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Replication and comparative analysis of instrument of manufacturing capabilities in a different context: the Brazilian case

Replicação e análise comparativa de instrumento de capabilities da manufatura em um contexto diferente: contexto brasileiro

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Abstract: Managers of organizations have few tools to evaluate manufacturing capabilities. Such scarcity implies in a greater difficulty to generate or maintain sustainable competitive advantages over competitors. This study aims to replicate the instrument developed by Jain et al. (2014) for the evaluation of manufacturing capabilities and analyze the results in the Brazilian business and cultural contexts. The instrument was translated into Portuguese using back-translation. After this, was performed a pre-test to verify understanding and clarity, then the instrument was distributed electronically. For data analysis, reliability analysis, face validation method, content validation, multiple regression analysis and factor analysis were performed. Subsequently, the results were compared with those of the work by Jain et al. (2014). Additionally, an exploratory factor analysis was performed to verify the convergent validity of the work. Statistical results were not adequate to validate the instrument in its current format, which requires improvements for it to be applied as a manufacturing capabilities assessment method in Brazil. The reliability index was adequate in approximately half of the instrument questions. As for multiple regression analysis, the results were not satisfactory. In addition, this research performed an exploratory factor analysis. Inconsistencies were identified. From ten expected factors, only four were obtained and had a low reliability index. These results contributed to the improvement of the instrument developed by Jain et al. (2014). It will be possible to take into account the results obtained in this study for implementations of statistical improvements and to observe questions that need to be changed in order to actually represent the 10 manufacturing decision areas of Hayes et al. (1988). Thus, it is necessary to conduct further studies and make improvements to make it a valuable tool for manufacturing.

Keywords: Manufacturing strategy; Replication; Back-translation; Exploratory factor analysis; Multiple regression analysis; Evaluation of manufacturing.

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Resumo: Os gestores das organizações possuem poucas ferramentas para avaliar as *capabilities* da manufatura. Essa escassez implica em uma maior dificuldade para gerar ou manter vantagens competitivas sustentáveis frente aos concorrentes. Este trabalho tem por objetivo replicar o instrumento de Jain et al. (2014) para avaliação das *capabilities* da manufatura e analisar os resultados no contexto empresarial e cultural brasileiro. O instrumento foi traduzido para português utilizando o método *back-translation*. Após isto, foi executado um pré-teste para verificação da clareza e compreensão, em seguida o instrumento foi distribuído eletronicamente. Para a análise dos dados, foram realizadas análises de confiabilidade, método de validação de face, validação de conteúdo, análise de regressão múltipla e análise fatorial. Posteriormente, os resultados foram comparados com o trabalho de Jain et al. (2014). Adicionalmente, foi realizada uma análise fatorial exploratória para verificar a validade convergente do trabalho. Os resultados estatísticos obtidos não foram adequados para validar o instrumento em seu formato atual, que necessita de aperfeiçoamentos para que seja aplicado como método de avaliação de *capabilities* de manufatura no Brasil. O índice de confiabilidade esteve adequado em, aproximadamente, metade das questões do instrumento. Quanto à análise de regressão múltipla, os resultados não foram satisfatórios. E, adicionalmente esta pesquisa executou a análise fatorial exploratória, com baixo índice de confiabilidade. Esses resultados contribuíram para o aprimoramento do instrumento desenvolvido por Jain et al. (2014). Será possível levar em consideração os resultados obtidos neste estudo para implementações de melhorias estatísticas e observar questões que precisam ser alteradas para realmente representar as 10 áreas de decisão de manufatura de Hayes et al. (1988). Portanto, é necessário realizar novos estudos e executar melhorias para torná-lo uma ferramenta valiosa para a manufatura.

Palavras-chave: Estratégia de manufatura; Replicação; *Back-translation*; Análise fatorial exploratória; Análise de regressão múltipla; Avaliação da manufatura.

1 Introduction

The literature on operations and manufacturing strategy has greatly evolved in the last fifty years. From the seminal work by Skinner (1969) to the recent work by Slack & Lewis (2010), Dombrowski et al. (2016), Cherra et al. (2017) and Shao (2020), operations and manufacturing strategy provided the basis for an understanding about how companies should make their decisions to improve competitive advantage. Among the ideas developed by many scholars, the concept of manufacturing capabilities seems to represent building blocks for operations strategy because they can be seen as elements through which companies implement their strategies. For the purposes of this article, capabilities are defined as the ten manufacturing decision areas according to Hayes et al. (1988), namely, capability, facilities, process technologies, vertical integration/vendors, human resources, quality, production planning/materials control, new products development, performance measurement and reward, organization/systems.

To collaborate with such literature, Jain et al. (2014) developed an instrument that aims to support managers in identifying and assessing strengths and weaknesses of manufacturing capabilities individually in each decision area. This instrument seeks to address the lack of reliable tools for the assessment and measurement of capabilities (Jain et al., 2014; Lekurwale et al., 2015; Maldaner & Kreling, 2019; Mousavi et al., 2007). Moreover, the work by Jain et al. (2014) explores the relation between manufacturing capabilities and production competence. Their study was the first to propose a measurement instrument directly related to manufacturing capabilities.

However, the study by Jain et al. (2014) must be subjected to replications in order to improve its level of validation. Similar results must be found in different contexts to provide evidence that the measurements capture the same phenomena even if applied to other areas. Thus far, a few studies mentioned the work by Jain et al. (2014) but none replicated their working method (Guo et al., 2015; Jain et al., 2016; Vivares-Vergara et al., 2015). Based on that work, we propose the following questions: Does the instrument proposed by Jain et al. (2014) to measure manufacturing capabilities present a valid and reliable result in a context different from that originally analyzed by its authors? Is it possible to replicate the work by Jain et al. (2014) and obtain similar results in terms of validity and reliability of manufacturing capabilities? How the relation between manufacturing capabilities and production competence occur in another context?

In addition, the increasing development of industry, shows a high amount of data to be managed as well as simulations of different scenarios to support decision making and system operation (Mourtzis, 2020). Every decision-making process requires reliable information about the system (production capacity, failures, etc.) and the environment (demand, subcontracting, etc.) (Assid et al., 2020). Decision making is based on requirements management, between the productive sector and the restrictions imposed by the production capacity (Dolgov et al., 2020).

However, despite organizations being globally connected, decision makers are exposed to different factors in their respective local contexts. Decision-makers have their unique interpretations of the environment, being also impacted by the information they have and the time available for decision making (Gylling et al., 2015; Maynard et al., 2020). In addition, global businesses use financial metrics on detriment of strategic value, thus impacting the decision making (Nujen & Halse, 2017). In view of the above, it's inferred that the context in which decision-making is being defined influences the decision, thus, evaluating the present questionnaire in a context other than the initial one has theoretical implications.

Therefore, the first objective of this study is to assess the psychometric properties of the instrument developed by Jain et al. (2014) to evaluate manufacturing capabilities in the context of an emerging country. Specifically, we will evaluate the validity and reliability of constructs that address manufacturing capabilities as proposed by Jain et al. (2014). The second objective of this study is to evaluate the relation between manufacturing capabilities and production competence as perceived by employees and managers of manufacturing companies.

Finding the answer for these questions may help us to determine whether an instrument to measure manufacturing capabilities is able to correctly capture the perception of managers on the company's capabilities to manufacture products. Such an instrument is relevant because it can operationalize part of the manufacturing strategy tenets discussed in the literature.

