.0
Involvement into improvement	57.7	Digital exchange of product/process data with suppliers/customers	29.6	Training	15.8
Total productive/preventive maintenance	54.3	Systems for automation and management of internal logistics	25.1	Customer support services	
				Design, consulting, project planning	26.4
Development of suppliers	43.1	Simulation for product design and development	24.1	Revamping or modernization	16.0
Integration of tasks	36.7	Industrial robots for manufacturing processes	16.1	Online training, documentation, error description	15.0
Statistical process control	30.7	Industrial robots for handling processes	12.6	Web services product configuration or product design	13.0
Visual management	29.7	3D printing technologies for prototyping	4.5	Mobile devices for diagnosis, repair, or consultancy	9.8
5S	28.9	3D printing technologies for manufacturing	5.0	Remote monitoring of operating status	9.6
Setup time reduction	25.9	–	–	Software development	9.4
Value stream mapping	25.3	–	–	Data-based services based on big data analysis	1.6
Customer- or product-oriented lines/cells	23.6	–	–	Result-oriented services	
				Full-service contracts	28.8
Pull of production	19.8	–	–	Operation of products at customer site for the customer	14.0
–	–	–	–	Taking over the management of	9.4

(continued)

Table 8.3 (continued)

Lean		Agile		Service-oriented	
Title	Used, %	Title	Used, %	Title	Used, %
				maintenance activities	
–	–	–	–	Renting products, machinery, or equipment	6.4

Table 8.4 Percentage of companies that have better and much better performance on a particular performance dimension ($N = 500$, %)

	Lean		Agile			Service-oriented	
	Quality	Cost	Innovation	Delivery	Flexibility	Digitalization	Services
Much better	15.2	2	5.5	11.3	15.8	2.6	1.35
Somewhat better	28.1	16.3	14.9	26.6	29	3.9	3.3
Better (sum of above)	43.3	18.3	20.4	37.9	44.8	6.5	4.7
About the same	46.3	44.1	43.7	44	32.1	22.3	11.55
Somewhat worse	0.7	5.4	5.1	1	1.1	6.2	0.9
Much worse	0.1	0	1.4	0	0.2	8.45	21.8
I don’t know	9.6	32.2	29.3	17.1	21.8	56.6	61.1

possessed by 44.8%, 43.3%, and 37.9% of companies, respectively. Innovation and cost are less developed competitive performance dimensions. Finally, only 6.5% and 4.7% of companies claim that their digitalization and service performance is much or somewhat better than their competitors.

In summary, we empirically assessed how competitive orientations, practices, and performance dimensions associated with lean, agile, and service-oriented organizations were distributed in a country. In the next paragraph, we discuss the implications of our findings.

The empirical assessment of the prevalence of competitive priorities, practices, and competitive performance dimensions associated with templates contributes to lean, agile, and servitization literature in several ways. First, it provides a representative snapshot of the manufacturing sector in an industrialized country which can be used for comparative studies. Second, the findings provide insight into which of the three templates can be the source of symbolic performance. Third, it advances contingency research on organizational templates, revealing how the usage of template-associated practices is contingent on internal and external factors. Fourth, it provides empirical evidence of the lack of confidence in digitalization performance among manufacturing organizations.

According to the World Economic Forum's Future of Production report, the current Lithuanian manufacturing situation is ranked 31st, and the future manufacturing situation is ranked 37th in a list of one hundred industrialized countries (WEF 2018; Vilkas et al. 2021c). Eight thousand companies constitute a vibrant manufacturing sector in a country. Manufacturing creates 18.4% of value added. The sector employs 15.2% of the country's working population. The manufacturing industry is well integrated into the international value chains—manufacturing companies export approximately 65% of their production. The research reported in this book is based on the effective sample of 500 manufacturing companies. The sample represents the population of manufacturing companies in terms of size, regions, and sectors. The effective sample provides results within a 95% confidence interval and approximately with a 4% margin of error. Empirical studies representing countries are rare. The empirical evidence provided in this book constitutes a representative snapshot of manufacturing companies' behavior in an industrialized country. The empirical evidence provided in this book also can be used for comparative purposes.

