ISSN 1980-5411 (On-line version)
Production, 33, e20220095, 2023
DOI: 10.1590/0103-6513.20220095

Research Article

Methodological concerns in case-based research in industrial engineering: revisiting the challenges towards further recommendations

Paulo Augusto Cauchick-Miguel[a*], **Thayla Tavares Sousa-Zomer**[b], **Guilherme Tortorella**[a]

[a]Universidade Federal de Santa Catarina, Florianópolis, SC, Brasil

[b]Fundação Dom Cabral, São Paulo, SP, Brasil

[*]paulo.cauchick@ufsc.br

Abstract

Paper aims: This paper addresses difficulties among the Brazilian scholarly community in industrial engineering (IE) when conducting case-based research. It also provides further recommendations to increase methodological rigour.

Originality: The paper contributes to the practice of case research by providing a historical perspective of research methodology in Brazil and offering guidance to improve case research adoption as well as the methodological rigour.

Research method: The main challenges when conducting case research were first identified through a literature review. Then, an exploratory survey with Brazilian scholars was conducted to identify challenges perceived by those. Recommendations are then provided, especially regarding the data analysis stage. The recommendations are discussed in the light of the existing literature and based on authors' experience in conducting qualitative research.

Main findings: Difficulties when conducting case research identified by scholars can be classified in three 'Aquila's hells': (*i*) weak theoretical background, (*ii*) careless case study design/planning; and (*iii*) fragile/uncertain data analysis. Suggestions to improve the data analysis process consist of building a narrative, data reduction, improving coding, etc. Improving validity is also necessary.

Implications for theory and practice: The recommendations are especially meaningful to early-stage researchers and provide guidance to improve robustness when conducting case research.

Keywords

Case research. Case study. Research methodology.

How to cite this article: Cauchick-Miguel, P. A., Sousa-Zomer, T. T., & Tortorella, G. (2023). Methodological concerns in case-based research in industrial engineering: revisiting the challenges towards further recommendations. *Production*, *33*, e20220095. https://doi.org/10.1590/0103-6513.20220095

Received: Aug. 16, 2022; Accepted: July 26, 2023.

1. Introduction

Operations management (OM) is a domain that encompasses several other sub-areas. OM is a blend of different academic disciplines and practical fields of application; one of those fields is industrial engineering – IE (Slack et al., 2004). Whatever the purpose of investigation within OM, choosing an adequate research design and approach is a *sine qua non* condition to achieving robust, rigorous, and reliable results and conclusions.

The research design aims to lead the researcher to address questions of a specific research problem (Saunders et al., 2012). A suitable and consistently organized research design ensures rigour, reliability, and a comprehensive answer to the research question being addressed. Among a wide range of methodological approaches, case-based research has been pointed out as one of the most popular in OM (Filippini, 1997; Filippini & Voss, 1997; Scudder & Hill, 1998; Pannirselvam et al., 1999; Voss et al., 2002; Barratt et al., 2011), being widely adopted among the OM scholarly community over the last decades (Sousa-Zomer et al., 2022).

The seminal efforts of Eisenhardt (1989), Leonard-Barton (1990), Yin (1994), and others (e.g., Eisenhardt & Graebner, 2007) have placed case research as one of the most critical methodological approaches in management and other fields, e.g. OM. A significant contribution that increased case research use by OM scholars is the one of Voss et al. (2002), Voss (2009), and Voss et al. (2015). These studies summarized and updated relevant work on case research by providing a robust structure, contents, and helpful guidance on planning and conducting case research. Some authors even claimed that there has been a 'renaissance' in case research (Ketokivi & Choi, 2014; Voss et al., 2015).

Since the 90's, case-based research has been adopted in the Brazilian IE community as one of the most employed research approaches. For example, case research has accounted for more than a quarter of papers presented in a significant Brazilian industrial engineering conference in 12 years (Berto & Nakano, 2014) and almost 40% of articles published in a Brazilian Scopus-indexed journal in a five-year sample (Benvenuti et al., 2011; Cauchick-Miguel & Sousa, 2018). From time to time, a range of studies has offered a diagnosis of research methodology (e.g., Berto & Nakano, 2014; Cauchick Miguel, 2011), as well as analysis and recommendations (e.g., Cauchick Miguel, 2007; Cauchick Miguel, 2010; Dresch et al., 2015; Cauchick-Miguel & Sousa, 2018; Cauchick Miguel & Dresch, 2018; Cauchick-Miguel et al., 2019; Sousa-Zomer et al., 2022). Those studies have significantly helped less experienced researchers to a great extent.