If the proposed instrument is valid and reliable, then such instrument may be used by scholars and managers to capture the perception of manufacturing practitioners. The main contribution of this article is to show that 4 of the 10 dimensions proposed in the measured measuring instruments were shown to be consistent, whereas 6 dimensions show that they still need improvements for application in other contexts. In addition, improvements are suggested in the instrument developed by Jain et al. (2014).

This paper is organized as follows. In section literature review, the following topics are presented: operations strategy and competitive criteria, manufacturing decision areas, resources and capabilities in strategies of organizations, and measurement of capabilities. Then, the working method is described, i.e., the way this research was developed: methodology, adaptation of the instrument to Brazil, instrument pre-test, distribution and collection of data, statistical analyses and analysis of results. In the analysis results section, the study presentation and the data analysis are discussed. Finally, the conclusion presents a summary of results, limitations, criticism, suggestions for improvement and suggestions for future studies.

2 Literature review

2.1 Operations strategy and competitive criteria

Slack & Lewis (2009) define operations as a resource and process management that results in the delivery of goods and services. Strategy means decisions, mostly long-term, defining a path to be taken and achieving an overall target through overall objectives (Slack & Lewis, 2009). Lowson (2002) states that operations strategy involves strategic decisions focused on the system as a whole in the medium and long term. It can also be defined as the organization's goals and policies to obtain an advantage over competitors and to maximize the performance of manufacturing (Skinner, 1969, 2007). The strategy must be clear and widespread among managers, as it evidences the mission, the vision of the company and its short and long-term goals (Galbraith et al., 2011; Eidelwein et al., 2018a).

Strategy operations can be defined as a pattern of decisions focused on the organization as a whole, including core resources, skills and capabilities (Lowson, 2002, 2003; Szwejczewski et al., 2016). Such choices tend to be medium or long-term choices, evaluating existing technologies, product design strategy, skills and capabilities and resulting in a sustainable competitive advantage (Soosay et al., 2016; Lowson, 2003; Nunes et al., 2015; Piran et al., 2020; Mansilha et al., 2019). Technological investments carried out in conjunction with actions related to continuous improvement can contribute significantly to increase the of operational efficiency of the organization (Souza et al., 2018), as well as the use of other manufacturing systems or strategies (Camargo et al., 2018; Eidelwein et al., 2018b; Kasemsap, 2015; Piran et al., 2020; Sieckmann et al., 2018; Telles et al., 2020; Thürer & Stevenson, 2018; Zhu & Li, 2018).

Operations strategy, according to Hayes et al. (2004), means the set of goals, restrictions and policies that indicate how the organization will use and improve its operations. Lowson (2003) presents some questions that should be taken into account in operations strategy, such as capabilities needed for the future, necessary resources, necessary skills, quality levels, specific products and services, among others. Senior management should be responsible for a manufacturing strategy consistent with other policies also supporting the corporate strategy (Skinner, 2007). The operations strategy is formulated with performance objectives connected to its decision areas, playing an important role in the business competitive strategy due to the connection between the performance indicators and the company's objectives (Okoshi et al., 2019).

Competitive criteria, in turn, can be regarded as "[...] what a manufacturer wants to emphasize in terms of future improvements to achieve or maintain its competitive edge" (Thürer et al., 2014, p. 1177). It may be related to plant performance in relation to competitors (Bott, 2014). Used to define operations strategy (Lee, 2012; Skinner, 1969), competitive criteria are cost, quality, reliability, speed, delivery, innovation and flexibility (Bott, 2014; Slack, 2002; Thürer et al., 2014; Wheelwright, 1984). Most companies need to make several decisions in various sub-areas to achieve or implement the desired strategy (Wheelwright, 1984). Therefore, organizations must change strategies (policies) related to manufacturing to remain focused on their goals over time (Brumme et al., 2015).

However, during the implementation of operations strategies, trade-offs arise and must also be taken into account (Boyer & Lewis, 2002). The concept of trade-off, proposed by Skinner (1969), means that the manufacturing of a particular company should focus on a single competitive priority at a time because it is not possible to obtain a significant performance in more than one priority at a same time.

Boyer & Lewis (2002) state that trade-off studies conducted in a plant should focus on the company's strategic objectives and thereby improve the manufacturing capabilities related to such goals (strategic objectives). Other studies suggest that capabilities or competitive priorities are developed over time. First, they are excellent bases for quality, secondly for delivery, thirdly for costs, and then for flexible capabilities, in addition, other research highlights the importance of assessing attributes before trade-offs occur (Eidelwein et al., 2018b; Hussain et al., 2015; Li, 2000; Teixeira & Paiva, 2008).

2.2 Manufacturing decision areas

In a manufacturing process, there are several subsystems called "decision areas" classified into two groups: structure and infrastructure (Choudhari et al., 2012b; Jain et al., 2014; Slack & Lewis, 2009). Human resources, planning and control of production, and internal organization are examples of infrastructure decisions. Technology and facility processes are examples of structural decisions (Choudhari et al., 2010; Kasie et al., 2017). Miltenburg (2005) states that manufacturing decision area is directly related to the manufacturing and to the development of manufacturing capabilities since decisions made directly affect the production system. Operations strategy involves a series of decisions distributed into manufacturing areas. Table 1 shows the manufacturing decision areas according to four studies.

Table 1. Manufacturing decision areas according to four authors.

1. Hayes et al. (1988)	2. Skinner (1969)	3. Miltenburg (2005)	4. Slack & Lewis (2008)
1. Capacity	1. Plant and equipment	1. Human resource	1. Capacity
2. Facilities	2. Product design engineering	2. Organization structure	2. Process technologies
3. Process technologies	3. Labor and staffing	3. Sourcing	3. Supply network
4. Vertical integration/vendors	4. Production planning and control	4. Production planning and control	4. Organization and development
5. Human resources	5. Organization and management	5. Process technologies	
6. Quality		6. Facilities	
7. Production planning/materials control			
8. New product development			
9. Performance measurement and reward			
10. Organization/systems			

Source: Jain et al. (2014, p. 2092).

As noted, Hayes et al. (1988) established a higher number of categories. This is the model used in this work. However, there are studies that use categories common to two or more of these four authors, or the decision areas determined by Miltenburg (2005) (Choudhari et al., 2012a, 2013a; Vivares-Vergara et al., 2014). Table 2 shows the conceptual definitions of each of the ten decision areas developed by Hayes et al. (1988).

Table 2. Definitions for manufacturing decision areas.

Item	Description	Concept
A1	Capacity	Awareness on the capacity and changes thereof in relation to the demand, for companies should have an installed capacity greater than that required to meet the extra demand at certain times. Such availability may attract new customers or increase market share, resulting in competitive advantage.
A2	Facilities	Smaller companies tend to opt for generic facilities, thereby reducing costs and maximizing flexibility. However, larger companies tend to have more specific facilities in order to obtain a competitive advantage in a given market in addition to reducing their production costs.
A3	Process technologies	Companies should develop and research new technologies to improve current and future products. This will also help the company to remain competitive. This is due to the fast-technological changes taking place in today manufacturing. With the increasing development of organizations, they should invest in key technologies for manufacturing, resulting in unique advantages provided by this capability.
A4	Vertical integration/vendors	One way to obtain a strategic market advantage is vertical integration (downstream and upstream). The company will decrease its dependence on and insecurity of external resources.
A5	Human resources	Larger companies tend to consider their employees as resources capable of solving problems; organizations develop their capabilities. However, smaller companies consider their employees as problems and constraints. However, the employees of a company should be considered as a source of information and ideas for the improvement of the production system, encouraging them to give suggestions.
A6	Quality	Aims to improve product performance by eliminating problems, thus keeping the product reliable and meeting customer expectations. It should be also continuously developed to increase customer satisfaction.
A7	Production planning/materials control	Synchronized planning is found in larger companies. In smaller companies, there are fast changes usually to accommodate an uncertain demand. It should also involve different sectors of the company, such as marketing, production, purchasing, production control, among others.
A8	New product development	Most large companies tend to have a greater integration between sectors, which results in a faster launch of new products in the market. This integration between departments is also used in the development of new products.
A9	Performance measurement and reward	Organizations seek to equally focus on performance and individual contribution. However, with the company's increasing size, it tends to focus more on the performance as a whole.
A10	Organization/systems	Larger organizations need to integrate sectors and coordinate activities between departments. This helps them to produce products more easily because, as mentioned earlier, they have facilities focused on gaining a competitive advantage in a given market.