The neo-institutional theory proposes that adherence to organizing templates increases organizations' legitimacy, resulting in increased symbolic performance (Meyer and Rowan 1977; Heugens and Lander 2009). Our findings suggest that it is highly probable that adherence to the lean template does not guarantee increased symbolic performance because of its prevalence. The findings reveal that lean-associated competitive priorities, practices, and performance dimensions are more proliferated than agile and service-oriented ones. 49.5% of manufacturing companies in a country use quality as a competitive priority. Lean practices are extremely proliferated. Several lean practices are used by more than 50% of companies. Finally, even 43.3% of companies state that their quality performance is better than their competitors. The extent of diffusion of agile-related competitive orientations, methods, and performance dimensions follow lean template-related one. 20.8% of companies use product customization as a competitive differentiator. Digital innovations are moderately diffused. 44.8% of companies trust their flexibility performance. Finally, only 2.4% of companies argue that services constitute their strategic priority and only 4.7% of companies claim that they have better service performance than their competitors. Such findings are consistent with the research on lean and agile organizations (Psomas 2022; Danese et al. 2018; Dubey and Gunasekaran 2015). Further, agile-related priorities, practices, and performance dimensions are more diffused than service-oriented ones. Historically, the templates emerged in the following order: first lean, then agile, and finally, service-oriented templates. Toyota organized its production leanly, becoming famous for reliable and cost-effective cars in the 1960s (Womack et al. 1990). Dell represented the emergence of the agile movement by offering customized laptops with short delivery times (Fugate and Mentzer 2004). Finally, Rolls-Royce Aviation became known for its "Power-by-the-hour" program and additional services for customers based on data collected from jet engines they had been producing a decade ago (Smith 2013). Given the prevalence of competitive priorities, practices, and performance dimensions associated with the lean template, adherence to it could not result in increased symbolic performance. Stakeholders could be unable to channel additional orders and other resources to lean companies because most companies may claim they are lean. We do not say that lean practices are not valuable. There is an accumulated body of knowledge that lean practices help reduce cost and increase customer value (Dal Pont et al. 2008; Belekoukias et al. 2014; Chavez et al. 2013). We propose that adherence to the lean template will fail to increase the company's legitimacy in the eyes of interested parties. Following this line of reasoning, we propose that adherence to a Service-oriented template could become a source of increased symbolic performance. The service-oriented template is based on a current trend of digitalization of operating systems and products (Porter and Heppelmann 2014; Lenka et al. 2017; Paschou et al. 2020). The companies offering complex customer support and result-oriented services are not prevalent because the competencies required to provide such services are rare. In summary, we propose that adherence to the lean template does not result in an increased symbolic performance; however, adherence to the service-oriented—and potentially to agile—template still offers such an opportunity.

Our research advances contingency research on lean, agile, and service-oriented organizations, revealing whether the usage of template-associated practices is contingent on size, industry, product complexity, lot size, the design process type, and the manufacturing process of organizations. First, our research shows that size is a crucial variable allowing us to predict the extent of lean methods' adoption. Food companies also use lean methods more extensively than other companies, but the differences are not statistically significant. Similarly, companies that produce to stock tend to use lean methods more broadly than companies practicing make-to-order production, but the difference is not statistically significant. Second, we also found that large companies deploy digital manufacturing innovations more extensively than SMEs. Further, we discovered that companies in the metal and engineering industries tend to use more digital innovations, but the differences are not statistically significant. Finally, we discovered that the metal and engineering industries provide more services than other sector companies. We also revealed that other factors such as size, product complexity, lot size, the design process, and the manufacturing process type do not influence the provision of services. Our findings that large companies tend to deploy digital innovations and lean methods more extensively than SMEs aligns with current research (Horvath and Szabo 2019; Mittal et al. 2019; Müller et al. 2018, 2020; Raj et al. 2020). The complexity of production systems is higher within large companies compared to small companies. The leaning and digitization of complex production systems offer more benefits than leaning and digitizing less complex ones. Large companies tend to invest more in digital technologies compared to small companies. Large companies also possess financial and human resources that aid in adopting lean methods and digital manufacturing technologies. However, our findings reveal that the usage of services does not depend on a size of a company. Such findings confront the current evidence (Paiola 2018; Queiroz et al. 2020). These findings are not in line with current servitization literature. Large companies have product-related capabilities such as accumulated product usage data, product development, and manufacturing assets, an experienced product sales force and distribution network that facilitates service innovation (Ulaga and Reinartz 2011; Vilkas et al. 2022). In summary, our findings contribute to the research on lean, agile, and service-oriented organizations providing a more nuanced picture of the diffusion of template-related methods.