Nevertheless, scholars have continuously pointed out that there remain challenges when conducting case research and more rigour is necessary when conducting case research (Barratt et al., 2011; Eisenhardt et al., 2016). This implies that researchers still find difficulties adopting a case-based approach. Case studies are usually employed in the first stages of theory development when key variables and relationships are explored. A problematic or methodologically weak approach in the early stages of theory development would imply ripple effects throughout later stages when relationships between variables are elaborated and tested (Eisenhardt & Graebner, 2007). Thus, there have been continuous calls to increase qualitative research's rigour (Grodal et al., 2021). A recent review of case-based research published in one of the most recognized international outlets in operations management (International Journal of Operations and Production Management) has revealed that there have been some systematic flaws in case research (Sousa-Zomer et al., 2022), pointing out for the need to address such flaws and difficulties found among the IE scholarly community. There are also numerous issues to consider along the case research life cycle, and it is crucial to address them adequately. Based on the previous arguments a research question is: *What would be relevant to further improve the case-based research in the domestic community at this point in time?*

Thus, this paper aims to raise current difficulties when conducting case research to provide recommendations to mitigate those, especially concerning one of the most critical stages of the case research design, the data analysis stage. These efforts aim to help to increase rigor in case research among that scholarly community, especially the target audience of this journal, the Brazilian IE context, where qualitative approaches like case research have been employed but still with lack of appropriate rigour. The paper aims to raise awareness and provide recommendations to support the case-study application and improve the quality of its outputs. The contribution of this paper is two fold. First it provides a discussion on difficulties when carrying out case-based research, although is in a specific context of a developing country. Second, as data analysis is one of the most relevant Aquilles' hell in this context, the paper addresses this weakness.

The remainder of the paper is organized as follows. Section 2 presents a brief literature background on case research and steps involved in its execution, highlighting essential aspects that should be considered, as well as an historical perspective on research methodology and case research in the Brazilian IE context. Section 3 describes the research methods and procedures employed in this work by considering an exploratory survey and identified challenges. Section 4 shows the findings in terms of the main difficulties when conducting case research and provides recommendations, especially concerning one of the most critical steps in the case research approach: the data analysis stage. Section 5 provides an overview of what should be further considered to improve methodological rigour in case-based research. Finally, concluding remarks and directions for further research are presented in section 7.

2. Literature background on case-based research

Case research is a methodological approach that focuses on understanding the dynamics present within specific settings, studying phenomena in their contexts rather than independent of context. Case research is the method that uses cases studies as its basis", i.e. case study is the analysis element. A pertinent definition is provided by Leonard-Barton (1990) when considering case study as a historical investigation of a past or current phenomenon, in which the context is relevant. Hence, the adoption of case studies can provide a

description, generate, test, and/or refine theory (Eisenhardt, 1989). It is a compelling theory-building method, a sound approach to developing new models or concepts that can help industrial engineers, OM researchers, and practitioners understand or deal with a situation (Childe, 2011). Over the past years, scholars have recognized that qualitative research approaches, including case studies, can play a significant role in advancing OM theory and practice, which is still weak in theory-building efforts, especially at the grand theory level (Soltani et al., 2014).

The required rigor when doing research is understood as a fundamental element for an adequate adoption of any research method (Hatchuel, 2009). Moreover, methodological rigor contributes to the validity of the research and, thus, its recognition as a serious and well-conducted study. By considering the imperative need for rigor when doing investigations, researchers should justify and make their decisions understandable and unmistakable when planning and conducting research. The concern of adopting a suitable research approach has motivated several publications not only to dedicate to presenting and diagnosing research methods (e.g., Berto & Nakano, 2000, 2014) but also to offer recommendations (e.g., Cauchick Miguel, 2007; Mello et al., 2012; Cauchick Miguel & Dresch, 2018).

Internationally and particularly regarding the Brazilian IE context, one defining milestone that brought researchers' attention to the most common research methods in OM was a special issue of the *International Journal of Operations Management* (IJOPM). Four relevant manuscripts in research methodology were published discussing approaches such as action research (Coughlan & Coghlan, 2002), case research (Voss et al., 2002), modelling and simulation (Bertrand & Fransoo, 2002), and survey (Forza, 2002). Among those methodological research approaches, case research has consistently been one of the most powerful research methods (Voss et al., 2002). When case studies are well conducted, those enable an in-depth comprehension of a phenomenon. Relevant issues when carrying out case research are discussed next.