Source: Jain et al. (2014, p. 2094~2095).

As seen in Table 1, each of the four authors established different manufacturing decision areas. In Table 3, a correlation is made between the decision areas established by the authors Hayes et al. (1988), Skinner (1969), Miltenburg (2005) and Slack & Lewis (2008).

Table 3. Correlation of manufacturing decision areas based on the research by Hayes et al. (1988).

Manufacturing decision areas in the view	Capacity (A1)	Facilities (A2)	Process technologies (A3)	Vertical integration/ vendors (A4)	Human resources (A5)	Quality (A6)	Production planning/ materials control (A7)	New product development (A8)	Performance measurement and reward (A9)	Organization/ systems (A10)
Skinner (1969)	Plant and equipment (A1, A2, A4)	Plant and equipment (A1, A2, A4)	Product design engineering (A3, A8)	Plant and equipment (A1, A2, A4)	Labor and staffing (A5)	Production planning and control (A6, A7)	Production planning and control (A6, A7)	Product design engineering (A3, A8)	Organization and management (A9, A10)	Organization and management (A9, A10)
Miltenburg	Facilities (A1, A2)	Facilities (A1, A2)	Process technologies (A3, A6)	Sourcing (A4)	Human resource (A5)	Process technologies (A3, A6)	Production planning and control (A7, A8)	Production planning and control (A7, A8)	Organization structure (A9, A10)	Organization structure (A9, A10)
Slack &	Capacity (A1, A2)	Capacity (A1, A2)	Process technologies (A3)	Supply network (A4)	Organization and development (A5 - A10)	Organization and development (A5 - A10)	Organization and development (A5 - A10)	Organization and development (A5 - A10)	Organization and development (A5 - A10)	Organization and development (A5 - A10)

Source: Adapted from Jain et al. (2014). Note: There may be repetitions, as some authors establish fewer decision areas than Hayes et al. (1988).

Senior management must be aware of the impact of its decisions on the organization's strategy (Choudhari et al., 2013b). This is why the company needs to assess its capabilities and verify measurement methods.

2.3 Capabilities and measuring instruments

Capabilities are present at the basis of the competitive advantage of a company. Therefore, managers must know where to use them and recognize their importance to the organization (Gohr et al., 2014; Hitt et al., 2011). Capabilities as subsets of organization resources, i.e., they allow companies to use their resources to create and implement strategies, also contributing to obtain a competitive advantage (Barney & Hesterly, 2011; Iqbal et al., 2020). Grant (1991) capability as the overall result obtained by the company's resources. According to Breznik & Lahovnik (2016), the most relevant capabilities are management, marketing, technology, research and development, innovation and human resources. Manufacturing capability, in turn, is defined as the level of production output generated by the system which will define market competitiveness (Lekurwale et al., 2015). It may also be defined as the company's leverage to support organizational success through its manufacturing (Tan et al., 2007).

Capabilities, together with resources, are the core competence of companies (Boguslauskas & Kvedaraviciene, 2009; Ferreira & Garrido Azevedo, 2008). Core competences can be regarded as a technical management system used by the organization to create competitive advantages. It can also be defined as capabilities critical to ensure the continuity of a company that seeks to improve or develop competitive advantages (Sun, 2013).

Clearly defined and properly executed competitive criteria result in operation capabilities, resulting in positive results. This return to the organization confirms the strategic objectives, increasing competitive advantage. In the long run, expertise in manufacturing is developed, enabling seeking wider strategic goals (Tan et al., 2007). As noted, capabilities enable several advantages to organizations, therefore the importance of measuring capabilities.

A better capability provides lasting competitive benefits for an organization (Jain et al., 2014). The objectives of measuring capabilities are to reduce operation response time upon starting the production of a new item, to develop a flexible manufacturing system and to result in greater benefits due to a proper allocation of a certain resource (Baker & Maropoulos, 1998). Table 4 shows, from a systematic literature review, a survey of studies and identified tools to measure capabilities in addition to study objectives, contributions, justifications and limitations.

Table 4. Examples of measurement capabilities - objectives, contributions, justification and limitations.

Authors	Objective	How	Contribution	Justification	Limitations
Lekurwale et al. (2015)	Evaluate manufacturing capabilities based on a multi-criteria decision tool.	Tool based on analytical hierarchy process (AHP).	Evaluate capabilities and indicate which decision areas should be improved, in addition to increasing the competitiveness and the efficiency of the industry.	Structural or infrastructural decisions directly affect production capability. This is extremely important to obtain information on global production capacity and how much each decision affects a capability. These factors directly affect competitiveness in the market.	It is necessary to validate the model for different manufacturing systems. This enables the identification of ideal characteristics for each system.
Jain et al. (2014)	Tool to evaluate manufacturing capabilities.	Tool based on a questionnaire containing 25 questions.	Evaluate manufacturing capabilities and identify the strengths and weaknesses of the organization resulting in improvements in areas related to capabilities.	At certain times, it is not the financial superiority of the product, among other reasons, which results in a better performance in the market. But a higher capability provides lasting competitive benefits to an organization, in addition to not being easily duplicated.	According to the authors, this study was conducted for the first time. It is necessary to replicate it with a larger sample and population.
Al-Refaie (2012)	Evaluate the capabilities of a measuring system and manufacturing process simultaneously.	Tool based on tabular algorithm.	Provide information to determine which activities should be improved.	Increased attention to the evaluation of manufacturing capabilities.	Future works should make a direct comparison between tabular algorithm and analysis of variance (ANOVA).
Mousavi et al. (2007)	Evaluation of the capabilities of a manufacturing system.	Tool based on analytical hierarchy process (AHP) and fuzzy relations.	Generate a capabilities index to enable a comparison of companies competing in a same area.	This index will allow the comparison of capabilities between industries or generate a ranking of systems, services or technologies.	Future research should identify specific factors for each capability. It is also necessary to perform a sensitivity analysis to relate the impacts of changes in capabilities to these factors.
Hum & Leow (1996)	Tool for manufacturing system audits.	Tool based on a survey based on the framework of Hayes-Wheelwright (HW).	Evaluate the system under study in addition to allowing the creation of a benchmark.	Through audits, generate advantages over competitors. This is because it is possible to perform specific comparisons using the benchmark of operations in addition to providing a better analysis of the company's strategy.	Future studies may expand this tool to meet specific applications (customize).

Source: Prepared by the authors (2021).

The tool developed by Jain et al. (2014) was selected for this work because, to date, it has been applied only once. It is also a recent and relevant study for global contexts.