Finally, our research reveals a non-extensive prevalence of digital innovations among manufacturing companies. Less than 50% of manufacturing companies use the digital technologies we have studied. ERP systems are used by 43% of organizations. Warehouse management systems are used by 25.1% of organizations. Connectivity technologies such as Digital exchange of product or process data with suppliers or customers, Digital solutions to provide documentation directly to the shop floor are used by less than 30% of organizations. 16% of organizations use industrial robots. The absolute figures for digital technology usage are not high and reveal insufficient investments into digital technologies by companies, especially SMEs. Manufacturing SMEs confront multiple resources, technology, and change management-related barriers that obstruct digital transformation initiatives (Ghobakhloo et al. 2022; Müller et al. 2020; Raj et al. 2020; Horvath and Szabo 2019; Mittal et al. 2019; Müller et al. 2018; Rymaszewska 2014).

The evaluation of manufacturing companies' digitalization and servitization performance also indicates the companies' mistrust of their capabilities. Only 6.5% and 4.7% of companies claim superiority of their digitalization and service performance. 56.6% of companies answered that they do not know their digitalization performance status in relation to competitors. 61.1% of companies answered that they do not know if service performance is better or worse than competitors. Such results may be explained in several ways. Companies may be struggling to follow the fast-paced evolution of digital manufacturing innovations. New management information systems are constantly emerging. Consider recent robotic process automation, process mining, or manufacturing applications platforms available for the last 5 years only. The use cases of general-purpose digital technologies, such as AI, are multiplying (Bodrožić and Adler 2018). AI algorithms were used for sales and demand prediction, firstly. Afterward, machine learning algorithms have become typical for product development cycle optimization, predictive maintenance, procurement, spend analysis, and real-time re-planning (Bughin et al. 2018). Even though manufacturing companies apply some digital technologies, there are always newer and more recent digital innovations. In summary, our analysis revealed that superior digitalization and servitization performance is scarce among manufacturing firms and these performance capabilities are mastered by only a fraction of companies.

8.3 The Effects of Lean, Agile, and Service-Oriented Practices on Operational Performance

In this book, we intended to empirically assess how lean, agile, and service-oriented practices contributed to the operational performance of the manufacturing firms. The results of modeling the effect of lean methods, digital innovations, and services on operational performance are presented in Table 8.5. The empirical assessment of the effects of lean, agile, and service-oriented practices on operational performance contributes to lean, agile, and servitization literature by providing representative empirical evidence of which practices could contribute to the operational performance.

Contrary to our expectations, we found that only two lean methods positively affect quality and cost performance. Only pull of production and customer or product-oriented cells positively contribute to quality and cost performance. Even more, the development of suppliers negatively influences quality performance. At the same time, lean methods are positively associated with other performance dimensions such as delivery, flexibility, innovation, and digitalization performance.