2.1. Relevant issues when choosing case research

The choice of case study as the appropriate research approach to explore a specific phenomenon should be made by considering a range of aspects. Undoubtedly, one of the most challenging research decisions is to select the methodological research method among various alternatives usually available. Indeed, this is also true when deciding on case-based research. More broadly, the unit of analysis, the case study, is a history of a past or current phenomenon drawn from multiple sources of evidence, including data from on-site observation, interviews, secondary data, among others (Leonard-Barton, 1990). As added by the previous cited author, any fact relevant to the stream of events describing the phenomenon is a potential datum in a case study since the context is essential.

First, it is crucial to consider that if the phenomenon under consideration requires an interpretive philosophy, i.e., the researcher needs to make sense of the subjective and socially constructed meanings expressed about the phenomenon being studied, then a qualitative research design should be considered (Saunders et al., 2012). 'Then, in the realm of qualitative research, numerous research strategies can be contemplated such as action research, case-based research, and others (Saunders et al., 2012). The case study is a valuable research strategy to emphasize the rich, real-world context in which the phenomena occur (Eisenhardt & Graebner, 2007). As a theory-building approach deeply embedded in rich empirical data, building theory from case studies will likely produce an accurate and testable theory (Eisenhardt & Graebner, 2007). The case-based approach is appropriate for exploring answers to 'why', 'what' and 'how' types of questions (Saunders et al., 2012). For this reason, a case study is a practical research approach for both exploratory and explanatory research goals (Saunders et al., 2012).

As mentioned earlier, when applying case studies, the researcher will have to consider multiple data sources such as interviews, *in loco* observations, documentary data, etc. to build the 'whole picture of the phenomenon under analysis. Consequently, the multiple data sources must be 'triangulated' when analyzing the data. Triangulation refers to using different data collection techniques within a study to ensure that the data is showing is what the researcher has identified in the data analysis (Saunders et al., 2012; Hussein, 2009), to develop a chain of evidence (Carter et al., 2014).

Once case studies have been chosen as the most suitable research approach to explore a question or phenomenon, a range of other aspects needs to be defined. Yin (1994) points out that choices should be made concerning using single or multiple cases and holistic cases versus embedded cases. As additional definition of single and multiple case is offered by Coombs (2022), mostly based on Creswell & Poth (2018). Nevertheless, the reader should bear in mind that it is a simplistic source and more in-depth discussion would be required. Single cases should be considered when the case represents a critical case or a unique or extreme case (Yin, 1994). The selected case may provide the opportunity to observe and analyze a phenomenon few have considered. The critical aspect of single case selection is ensuring that the choice is the most suitable to answer the research question at hand and meet the study's objectives (Yin, 1994; Saunders et al., 2012).

On the other hand, a case study strategy can also incorporate multiple cases, focusing on identifying whether the findings can be replicated across cases (Yin, 1994). The cases will then be chosen on the basis that similar results are predicted, termed by Yin (1994) as literal replication or based on a contextual factor that is different across the cases. In this situation, the impact of the difference across the case is predicted by the researcher, and when it is realized, it is termed theoretical replication (Saunders et al., 2012). When the study starts with a range of predictions and theoretical propositions on which the predictions are based, the study adopts a deductive approach aiming to test the theory. Therefore, a multiple case study approach is chosen to address one of the two forms of replication. The second dimension Yin (1994) proposed refers to the unit of analysis. If the research is concerned with an entire organization, the unit of analysis is considered holistic (Yin, 1994; Saunders et al., 2012). The case is considered embedded if the research is concerned with an organization's group, department or sub-unit.

Besides the decisions on the units of analysis, a case-study design involves the definition of other elements, including the case study boundaries and analytical techniques, which are part of the stage' plan the case', which are elaborated next.

2.2. Planning and conducting case research

There are a couple of issues that should be taken into consideration when planning case research. Firstly, the research question (and/or objectives) should be developed based on the literature and research gaps. Secondly, the researcher should critically consider the methodological fit, i.e., if case-based approach is a suitable research approach to tackle the research problem. Table 1 elaborates on the alignment between the broad research purpose and methodological approach and Table 2 summarizes some examples of sources according to the purpose of case research.