2.4 Production competence

The calculation of production competence (PC) is used to explain the relation between manufacturing strategy and business performance (Szász et al., 2015). As conducted by Jain et al. (2014), this research will perform the calculation of production competence (PC) using the expression suggested by Vickery et al. (1993). This is because this study considers importance and productivity as competitive dimensions (cost, quality delivery, flexibility and innovation). However, Szász et al. (2015) state that the concept used by Vickery et al. (1993) is not the most appropriate. It is necessary to assess the complex relation existing among variables. However, the method performs only a simple combination (Szász et al., 2015).

Based on the concepts presented, it is possible to verify the importance of operations strategy and its impact on strategic decisions. Therefore, it is important that companies are able to measure their capabilities (in this article, the ten manufacturing decision areas according to Hayes et al., 1988) to obtain competitive advantages. In the next topic, the methodological conduction this work will be explained, positioning it in relation to different existing perspectives. Future research in similar contexts or its replication elsewhere is necessary.

3 Research method

3.1 Identification and translation of the evaluation tool

The instrument developed by Jain et al. (2014) to assess manufacturing capabilities consists in closed multiple choice questions, facilitating data analysis due to their objectivity (Dresch et al., 2015). Because the instrument developed by Jain et al. (2014) was applied only once, this work replicated it. A study can be replicated when it allows possible evaluations in different situations such as locations, different languages, among others (Mackey, 2012).

For this, the instrument for evaluating manufacturing capabilities developed by Jain et al. (2014) was translated into Portuguese using back-translation, which is the method most used to verify the accuracy of translations in research (Agrela et al., 2020; Chen & Boore, 2010; Douglas & Craig, 2007; Güneş & Bahçivan, 2018; Rocha, 2010; Rocha et al., 2013; Vaibhav et al., 2019). The translation was performed in three stages: first, a bilingual native speaker initially translated the text from English into Portuguese; then, another bilingual native translated it from Portuguese into English; finally, the texts were compared looking for differences and compatibilities (Douglas & Craig, 2007). Then, the instrument was validated in Portuguese by a specialist, who compared the three versions, verifying and making modifications towards a greater understanding by the respondents. After the translation, the pre-test instrument was executed.

3.2 Pre-test

The realization of a pre-test is necessary to verify understanding and clarity and improve it (Cyr, 2019; Douglas & Craig, 2007; Malhotra, 2012). The first pre-test was conducted with a group of five people working for an elevator manufacturer. At this stage, some questions were not fully understood. Based on this feedback, the questions were reviewed. After the improvement, a second pre-test was carried out with a group of ten people: five respondents worked in the same elevator manufacturer and five respondents worked in a manufacturer of machinery for cellulose factories and steel structures. In this second pre-test, there was a full understanding of the instrument, thus enabling the start of data collection. Table 5 shows the characteristics and reasons for the use of this sample.

Table 5. Sample characteristics.

	Company	Sample size	Sample characteristics	Reason for choosing the company	Reason for choosing the interviewees
Pre-test 1	Manufacturer of elevators	5 participants	Analysts and industry leaders; Area of activity: Production, Quality.	It facilitated the follow-up of the questionnaire in person. The best alternative according to Malhotra (2012).	As for the analysts, due to the prospect of promotion or the fact of acting as reference or leadership in the sector in question. The management/leadership position includes the pre-tests and the target audiences of the questionnaire. All involved are graduated or are taking courses in engineering or management, both related to production and mechanics.
Pre-test 2	Manufacturer of elevators	5 participants	Analysts and industry leaders; Area of operation: Quality, Maintenance, Engineering, Costs and Processes.		
	Manufacturer of machines for cellulose area and metal structures	5 participants	Analysts, leaders and coordinators; Area of activity: Production, Quality, Processes, Engineering.		

Source: Prepared by the authors (2021).

3.3 Distribution and data collection

The instrument was distributed electronically. The respondents accessed an electronic address to access the electronic form. The sample consisted of students and alumni in Production Engineering, Administration, Master's and Doctorate researchers in Production and Systems Engineering, Master's and Doctorate researchers in Administration and all MBA courses of the Vale do Rio dos Sinos University (UNISINOS), as well as employees of several Brazilian companies. No restrictions were made as for demographic region or segment. As the only limitation, the company, whether national or multinational, headquarters or branch, should be located in Brazil. This was because the objective of this work was to study companies located in Brazil. The survey was sent to 500 respondents, of which 81 responded, including over 32 companies in the sample.

In order to support the analyses and the comparisons with the results obtained by Jain et al. (2014), this study compared two groups of respondents. The first group, called “all respondents”, comprised 81 answers and included all company positions and market segments. The second group, called “industry managers”, was composed of 47 answers and included only management positions and segments related to manufacturing, the target audience of the instrument. Table 6 shows the profile of the participants and the companies of the all respondents and industry managers sample.

Table 6. Profile of participants and their companies - All respondents & Industry managers.

	All Respondents	Industry Managers
Company sector	Public administration, defense and social security (2); Agribusiness (2); Business (1); Building construction (4); Aircraft industry (1); Automotive industry (6); Rubber industry (2); Wood industry (1); Machinery and equipment industry (18); Industry of electrical, electronic, communications (3); Paper and cellulose industry (1); Oil/gas industry (1); Plastic industry (1); Transport industry (except for naval and automotive) (9); Footwear/clothing/fabrics industry (4); Mechanical industry (6); Basic metallurgical industry (6); Chemical industry (2); Textile Industry (1); Financial branch (1); Health (1); Telephone communication services (1); Educational services (3); Utilities services (1); Services rendered to the community (1); Transport - wide and long loads (2)	Automotive industry (5); Rubber industry (2); Machinery and equipment industry (13); Industry of electrical, electronic, communications (1); Oil/gas industry (1); Plastic products industry (1); Transport industry (except for naval and automotive) (9); Footwear/clothing/fabrics industry (4); Mechanical industry (4); Basic metallurgical industry (4); Chemical industry (2); Textile Industry (1)
Revenue	up to R$ 360,000.00 (4); above R$ 360,000.00 up to R$ 3,600,000.00 (13); above R$ 3,600,000.00 up to R$ 16,000.00.00 (14); above R$ 16,000,000.00 up to R$ 90,000,000.00 (26); above R$ 90,000,000.00 (24)	Up to R$ 360,000.00 (3); above R$ 360,000.00 to R$ 3,600,000.00 (8); above R$ 3,600,000.00 up to R$ 16,000.00.00 (7); above R$ 16,000,000.00 up to R$ 90,000,000.00 (19); above R$ 90,000,000.00 (10)
Number of employees	up to 19 employees (8); from 20 to 99 employees (13); from 100 to 499 employees (33); from 500 employees to 999 employees (3); from 1,000 employees to 4,999 employees (19); from 5,000 employees to 9,999 employees (2); more than 10,000 employees (3)	Up to 19 employees (6); from 20 to 99 employees (5); from 100 to 499 employees (25); from 500 employees to 999 employees (0); from 1,000 employees to 4,999 employees (9); from 5,000 employees to 9,999 employees (1); more than 10,000 employees (1)
Production system used	Batch shop (9); Job shop (23); Flow shop (23); Continuous shop (16); Line shop (10)	Batch shop (5); Job shop (14); Flow shop (14); Ccontinuous shop (6); Line shop (8)
Department	Administrative (16); Purchasing (7); Engineering (12); Expedition (1); Financial (1); Maintenance (4); Production Planning and Control (9); Process (10); Production (10); Programming (3); Quality (4); Receiving (1); Human Resources (0); Information Technology (3)	Administrative (9); Purchasing (4); Engineering (5); Expedition (1); Maintenance (3); Production Planning and Control (6); Processes (5); Production (8); Programming (2); Quality (3); Receiving (1)
Position	Leader (8); Supervisor (14); Coordinator (16); Manager (11); Director (9); President (0); Other (23)	Leader (7); Supervisor (10); Coordinator (13); Manager (10); Director (7); President (0); Other (0)
State	Rio Grande do Sul - RS (78); Santa Catarina - SC (1); São Paulo - SP (2)	Rio Grande do Sul - RS (45); Santa Catarina - SC (1); São Paulo - SP (1)

Source: Prepared by the authors (2020).