We found a moderate effect of digital manufacturing innovations on operational performance. Systems for automation and management of internal logistics (e.g., RFID) positively influence the quality, flexibility, and cost performance, making it the most beneficial digital innovation. Virtual Reality or simulation for product design also positively contributes to flexibility performance. Mobile/wireless devices for programming and controlling facilities and machinery increase delivery. Finally, the near real-time production control system (e.g., MES) positively influences cost-effectiveness. Other relations are too weak, and we could not confirm them due to the lack of statistical power. Contrary to our expectations, digital innovations do not affect digitalization performance. The lack of statistical power could be the main reason for this controversial finding. The effects of digital innovation were analyzed based on a sample of 200 companies. Given that digitalization capabilities are rare and digital innovations are not extensively diffused, the resulting associations are judged on a small effective sample. Thus, it is difficult to establish statistically significant relations. The other explanation is that other organizational phenomena potentially mediate the relationships. For example, it was suggested that digital innovations and other organizational methods constitute organizational competencies that positively affect operational performance (Vilkas et al. 2021a). Finally, maintenance and repair, remote support for clients, Web-based offers for product utilization, and taking over the management of maintenance activities for the customer services have a positive effect on service performance. The results reveal that Full-service contracts negatively influence service and cost performance indicating that companies are not ready to provide such complicated services and take too much risk-taking over the customers' maintenance activities. In summary, our research provided empirical evidence of the effects of lean methods, digital manufacturing innovations, and services on the operational performance of organizations.

Table 8.5 Relationship effects of digital innovations, lean methods, and services on operational performance

	Lean		Agile			Service-oriented	
Method/capability	Cost	Quality	Delivery	Flexibility	Innovation	Services	Digitalization
Lean methods							
Pull of production	0.161*	0.139*	–	–	–	–	–
Customer- or product-oriented lines/cells	–	0.103*	0.143*	–	–	–	–
Development of suppliers	–	– 0.110**	–	–	–	0.214*	–
Involvement of employees	–	–	–	0.145*	0.118*	–	–
Statistical process control	–	–	–	0.15**	–		
Total productive/preventive maintenance	–	–	–	–	–	0.221*	–
Setup time reduction	–	–	–	–	–	–	0.168*
Visual management	–	–	–	–	–	–	0.16*
Integration of tasks	–	–	–	–	–	–	0.201*
Digital manufacturing innovations							
Systems for automation and management of internal logistics (e.g., RFID)	0.187*	0.295**	–	0.232**	–	–	–
Virtual reality or simulation for product design or product development	–	–	–	0.219*	–	–	–
Mobile/wireless devices for programming and controlling facilities and machinery	–	–	0.186*		–	–	–
Near real-time production control system (e.g., MES)	0.229*	–			–	–	–
Services							
Installation, start-up	–	–	0.145*	–	–	–	–
Revamping or modernization	–	–	–	–	0.137*	–	–
Maintenance and repair	–	–	–	–	–	0.216*	–
Remote support for clients	–	–	–	–	–	0.388**	–
Take-back services	–	–	–	–	–	– 0.219*	–

Design, consulting, project planning	–	–	–	–	–		0.224*
Software development	–	–	–	–	–		–0.25*
Web-based offers for product utilization	–	0.103*	0.032*	–	–	0.257*	–
Data-based services based on big data analysis	–	–0.115**	–	–	–	–	–
Taking over the management of maintenance activities for the customer	–	–	–	–	–	0.173*	0.181*
Full-service contracts with a defined scope to maintain products	–0.193*	–	–	–	–	–0.146*	–
Renting products, machinery, or equipment		–	–	–	0.15*	–	–

8.4 The Effects of Lean, Agile, and Service-Related Performance Dimensions on Financial Performance

Finally, in this book, we aimed to understand which lean, agile, and service template-related operational performance dimensions result in increased financial performance. The neo-institutional and ambidexterity theories propose possibly conflicting propositions for the development of superior performance. The neo-institutional theory argues that adherence to a template of organizing relevant to a company's stakeholders results in increased symbolic performance, which positively influences substantive performance such as financial performance. In case of the fit between the company's technical core and adopted template-related goals and practices, the company enjoys additional benefits in the form of increased operational performance, which also contributes positively to substantive performance. For example, JIT manufacturing practices fit with companies employing high-volume, repetitive manufacturing processes (Sousa and Voss 2008). JIT practices could be adopted by an organization that produces low-variety and unique products. Such companies may benefit from the increased symbolic performance, but not because of increased operational performance. In this book, we have analyzed three templates—adoption of each result in the unique performance dimensions. In the next paragraph, we summarize whether template-related performance dimensions increase financial performance. The results of the modeling initiated to reveal which template-related performance dimensions contribute to increased financial performance are presented in Table 8.6.