Thirdly, a robust plan should be developed when adopting case research, i.e., efforts and time must be put before thinking in going to the field. Figure 1 summarizes the main stages of case research and its overall design and execution. More details on the steps to plan and conduct case research can be found elsewhere (Cauchick Miguel, 2007).

Table 3 provides a brief description of each case research step in Figure 1 and highlights some relevant issues to be considered when designing and conducting case research.

Table 4 was adapted from Corrêa (1992) and provides a valuable structure to address some of the questions researchers face when making choices and developing the research design. The table compares different approaches regarding the research requirements and characteristics.

Table 1. Research purpose and methodological approach alignment.

Purpose	Research question	Research structure
Exploring areas for theory development	Are there enough interesting aspects to justify research?	In-depth case studies; longitudinal case studies
Theory building – identification of key variables; relationship among variables; and identification of 'why' those relationships occur	What are the key variables? What are the standards and relationship among variables? Why do those relationships exist?	Few focused case studies; in-depth field studies; case studies in multiple context
Theory testing – test of theories developed in earlier stages, and prediction of future results	Are the theories generated so far able to survive to the empirical data testing? Was the behavior predicted by the theory observed? (or) Was another unpredictable behavior observed?	Experiments; quasi-experiments; multiple case studies, large samples
Extension/ refinement of theory – better theory structure in the light of observed results	How is the theory generalizable? Where can this theory be applied?	Experiments; quasi-experiments; case studies, large samples

Note: the original table from Cauchick-Miguel et al. (2019) was developed based on Voss et al. (2002).

Table 2. References on case study considering its intent with regards to theory advancement.

Using case studies to	Brief definition	Selected relevant sources
Build theory	Using one or more cases to create theoretical constructs, propositions and/or midrange theory from case-based, empirical evidence	Eisenhardt (1989); Meredith (1998); Narasimhan & Jayaram (1998); Eisenhardt & Graebner (2007); Ketokivi & Choi (2014)
Test theory	Using one or more case data to test theory in form of established propositions	Larsson (1993); McLachlin (1997); Boyer & McDermott (1999); Ketokivi & Choi (2014)
Extend/refine theory	Using one or more cases to explore an aspect within the context of an existing theory	Meredith & Vineyard (1993); Hyer et al. (1999); Eisenhardt & Graebner (2007)

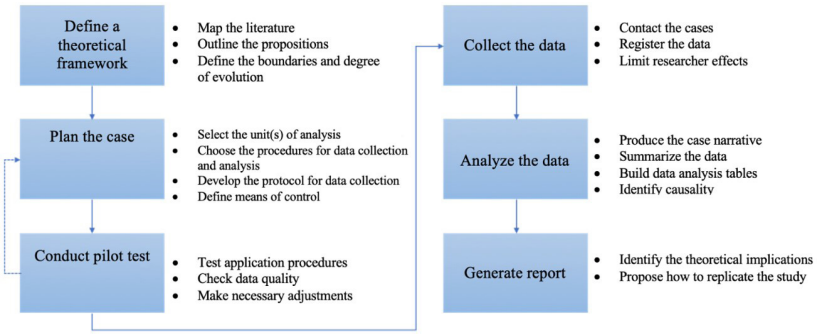

Figure 1. Stages for planning and conducting case research (Cauchick Miguel, 2007).

Table 3. Case research stages and their description, and relevant issues to take into account.