3.4 Data analysis

For data analysis, reliability analysis, face validation method, content validation, multiple regression analysis and factor analysis were performed. Subsequently, the results were compared with those of the work by Jain et al. (2014). Additionally, an exploratory factor analysis was performed to verify the convergent validity of the work.

Reliability is a term used to verify whether a procedure produces similar results when replicated (Jain et al., 2014). We used the internal consistency method according to Saraph et al. (1989), which is used to measure the levels of homogeneity of items in a study group. Such level can be estimated by using the Cronbach's Alpha coefficient (Hair et al., 2005a; Saraph et al., 1989), “[...] which is a measure of reliability ranging from

0 to 1; values from 0.60 to 0.70 are considered the lower limit of acceptability" (Hair et al., 2005a, p. 90).

Face validation was used to verify whether the item to be evaluated measures what it is supposed to measure (Hair et al., 2005b; Jain et al., 2014). This method was used during the preparation of the final instrument in Portuguese to obtain a proper and understandable formulation for all managers. The translated version found differences. After they were eliminated, face validation was adequate as in the original version, that is, it will allow evaluating the manufacturing capabilities properly.

Content validation was performed to ascertain whether the content of the questions was aligned with the specifications of the universe in which it was tested. That is, it is a subjective assessment of capability scale to measure what should be measured (Hair et al., 2005b). As in the original version, and as observed in the literature review and in the review by experts in the area during back-translation, it can be said that this work presents content validity.

To calculate production competence (PC), we used the expression suggested by Vickery et al. (1993), in which importance and productivity are considered as competitive dimensions (Equation 1).

$$PC = \sum_{i=1}^{n} \text{MR x Ii x Pi} \tag{1}$$

Where:

Factor i = 1 (cost), 2 (quality), 3 (delivery), 4 (flexibility) and 5 (innovation);

Ii = Strategic importance of the factor i;

Pi = Performance of the factor i;

MR = Manufacturing Responsibility.

To calculate this index, we used the form provided in Appendix 2 of Jain et al. (2014) research. Respondents had to score the importance of competitive priorities (Ii) from not important (1) to extremely important (5). They also scored the performance of competitive priorities (Pi) from significantly low (1) to significantly high (5). As for manufacturing responsibility (MR), just as in Jain et al. (2014), this work will assume the MR as equal to 1.

To transform the answers to the questions as percentage into a single factor, the same procedure adopted by Jain et al. (2014) was performed. For the statistical analysis, the questions that used this method generated a new variable named with the number of the question plus a "T" at the end, for example, question 4, new variable "Q4T".

Later, a multiple regression analysis was performed with a 95% significance level. PC is the dependent variable, and the mean of the remaining questions, grouped by the author as shown in Table 1, represents the independent variables. The higher the result, the greater the relation strength between the variables under examination (Hair et al., 2005b). The assumptions of multiple regression analysis were also tested.

"Factor analysis plays a confirmatory role, i.e., it assesses the degree to which data satisfy the expected structure" (Hair et al., 2005a, p. 92). For this reason, exploratory factor analysis was chosen to explore the constructs studied because, through the resulting variable "R^2", it will be possible to observe to what extent the instrument is being explained by the variables. Some purifications were performed during the process: if a same question was displayed in more than one component at the same time, such question was excluded from the analysis.

4 Results

4.1 Reliability

Table 7 shows the reliability of the data. A color scale was used to assist in the analysis. Green and yellow indicate only the questions that obtained a score above or at the lowest limit of acceptability.

Table 7. Comparison of results of reliability using Cronbach's Alpha.

Authors	Manufacturing decision areas	Questions included in each manufacturing decision areas	Cronbach's alpha obtained in this research - All Respondents	Cronbach's alpha obtained by Jain et al. (2014)	Cronbach's alpha obtained in this research - Industry Managers
1. Hayes et al. (1988)	1. Capacity	1-3	0.565 [C]	0.538 [C]	0.436 [B]
	2. Facilities	4-5	0.206 [A]	0.513 [C]	0.513 [C]
	3. Process technologies	6-7	0.417 [B]	0.259 [A]	0.447 [B]
	4. Vertical integration/vendors	8-11	0.169 [A]	0.495 [B]	0.068 [A]
	5. Human resources	12-16	0.858 [F]	0.739 [E]	0.852 [F]
	6. Quality	17-18	0.757 [E]	0.861 [F]	0.856 [F]
	7. Production planning/materials control	19-20	0.773 [E]	0.830 [F]	0.720 [E]
	8. New product development	21-22	0.747 [E]	0.565 [C]	0.754 [E]
	9. Performance measurement and reward	23	*	*	*
	10. Organization/systems	24-25	0.760 [E]	0.584 [C]	0.651 [D]
2. Skinner (1969)	1. Plant and equipment	1-5 e 8-11	0.374 [A]	0.718 [E]	0.372 [A]
	2. Product design engineering	6-7 e 21-22	0.619 [D]	0.608 [D]	0.592 [C]
	3. Labor and staffing	12-16	0.858 [F]	0.739 [E]	0.852 [F]
	4. Production planning and control	17-20	0.797 [E]	0.862 [F]	0.820 [F]
	5. Organization and management	23-25	0.816 [F]	0.697 [D]	0.749 [E]
3. Miltenburg (2005)	1. Human resource	12-16	0.858 [F]	0.739 [E]	0.852 [F]
	2. Organization structure	23-25	0.816 [F]	0.697 [D]	0.749 [E]
	3. Sourcing	8-11	0.169 [A]	0.495 [B]	0.068 [A]
	4. Production planning and control	19-22	0.831 [F]	0.742 [E]	0.832 [F]
	5. Process technologies	6-7 e 17-18	0.684 [D]	0.723 [E]	0.685 [D]
	6. Facilities	1-5	0.135 [A]	0.618 [D]	0.325 [A]
4. Slack & Lewis (2008)	1. Capacity	1-5	0.135 [A]	0.618 [D]	0.325 [A]
	2. Process technologies	6-7	0.417 [B]	0.259 [A]	0.447 [B]
	3. Supply network	8-11	0.169 [A]	0.495 [B]	0.068 [A]
	4. Organization and development	12-25	0.927 [G]	0.894 [F]	0.925 [G]

Source: Prepared by the authors (2020). Note: *Includes only one factor; it is not possible to run the analysis.
Note: [A] = 0~0.399; [B] = 0.400~0.499; [C] = 0.500~0.599; [D] = 0.6~0.699; [E] = 0.700~0.799; [F] = 0.800~0,899; [G] ≥ 0.900

Upon separating manufacturing decision areas according to each author, it was observed that 55% of decision areas established by Hayes et al. (1988), 40% of the areas established by Skinner (1969), 50% of the areas established by Miltenburg (2005) and 75% of the areas established by Slack & Lewis (2008) are at the lowest limit or below acceptability. It is observed that, regardless of the categorization method of the manufacturing decision area as for reliability (Cronbach's alpha), only from the question 12 the results began to be above the lowest limit. This may explain the performance of Skinner (1969), since it comprises substantially all questions previous to the 12th question in first categorization.