The analysis reveals that one of two performance dimensions associated with the lean template—quality—positively impacts revenue growth. Our results also reveal that agile template-related innovation performance dimension also has a positive impact on revenue growth. However, service performance does not predict an increase in financial performance. Finally, we have found that digitalization performance positively contributes to the productivity of the companies.

The empirical assessment of lean, agile, and service-oriented performance dimensions' effect on financial performance allows several contributions to lean, agile and servitization literature. First, the findings provide insights into whether performance dimensions associated with lean, agile, and service-oriented templates result in increased financial performance. Second, the efforts provide insight that service performance do not result in increased financial performance, though the measurement approach used in this book has deficiencies. Third, we could associate digitalization performance with increased productivity of the company.

The findings reveal that quality, innovation, and digitalization performance are associated with increased financial performance. First, we have identified the cost performance as differentiating competitive performance dimension of companies that adopt the lean template in this book. We continuously avoided using quality performance dimension as an indicator of adherence to the lean template. Which company would claim it does not seek product quality? However, the adherence to the lean template results in multiple benefits, among which could be increased

Table 8.6 The impact of template-related performance dimensions on financial performance

	Revenue growth	Profit	Revenue per employee	Revenue growth	Profit	Revenue per employee	Revenue growth	Profit	Revenue per employee
Cost	0.078	−0.080	0.038						
Quality	**0.160***	0.087	−0.017						
Flexibility				0.005	0.026	0.148			
Innovation				**0.257****	0.017	0.055			
Delivery				0.074	0.088	−0.080			
Services							0.004	0.061	0.059
Digitalization							0.001	−0.094	**0.170****
No. Obs.	169	214	170	170	214	171	226	292	228
R^2	0.037	0.010	0.001	0.077	0.012	0.027	0.000	0.009	0.036
R^2 Adj.	0.025	0.001	−0.010	0.060	−0.002	0.010	−0.009	0.002	0.027

quality performance. Our findings show that cost performance dimension does not increase financial performance. At the same time, the quality performance can facilitate revenue growth. Earlier, we have expressed doubts about whether adherence to the lean template increases symbolic performance. It is possible that lean practices can contribute to quality operational performance, which later facilitates increased financial performance. Thus, additional research on whether and which lean template-related performance dimensions contribute to increased financial performance is warranted. Second, our findings allow associating agile template-related innovation performance with revenue growth. Interestingly, we revealed that innovation was neither sought nor possessed widely by companies. Such findings are in line with studies that emphasize the importance of innovation capabilities (Peng et al. 2008; Nair and Boulton 2008; Narasimhan and Schoenherr 2013; Vilkas et al. 2021c). Third, our findings reveal that service performance does not predict increased financial performance. Further, we consider why we have failed to associate the service performance with the increased financial performance, despite previously we have proposed that adherence to a Service-oriented template could be a source of increased symbolic performance. Several arguments could explain such findings. Other servitization studies showed that product support services were not associated with increased financial performance (Gebauer et al. 2011). Customers tend to treat such services as part of the product, and providers fail to generate additional revenue from product support services. Further, servitization scholars provide empirical evidence that the relationship between advanced customer support services and financial performance is not linear (Kohtamäki et al. 2020; Brax et al. 2021). The initial investment into the provision of customer support services results in increased performance which later declines. The development of service customization, outcome-based sales, and other advanced customer support services-related capabilities requires extensive resources. Eventually, only companies that develop "extensive service portfolio, high service turnover, separate service organization, high managerial service orientation and high organizational relational capabilities" can achieve high sales and profitability (Brax et al. 2021, p. 537). Our measure of service performance is unable to capture such a nuanced picture. We used summated service performance scales, including product support and customer support services. This approach allows measuring general service performance, but the previous research revealed that this could not be enough to capture complex relations between servitization and substantive performance.