Stage		Brief description	Issues to be considered
Stages	Define theoretical framework	The starting point for case research is the literature, that should be mapped before designing the cases and going to the field	- Review the literature to identify constructs that will be tested in the field - Develop a framework that represents the constructs and their relations - Develop research questions and/or objectives
	Design and plan the cases	A careful design and a detailed planning make case research more robust and enable to minimize possible research limitations in the next steps	- Establish robust criteria for selecting the cases and unit of analysis (define it accurately) - Contact interviewers as early as possible and plan ahead the schedule for data collection - Develop a research protocol for data collection (research questions, interviewees' profile, support documents, etc.) - Define previously 'how-to' analyze data - Consider a pilot test for debugging instruments for data collection
	Conduct pilot test	A pilot trial helps to mitigate possible misunderstandings and mistakes to be avoid in the 'real' data collection and analysis	- Check constructs, data collection procedures, and evidence sources at preliminary level - Enable to examine data quality and assess analysis procedures - Provide a bit of experience for researcher less familiar with case research
	Data collection	After contacting the informants' and have their consent, all data collection instruments should be applied for gathering data from the units of analysis	- Check the quality of evidence sources and their contents - Employ multiple sources of evidence as well as data collection techniques - Get and record data using multiple approaches, if available - Reduce/mitigate the influence of the researcher(s)
	Data analysis	Establish a comprehensive and robust data analysis by employing appropriate strategies and techniques to interpret data from all sources of evidence	- Use of support tools and software (e.g., Atlas.ti, NVivo, VOS Viewer, etc.) - Produce an overall narrative and apply data reduction - Employ content analysis and develop ways to display data for further analysis - Establish causal relationship among constructs
	Generate report	A strong report provides evidence that the research is rigorous and well-designed and conducted	- Provide a detailed presentation of methodological design and procedures employed for collecting and analyzing data - Show the research protocol and other research supporting documents - Draw managerial and/or theoretical implications

Source: developed based on Voss et al. (2002) and Cauchick Miguel (2007).

Table 4. Design choices when comparing case research with other approaches.

Research requirements/characteristics	Experiment	Survey research	Case research	Action research
Researcher presence in data collection	Possible	Unusual/ difficulty	Usual	Usual
Small sample size	Possible	Unusual	Usual	Possible
Variables difficult to quantify	Possible	Possible	Possible	Possible
Perceptive measures	Possible	Possible	Possible	Possible
Construct not pre-defined	Unusual	Difficult	Adequate	Possible
Causality is central	Adequate	Possible	Adequate	Possible
Need to build theory	Possible	Difficult	Adequate	Possible
In-depth understanding of decision-making process	Difficult	Difficult	Adequate	Possible
Non-active role of researcher	Possible	Possible	Possible	Impossible
Lack of control over variables	Difficult	Possible	Possible	Possible

Note: adapted from Corrêa (1992).

As shown in Table 4, each methodological approach has specific characteristics. Case research combines a range of distinct characteristics but conducting case research with adequate methodological rigor is not a trivial task. The following section discusses some challenges when conducting case research identified in the literature and highlighted by researchers among the Brazilian IE community.

2.3. The context of research methodology and case research in the Brazilian IE scholarly

The movement towards improving the adoption of more robust research methodologies and increasing methodological rigor in Brazilian IE academics is relatively recent compared to other countries. This movement was triggered by a few scholars in the middle 90s in the Department of Production Engineering at the University of São Paulo (USP). Later on, other scholars from different institutions across the country were involved with the subject. When Professor Henrique Correa (now in the Rollins College at Florida in the USA) returned from a doctorate obtained in Warwick, he proposed to the head of the department that research methodology should be introduced. As Professor Correa highlighted (Correa, 2020):

> *He* [the head of department] *suggested that I should lead a course on research methodology* [...] *but I replied that I would organize research seminars to discuss research design and methods with master and doctorate students based on the material I was collecting and studied during my doctorate degree. Participants in this seminar included research students such as Roberto Martins, João Turrioni, José Paulo Fusco, and many others from other educational institutions.*

The research methodology seminars were conducted from 1993 to 1995 until Professor Correa left the University of São Paulo in 1996. In 1997, Professor Afonso Fleury created a course on research methodology that is still being delivered today. The seminars and the course have educated several research students through the decades. As a reference for this time, one of the first theses with a proper chapter on research methodology is the one by Martins (1999). Later on, he was involved in the efforts to improve research methodology within the industrial engineering community. Figure 2 illustrates the macro phases in the progress of research methodology adoption and improvement in Brazil. This representation was developed by the authors based on main milestones, checking facts with one of the main contributors involved, as well as the accumulated experience of one of the person in this movement.

Case research is less employed among the North American operations management community, but is a widely applied approach in Europe (Drejer et al., 2000) as well as in the Brazilian IE scenario (e.g., see Berto & Nakano, 2014; Cauchick Miguel & Dresch, 2018). To the best of our knowledge, no equivalent study has been published in the past decade as the data in Figure 3. However, the figure illustrates this point by offering an example of the adoption of case research in a major domestic IE journal (anonymized).