However, the high number of decision areas below the acceptable limit (53-75%) shows that the instrument still needs improvements for practical applications. This shows that respondents are understanding the questions in different ways. Thus, by using the instrument under evaluation it is not possible to determine what is being measured.

4.2 Relation between manufacturing capabilities and production competence

Table 8 summarizes the results to verify the relation between manufacturing capabilities and production competence.

Table 8. Comparison of results - Multiple regression analysis.

Authors	Manufacturing decision areas	Questions included in each manufacturing decision areas	Multiple regression analysis (R^2) obtained in this research - All Respondents	Multiple regression analysis obtained by Jain et al. (2014)	Multiple regression analysis (R^2) obtained in this research - Industry Managers
1. Hayes et al. (1988)	1. Capacity	1-3	0.371	0.768	0.303
	2. Facilities	4-5			
	3. Process technologies	6-7			
	4. Vertical integration/vendors	8-11			
	5. Human resources	12-16			
	6. Quality	17-18			
	7. Production planning/materials control	19-20			
	8. New product development	21-22			
	9. Performance measurement and reward	23			
	10. Organization/systems	24-25			
2. Skinner (1969)	1. Plant and equipment	1-5 e 8-11	0.361	0.683	0.296
	2. Product design engineering	6-7 e 21-22			
	3. Labor and staffing	12-16			
	4. Production planning and control	17-20			
	5. Organization and management	23-25			
3. Miltenburg (2005)	1. Human resource	12-16	0.351	0.719	0.282
	2. Organization structure	23-25			
	3. Sourcing	8-11			
	4. Production planning and control	19-22			
	5. Process technologies	6-7 e 17-18			
	6. Facilities	1-5			
4. Slack & Lewis (2008)	1. Capacity	1-5	0.354	0.704	0.277
	2. Process technologies	6-7			
	3. Supply network	8-11			
	4. Organization and development	12-25			

Source: Prepared by the authors (2020).

As shown in Table 8, the R^2 results were below 0.4 for both samples. The results show that, in 62-65% of the sample including "all respondents" and in 69-73% of the sample including only "industry managers", PC is not dependent on the studied variables. That is, there is an association between the dependent variable and the independent variables ranging from 27 to 38%.

A residue analysis of both samples followed a normal distribution. Concerning the VIF tolerance, both samples, obtained results within the acceptable. As for residue homoscedasticity, both samples are within the recommended. The data are homogeneously distributed in an ellipse format. Both samples present some problems not considered serious. However, the industry managers sample presented results below the all respondents sample. Finally, about absence of residue serial/spatial autocorrelation, all samples were at levels close to two. That is, the assumptions of multiple regression analysis were met.

4.3 Exploratory factor analysis

About results of KMO and Bartlett's testes, in both samples, the method is suitable for the data (KMO test) and the data are suitable for exploratory factor analysis (Bartlett's Test of Sphericity). On KMO test, the sample "all respondents" obtained 0,823 and the sample "industry managers" 0,695 as a result. On Bartlett's Test of Sphericity, both samples obtained a P-Value less than 0,05 and about Approx. Chi-Square, "all respondents" sample obtained 342,385 and "industry managers" 94,390 as a result.

Tables 9 (all respondents) and 10 (industry managers) shows the rotated components matrix of the sample. Tables assign how many components/factors have been identified and which questions include each of the components/factors.

Table 9. Rotated components matrix - All respondents.

Manufacturing decision area according with:					**Component/Factor**			
Hayes et al. (1988)	Skinner (1969)	Miltenburg (2005)	Slack & Lewis (2008)	Question	1	2	3	4
Human resources	Labor and staffing	Human resources	Organization and development	Q13	0.843			
Human resources	Labor and staffing	Human resources	Organization and development	Q16	0.816			
Human resources	Labor and staffing	Human resources	Organization and development	Q12	0.772			
Performance measurement and reward	Organization and management	Organization structure	Organization and development	Q23	0.701			
Organization/systems	Organization and management	Organization structure	Organization and development	Q25	0.685			
Human resources	Labor and staffing	Human resources	Organization and development	Q15	0.662			
Capacity	Plant and equipment	Facilities	Capacity	Q3		0.785		
Capacity	Plant and equipment	Facilities	Capacity	Q2		0.768		
Vertical integration/vendors	Plant and equipment	Sourcing	Supply network	Q9T			0.771	
Facilities	Plant and equipment	Facilities	Capacity	Q4T			0.696	
Facilities	Plant and equipment	Facilities	Capacity	Q5T			0.611	
New product development	Product design engineering	Production planning and control	Organization and development	Q22				0.844
Process technologies	Product design engineering	Process technologies	Process technologies	Q7				0.489

Source: Prepared by the authors (2020).

Table 10. Rotated components matrix - Industry managers.

Manufacturing decision area according with:					Component/Factor			
Hayes et al. (1988)	**Skinner (1969)**	**Miltenburg (2005)**	**Slack & Lewis (2008)**	**Question**	**1**	**2**	**3**	**4**
Production planning/materials control	Production planning and control	Production planning and control	Organization and development	Q19	0.872			
Organization/systems	Organization and management	Organization structure	Organization and development	Q24	0.863			
New product development	Product design engineering	Production planning and control	Organization and development	Q22	0.825			
Human resource	Labor and staffing	Human resources	Organization and development	Q16	0.628			
Facilities	Plant and equipment	Facilities	Capacity	Q4T		0.81		
Vertical integration/vendors	Plant and equipment	Sourcing	Supply network	Q9T		0.801		
Capacity	Plant and equipment	Facilities	Capacity	Q3			0.776	
Vertical integration/vendors	Plant and equipment	Sourcing	Supply network	Q8			0.604	
Vertical integration/vendors	Plant and equipment	Sourcing	Supply network	Q11T				0.917

Source: Prepared by the authors (2020).

The Tables above do not show factor loadings lower than 0.4 nor questions that appear in more than one factor at a time. The reason for a question to be on two factors is that it represents different concepts at the same time for this or any instrument, and this should not happen.

Exploratory factor analysis, in both samples, obtained four components, namely, manufacturing capabilities. However, according to Hayes et al. (1988), there are ten manufacturing capabilities. That is, the instrument studied is not reflecting manufacturing capabilities through its questions.

The Tables 9 and 10, referring to both samples, evidence that the factors encompassed several topics incompletely. However, unlike the others, the factor 2 of the “all respondents” sample and the factor 4 of the “industry managers” sample grouped questions in a same manufacturing decision area, however incompletely. Other factors mixed more than one topic. This raises two hypotheses: the differences between the questions are unclear, or there are no major differences between them, or in fact they do not belong to the specified topic.

About reliability analysis results of the resulting four components using Cronbach's Alpha. Only the component 1 has a reliability above the minimum (result 0.829~0.879). However, the other factors have a reliability below the acceptable lowest limit (0.60~0.70).

The low reliability of the factors of exploratory factor analysis corroborates the data shown in Table 7, where the results also showed a low reliability. An unreliable instrument evidences that respondents are understanding the questions in different ways. Therefore, it is not possible to determine what is being measured. Also, note that, regardless of the position held or the segment of the company, i.e., both samples, the results about multiple regression analysis and reliability analysis were not adequate.