Finally, our findings reveal that digitalization performance positively affects revenue per employee. The revenue per employee characterizes the company's productivity level. Such findings contribute to accumulating empirical evidence that digitalization facilitates firm's productivity. For example, Gilbert et al. (2021) have found that the employment of ICT specialists and the use of digital technologies improve a firm's labor productivity by about 23% and its total factor productivity by about 17%. Kharlamov and Parry (2021) suggest that digitized and servitized firms show greater productivity than not digitized and servitized ones. In summary, using a representative sample of manufacturing companies in a country, we reveal that quality and innovation contribute to the growth of revenues. At the same time, we additional provide empirical evidence that digitalization is associated with an increase in the productivity of manufacturing companies.

8.5 Balancing Templates for Increased Financial Performance

After revealing that templated-related performance dimensions in isolation can be associated with increased financial performance, we initiated an empirical test to reveal if balancing performance capabilities could positively affect financial performance. Drawing on the ambidexterity theory (Raisch and Birkinshaw 2008; O'Reilly and Tushman 2013), we have proposed that companies' efforts focused on balancing lean and agile-associated performance capabilities are associated with superior performance. Lean-related performance dimensions of quality and cost contribute to the exploitation which is associated with efficiency and reliability (Farjoun 2010; Vilkas et al. 2021b). Agility-related performance dimensions of flexibility and innovativeness contribute to the exploration which is associated with search, experimentation, and introduction of newness (Farjoun 2010; Vilkas et al. 2021b). According to ambidexterity theory, both efficiency and innovativeness are essential for the survival of the company in the long run. We initiated two empirical tests to falsify the ambidexterity proposition. First, following Venkatraman (1989), we assessed whether the balance of performance dimensions associated with lean and agile templates predicts superior financial performance. We used two measures of financial performance: profit and sales revenue growth rate. Further, we applied *Deviation score* and *Fit as a profile deviation* approaches to check the hypotheses stating that possession of lean and agile-associated performance dimensions is characterized by superior financial performance. The Deviation score approach conveys that the absolute difference in scores of two variables indicates a misfit between the variables of the domain of interest. Then, the performance variable is regressed on misfit to test the misfit's performance implications between agile and lean capabilities. The Fit as a profile deviation approach proposes that the organizations which exhibit high levels of lean-associated cost performance and Agile-associated innovation and flexibility performance simultaneously demonstrate better performance outcomes. We took 10% of the organizations with the highest revenue growth rate and calculated their average cost, innovation, and flexibility scores. The same was done for the highest profit category. The new variable (deviation from the high-performance profile) was computed. The deviation from the high-performance profile was then used in the linear regression model with profit as the dependent variable. *Fit as a profile deviation* approach failed to achieve statistically significant conclusions. The *Deviation score* approach, however, provided unexpected insights. Contrary to expectations, misfit was found to be positively and significantly related to the revenue growth rate. Such findings reveal that

Table 8.7 Relationship between performance dimensions

	Digitalization	Quality	Delivery	Flexibility	Cost	Innovation	Services
Digitalization	1.00						
Quality	0.126	1.00					
Delivery	0.103	**0.459****	1.00				
Flexibility	**0.150***	**0.341****	**0.329****	1.00			
Cost	**0.228****	**0.255****	**0.362****	**0.305****	1.00		
Innovation	**0.374****	**0.417****	**0.342****	**0.409****	**0.453****	1.00	
Services	**0.433****	0.106	0.005	−0.156	0.155	0.119	1.00

Spearman correlation, pairwise; **. Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

contrary to the ambidexterity proposition, companies that excel at cost or flexibility and innovation performance exhibit a higher level of sales growth.

Relying on our findings, we propose that companies should adhere to a single template if they want to increase symbolic and operational performance. A company can be lean, agile, or service-oriented, but we discourage claiming to become a lean-agile or lean-agile-service-oriented company. Being known as a lean company does not preclude the possibility of developing agile-related flexibility and innovation performance dimensions. Even more, the research shows that innovative companies such as Toyota achieve unprecedented innovations without stopping being role models for lean (e.g., Adler et al. 2009). Our analysis reveals that competitive performance dimensions reinforce each other (Table 8.7).