5 Discussion of the results

Generating or maintaining competitive advantage has been a challenge for companies. In part, this is due to the difficulty of managers to evaluate manufacturing capabilities. For this reason, functional tools for the evaluation of manufacturing capabilities are relevant.

As for the working method, as described in the section 3 of this study, all the procedures recommended in the literature for the replication of an instrument were adopted. Jain et al. (2014), p. 2092) stated that "... it was the first time such work was done." Because of this, our replication of the developed instrument shows needs for a more robust working method in which the pre-test sample should have been larger and also statistically analyzed. This is one of the contributions of our work. With these early statistical results, they would probably indicate the need to improve the instrument regarding its reliability level (Cronbach's Alpha) and multiple regression analysis. An exploratory factor analysis should have also been performed to verify whether the instrument results in 10 factors (10 manufacturing decision areas according to Hayes et al. (1988)).

Upon developing the instrument, Jain et al. (2014) should have focused on only one manufacturing decision area, in the case, the 10 decision areas established by Hayes et al. (1988). By adapting it to the decision areas according to Skinner (1969), Miltenburg (2005) and Slack & Lewis (2008), the questions were just subjectively grouped in less manufacturing decision areas and, with it, possible statistical problems were diluted.

The results of this research show that certain questions of the instrument are not suitable for an evaluation of capabilities identified in manufacturing. This is due to the poor performance in the reliability analysis, where part of the results is below the lowest limit of acceptability. Regarding the questions that were at the reliability limit of acceptability, they should be improved to obtain a better representation. Regarding the results of multiple regression analysis, it is necessary to conduct a study to ascertain the causes of the low relation between manufacturing capabilities and production competence. We speculate that questions relating to manufacturing capabilities cannot depend on the result of the production competence (PC) calculation. Another alternative may be because the variables used to represent the PC, obtained using Form 2 (Appendix 2 of Jain et al., 2014, research), do not characterize the variable. Or yet, the calculation of the PC is not applicable to this situation. There may be other possible reasons.

Additionally, this research performed an exploratory factor analysis, which, contrary to expectations, obtained only 4 factors. The entire instrument is based on the 10 manufacturing areas established by Hayes et al. (1988). Therefore, it was expected that the instrument obtained 10 factors. However, the confirmatory factor analysis revealed only 4 factors. Upon performing a reliability analysis of these 4 factors, the results were mostly not suitable. The results of exploratory factor analysis confirm the need to improve the questions of the instrument.

By comparing this research with that conducted by Jain et al. (2014), it is observed that the instrument developed by the authors needs to be improved to be considered valid and reliable. In both studies, the evidence suggests that the instrument needs to be improved so that it can properly represent manufacturing areas, and consequently be understood by all respondents in a same way.

All statistical analyses in this study were performed on two samples, "all respondents" and "industry managers". The sample "all respondents" obtained better results. It is possible to enumerate several theories for such fact. To prove them, an in-depth study would be needed. We speculate that the sample "all respondents" obtained a higher result because it diluted bad answers amid best answers. Another alternative is that managers did not respond the instrument with full attention. Or yet, managers are separated from the operational part of the company, contributing to a low result. There is also the possibility of managers being outdated and, together with the fact that the instrument was distributed on-line, it was not possible to remove doubts upon answering the questions, among other possible causes.

Part of the instrument was applicable in other economic and cultural contexts. Therefore, there is potential to evaluate some manufacturing capabilities. It was possible to verify, for example, that, from the middle of the instrument on (question 12 onwards), it presented acceptable indicators of validity and reliability. Both surveys contributed to obtain an instrument to evaluate manufacturing capabilities. As explained in this research, more and more managers have difficulties in identifying them and thus keeping the company ahead of competitors.

6 Conclusion

This research sought to replicate an instrument that was developed to evaluate manufacturing capabilities, assessing its validity and reliability. As previously mentioned, it was the first time the instrument was applied in a context different from the original. Overall, the results of this study show that the original instrument needs to be improved to be considered valid and replicable. Several constructs related to manufacturing capabilities did not meet the minimum requirements for convergent and divergent validity and reliability. However, other constructs could be validated and had some reliability. Moreover, the results showed that manufacturing capabilities explain less than a third of the variation in production competence, indicating that constructs of manufacturing capabilities need to be improved to better explain production competence. This work limited to contribute with specific points to improve the instrument under study and not to evidence the reasons for differences. One reason could be the need to access to more data for further analyses and comparisons. Another reason can be inferred from the Brazilian context. Because, as previously presented, decision making is not only based on reliable information, it is also related to financial metrics and mainly to the environment, information and time available for decision making (Assid et al., 2020; Dolgov et al., 2020; Gylling et al., 2015; Maynard et al., 2020; Nujen & Halse, 2017) .

For future works, the questions of the instrument should be reviewed so that they really portray all ten manufacturing decision areas, in addition to presenting better statistical results. In addition, future works must assess whether the questionnaires (Appendix A and B) need to be changed to meet the particularities of the Brazilian context or reformulate it so that it is able to measure their capabilities in Brazil to obtain competitive advantages. Future studies could use this work as a starting point, as the exploratory factor analysis indicated several questions that mixed more than one component. It will also help to highlight which questions are well-defined and which need to be improved. It is also suggested to analyze, using Table 4, which would be the ideal distribution method of the instrument, the reduction of tool size and the new questions. Similar studies suggest questions that can be incorporated into the instrument of this work for future research. The following are some of them: i) identify specific factors for each capability, ii) perform a sensitivity analysis to relate the impacts of the change in capabilities and modifications to meet specific applications (customization of the instrument) (Hum & Leow, 1996; Mousavi et al., 2007), iii) in addition to applying both the instrument and the pre-test to a larger sample.

Given the facts presented above and the results shown in this study, the authors of this work do not recommend that the instrument be used as an evaluation method of capabilities in Brazil until it is perfected. However, it is a valuable tool for use in manufacturing in the future. It should improve its questions and the instrument should be replicated in Brazil to certify its validity and effectiveness. However, it is interesting that this study be reproduced in another emerging country (this research) or further developed (study conducted by Jain et al. (2014)) for a new comparison of data. With this new research, it will be possible to analyze whether the instrument is subject to the specific characteristics of a country or whether the problem is only in the inconsistencies in its questions.

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Appendix A. Instrument to evaluate manufacturing capabilities

Note: Translated to Portuguese using the back-translation method.
Source: (Jain et al., 2014), p. 2100~2103

Capacidade

(1) A estratégia de Capacidade (ex., quantidade e tempo que leva para adicionar capacidades de acordo com as alterações de demanda) de sua planta é:

1	2	3	4	5
Capacidade não atende a demanda	⟵		⟶	Capacidade atende a demanda

(2) A justificativa para decisões relacionadas à capacidade é principalmente baseada em:

1	2	3	4	5
Somente ferramentas de investimento de capital	⟵	Mesma importância	⟶	Vantagem Competitiva estratégica

(3) O horizonte de planejamento (em quantos anos a seguir) da capacidade de planejamento da empresa é:

1	2	3	4	5
Curto (até 1 ano)	⟵		⟶	Longo (mais que 5 anos)

Instalações

(4) Grau de especialização do seu equipamento comparado ao padrão da indústria (Indique a porcentagem do equipamento conforme as diferentes classificações):