Quality and cost performance dimensions associated with the lean template correlate positively. Agile-related performance dimensions also correlate positively. Interestingly, the service performance dimension correlates only with digitalization, which suggests that the companies that adhere to the service-oriented templates must rely heavily on digital innovations. However, quality and cost performance are also related positively to flexibility, innovation, and delivery performance dimensions associated with the agile template. Such findings reveal that lean and agile template-related performance dimensions are compatible. The results show that digitalization positively relates to all performance dimensions except quality and delivery performance. This makes digitalization capability overall a beneficial trait. Despite such complementarity, our results reveal that 33.2% of companies have not yet mastered any superior competitive performance dimension in relation to other companies. 26.6% of companies have mastered one performance dimension, while 40.2% have already possessed more than one capability.

In the book's last chapter, we reviewed our results and discussed the theoretical implications of our findings. In this book, we characterized the emerging service-oriented organizing template in relation to already established lean and agile templates. Further, we revealed the prevalence of lean, agile, and service-oriented templates-related competitive orientations, practices, and competitive performance capabilities. Finally, we empirically assessed how lean, agile, and service-oriented practices contributed to operational performance and whether the performance capabilities contributed to manufacturing firms' financial performance. We expect that our efforts to characterize lean, agile, and service-oriented templates of organizing using the neo-institutional perspective contributed to lean, agile, and servitization literature and provided tangible insights for production companies' managers.

Annex 8.1 Measurement Scales[1]

Measurement of Competitive Priorities

Please rank the following competitive factors in order of significance to distinguish your factory positively from competitors.

Please rank from 1 to 6, 1 indicating "the most important." Please do not assign equal importance to any factors.

- Product price
- Product quality
- Innovative products
- Customization to customers' demands
- Delivering on schedule/short delivery times
- Services

Measurement of Organizational Characteristics

Which of the following characteristics best describes your main product or line of products?

Product Development

Please tick one box only.

- According to customers' specification.
- As a standardized basic program incorporating customer-specific options.
- For a standard program from which the customer can choose options.
- Does not exist in this factory.

[1] European manufacturing survey scales (EMS 2022).

Batch or Lot Size

Please tick one box only.

- Single unit production
- Small or medium batch/lot
- Large batch/lot

Manufacturing

Please tick one box only.

- Upon receipt of customer's order, i.e., made-to-order.
- Final assembly of the product is carried out upon receipt of customer's order, i.e., assembly-to-order.
- To stock (before customer's order).
- Does not exist in this factory.

Product Complexity

Please tick one box only.

- Simple products
- Products with medium complexity
- Complex products

Measures of Lean Methods

Which of the following organizational concepts are currently used in your factory? 0—No; 1—Yes.

If Yes, what is the extent of the used potential of the method? 1—Low; 2—Medium; 3—High.

(Extent of the used potential—Extent of actual utilization compared to the most reasonable maximum potential utilization in your factory: Extent of the utilized potential "low" for an initial attempt to utilize, "medium" for partly utilized, and "high" for extensive utilization.)

- Standardized and detailed work instructions (e.g., standard operation procedures SOP, MOST).

- Measures to improve internal logistics (e.g., Value Stream Mapping/Design, changed spatial arrangements of production steps);
- Fixed process flows to reduce setup time or optimize change-over time (e.g., SMED, QCO).
- KANBAN, Internal zero-buffer principle.
- Customer- or product-oriented lines/cells in the factory (instead of task-/operation-structured shop floors).
- Detailed regulations on the arrangement and setting of the work equipment and storage of intermediary products (e.g., Method of 5S).
- Decreasing the time of equipment downtime (Total Productive/Preventive Maintenance).
- SPC, process capability analysis.
- Display boards in production to illustrate work processes and work status (e.g., Visual Management).
- Involvement of employees into improvement (e.g., A3, KAIZEN, and PDCA).
- Integration of tasks (planning, operating, or controlling functions with the machine operator).
- Involvement of customers into production (e.g., sharing demand information and joint product development)
- Inventory managed by suppliers, exchange of cost structure information.
- Collecting supplier feedback (e.g., sharing information on quality and delivery problems).

Measures of Digital Innovations

Which of the following technologies are currently used in your factory? 0—No; 1—Yes.

If Yes, What is the extent of the used potential of the method? 1—Low; 2—Medium; 3—High. Extent of used potential—Extent of actual utilization compared to the most reasonable maximum potential utilization in your factory: Extent of utilized potential "low" for an initial attempt to utilize, "medium" for partly utilized and "high" for extensive utilization.

- Mobile/wireless devices for programming and controlling facilities and machinery (e.g., tablets).
- Digital solutions to provide drawings, work schedules, or work instructions directly on the shop floor.
- Software for production planning and scheduling (e.g., ERP system).
- Digital Exchange of product/process data with suppliers/customers (Electronic Data Interchange EDI).
- Near real-time production control system (e.g., Systems of centralized operating and machine data acquisition, MES).

- Systems for automation and management of internal logistics (e.g., Warehouse management systems, RFID).
- Virtual Reality or simulation for product design or product development (e.g., FEM, Digital Prototyping, computer models).
- Industrial robots for manufacturing processes (e.g., welding, painting, and cutting).
- Industrial robots for handling processes (e.g., depositing, assembling, sorting, packing processes, and AGV).
- 3D printing technologies for prototyping (prototypes, demonstration models, and 0 series).
- 3D printing technologies for manufacturing of products, components and forms, tools, etc.

Measures of Services

Which of the following product-related Services do you offer your customers? 0—No; 1—Yes.

- Installation, start-up
- Maintenance and repair
- Training
- Remote support for clients (e.g., User Helpdesk and web platform)
- Design, consulting, project planning (incl. R&D for customers)
- Software development (e.g., software customization)
- Revamping or modernization (including enhancement of functions and software extensions)
- Take-back Services (e.g., recycling, disposal, and taking back)

Which of the following digital solutions do you offer as part of your Service portfolio? 0—No; 1—Yes.

- Web-based offers for product utilization (online training, documentation, error description).
- Web-based Services for customized product configuration or product design (development).
- Digital (remote) monitoring of operating status (e.g., condition monitoring).
- Mobile devices for diagnosis, repair, or consultancy (e.g., digital camera, smartphone, and tablets).
- Data-based Services based on big data analysis.

Which of the following business models do you offer your customers? 0—No; 1—Yes.

- Renting products, machinery, or equipment.
- Full-service contracts with a defined scope to maintain your products.

- Operation of your own products at customer site/for the customer (e.g., pay on production).
- Taking over the management of maintenance activities for the customer in order to guarantee availability or costs.

Measurement of Operational Performance

Indicate how well your factory performed compared to its competition within your industry along these different performance dimensions, 1—Much worse, 2—Somewhat worse, 3—About the same, 4—Somewhat better, 5—Much better, 6—I don't know.

Quality

- Product overall quality performance
- Product reliability
- Product features
- Product conformance
- Product durability

Cost

- Unit cost
- Manufacturing overhead cost
- Inventory turnover

Flexibility

- Ability to adjust production volumes
- Ability to respond to changes in delivery requirements
- Ability to customize products
- Ability to produce a range of products
- Speed of new product introduction into the plant

Delivery

- Delivery accuracy
- Delivery dependability
- Delivery quality
- Delivery availability
- Delivery speed

Innovation

- Lead time to introduce new products
- Number of new products introduced each year
- The extent of innovativeness of products

Service

- Regular products support services
- Online product support services
- Advanced service provision models
- Data-driven services

Digitalization

- Digitalization of production data
- Connection production system elements
- Autonomous production data collection and analysis
- Automation of production processes

Measures of Financial Performance

Please characterize your factory:

- Annual turnover

  In 2017 XX million €
  In 2015 XX million €

– Number of employees

In 2015 XX number
In 2015 XX number

– Return on sales (before tax, 2017)

Negative
0 up to 2%
>2 up to 5%
>5 up to 10%
>10%

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