____%	____%	____%	____%	____%
1	2	3	4	5
Uso Geral (utilizado por ampla gama de produtos)	⟵	Igual à média da indústria	⟶	Especializado (customizado para uso de uma gama restrita de produtos)

(5) O quanto as modificações, melhorias ou adaptações são feitas internamente nos equipamentos da sua organização:

____%	____%	____%	____%	____%
1	2	3	4	5
Projeto estático (sem modificações)	⟵		⟶	Evolução de Projeto (melhoria de performance)

Tecnologias de Processo

(6) Fonte de informação sobre novas tecnologias de equipamentos/processos:

1	2	3	4	5
Fonte externa (ex.: fornecedores, concorrente)	⟵	⟶		Fonte interna (ex.: P&D, empregados)

(7) A justificativa para adoção de equipamento/tecnologias de processo é primariamente baseada em:

1	2	3	4	5
Corte de custos	⟵	Mesma importância	⟶	Melhoria de capacidade

Integração vertical - fornecedores

(8) Decisão de terceirização (produzir internamente ou externamente) é principalmente:

1	2	3	4	5
Para redução de custos	⟵	Mesma importância	⟶	Para ganhar vantagem estratégica (ex.: aumento de capacidade)

(9) Relacionamento com fornecedores (mostre a porcentagem sobre as diferentes possibilidades):

____%	____%	____%	____%	____%
1	2	3	4	5
Compra no mercado (sem retalhamento com fornecedores)	⟵	⟶		Parceria (compartilhamento de responsabilidades)

(10) Frequência de assistência aos fornecedores para cumprimento dos objetivos da sua empresa:

1	2	3	4	5
Nunca	⟵	⟶		Frequentemente

(11) Número médio de fornecedores (mostre o porcentual de itens em relação as diferentes composições de fornecedores):

____%	____%	____%	____%	____%
1	2	3	4	5
Muitos (>20)	⟵	Médio (10)	⟶	Poucos (<5)

Recursos Humanos

(12) O quanto os trabalhadores estão envolvidos com a melhoria do processo/sistema de produção da empresa:

1	2	3	4	5
Muito pouco (estabilidade dos processos)	⟵	⟷	⟶	Muito alto (processos em evolução)

(13) Escopo do trabalho dos empregados (ex.: número de trabalhos realizados):

1	2	3	4	5
Estreito (poucos)	⟵	⟷	⟶	Amplo (muitos)

(14) Nível de qualificação dos trabalhadores quando comparado ao padrão da indústria:

1	2	3	4	5
Muito pouco (sem qualificação)	⟵	Mesmo padrão da indústria	⟶	Muito alto (altamente qualificado)

(15) Frequência de treinamentos na sua empresa quando comparado à média da indústria:

1	2	3	4	5
Muito pouco	⟵	Mesmo padrão da indústria	⟶	Muito alto

(16) A filosofia sobre como lidar com os trabalhadores na sua empresa é:

1	2	3	4	5
Comando e controle	⟵	⟷	⟶	Delegação (fonte de aprendizado)

Qualidade

(17) O objetivo das "medições de qualidade" na sua empresa são:

1	2	3	4	5
Para identificar produtos defeituosos (ex.: papel de policiamento)	⟵	⟷	⟶	Para identificar e eliminar fontes de erros no processo

(18) O objetivo geral da "função de controle e planejamento da qualidade" na sua empresa é:

1	2	3	4	5
Principalmente para estabelecer o nível de aceitação de um produto	⟵	⟷	⟶	Principalmente para melhorar a performance de um produto

Planejamento de Produção/Controle de Materiais

(19) Envolvimento de diferentes setores da organização (ex.: marketing, compras e produção) na preparação dos planos de produção:

1	2	3	4	5
Muito baixo (setores são preparados para uma única função)	⟵	⟶		Muito alto (coordenado)

(20) Maneira com que a incerteza quanto à previsão de demanda é gerenciada em sua empresa:

1	2	3	4	5
Reativa (procura formas para adaptação da demanda incerta)	⟵	Mesma importância	⟶	Proativa (procura formas para reduzir/eliminar incertezas de demanda)

Desenvolvimento de Novos Produtos

(21) Grau de interação entre os diversos departamentos (ex.: marketing, produção, projeto) no desenvolvimento de produtos:

1	2	3	4	5
Muito baixo (Desenvolvimento de processo e produto é sequencial)	⟵	⟶		Muito alto (desenvolvimento de projetos e produtos em conjunto)

(22) Frequência com que são lançados/apresentados novos produtos em relação aos concorrentes:

1	2	3	4	5
Muito baixo	⟵	⟶		Muito alto

Medições de Performance e Sistema de Recompensa

(23) Ênfase dada à avaliação de desempenho de sua empresa é:

1	2	3	4	5
Focada na mensuração das contribuições para realizações individuais	⟵	Mesma ênfase	⟶	Focada na mensuração das contribuições em prol de objetivos organizacionais

Organização/Sistemas

(24) Nível de interação entre os departamentos e a hierarquia gerencial:

1	2	3	4	5
Baixo (fragmentado)	⟵	⟶		Muito alto (Integrado)

(25) Nível de autoridade da linha de produção em relação às equipes de apoio:

1	2	3	4	5
Baixo (coordenação da equipe)	⟵	⟶		Alto (linha de produção responsável, equipe presta suporte)

Appendix B. Benchmarking manufacturing performance ***(used to execute the calculation of production competence (PC))***

Note: Translated to Portuguese using the back-translation method.
Source: (Jain et al., 2014), p. 2104.

Considere as dimensões da capacidade de produção abaixo com seus significados:

Dimensão	Significado
1. Custo	Produção e distribuição do produto à um baixo custo
2. Qualidade	Produzir os produtos com alta qualidade e padrões de performance
3. Desempenho na Entrega • Confiabilidade da entrega • Velocidade de entrega	Cumprir cronogramas de entregas ou promessas Reagir rapidamente aos pedidos dos clientes
4. Flexibilidade • Mix de produto • Volume	Reagir rapidamente às mudanças nos tipos de produtos produzidos Reagir rapidamente às mudanças de quantidade para um determinado *mix* de produção

Para cada dimensão da capacidade de produção, classifique a importância que está relacionada a venda de seus produtos no Formulário I e classifique a performance do seu produto relacionada com seus principais concorrentes no Formulário II.

Formulário 1 – Importância das Prioridades Competitivas

Para cada dimensão (ex.: coluna), assinale (√) na caixa apropriada.

Dimensão da Capacidade de Manufatura	IMPORTÂNCIA de seus principais produto(s)				
	1. Não importante	2. Um pouco importante	3. Bem importante	4. Muito importante	5. Extremamente importante
1. Custo					
2. Qualidade					
A) Desempenho na Entrega Confiabilidade de entrega Velocidade de entrega					
3. Flexibilidade Mix de produtos Volume de produção					
4. Capacidade de inovação					

Formulário 2 – Performance de Prioridades Competitivas

Para cada dimensão (ex.: coluna), assinale (√) na caixa apropriada.

Dimensão da Capacidade de Manufatura	PERFORMANCE (quando comparado com seus principais concorrentes)				
	1. Significativamente inferior	2. Um tanto quanto inferior	3. Praticamente igual	4. Um tanto quanto superior	5. Significativamente superior
1. Custo					
2. Qualidade					
A) Desempenho na Entrega Confiabilidade de entrega Velocidade de entrega					
A) Flexibilidade Mix de produtos Volume de produção					
3. Capacidade de inovação					

Custo está em escala inversa. Ex.: quanto mais alto o custo pior é a performance.