A recent search for case research published in the Production Journal, for instance, has shown that the number of case research has been growing since the 2000s. The growing number of case studies in recognized national and international academic outlets reflects the efforts among the operations management community, both nationally (e.g., Cauchick Miguel, 2007) as well as internationally (e.g., Voss et al., 2002) in supporting improvements and methodological rigor in qualitative research, as qualitative research methodologies are essential for new theory development and evolvement of the field. Nevertheless, improvements in methodological rigor among the Brazilian IE scholarly community are needed.

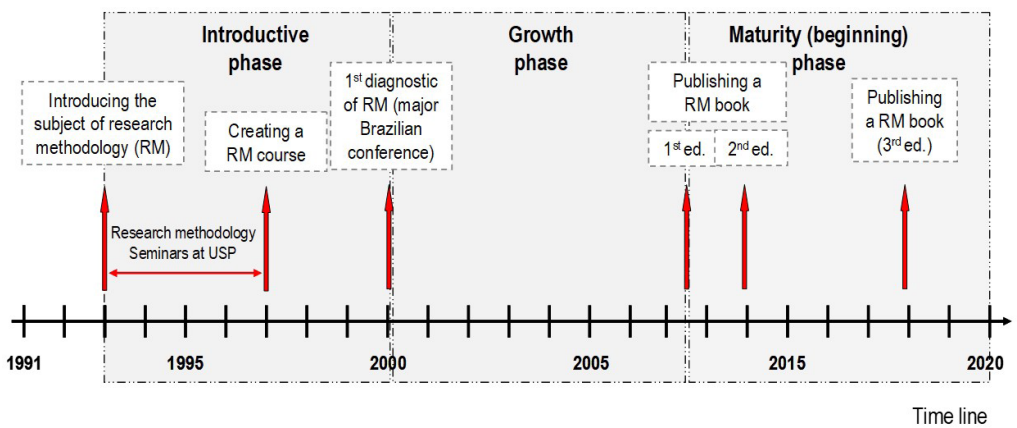

Figure 2. Milestones in IE research methodology.

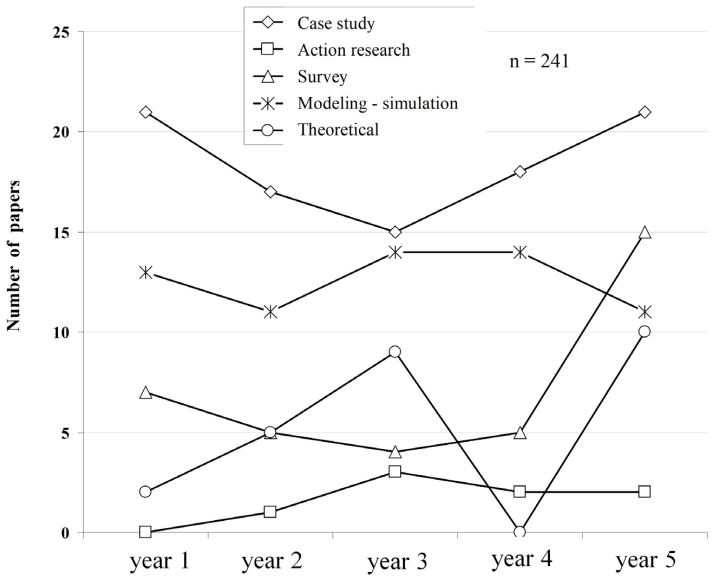

Figure 3. Examples of research approaches in a peer-reviewed Brazilian journal (Cauchick Miguel & Dresch, 2018).

3. Research design

The interdependently objectives of this paper was to address the existing difficulties among the Brazilian scholarly community in IE when conducting case-based research in addition to offer recommendations to mitigate those difficulties. The development of this work was then divided into three steps: (i) a literature search; (ii) an exploratory survey; and (iii) recommendations to address the difficulties. Those are described in more details next.

3.1. Literature search

Two main steps were followed in reviewing the literature on case research: (i) selection of the main methodological articles on case research approach published in the last 15 years or so (*circa* 30 publications), and (ii) a search in one of the main operations management journals publishing case-based research, in order to complement the previously mentioned set of articles.

First, a literature search was conducted to identify the main challenges when conducting case studies raised in the main case research papers. However, this literature review was not meant to be exhaustive of all publications on case study methodology that could have been retrieved. Instead, the review aimed to be representative of the most relevant articles (well-cited) on case research methodology published in peer-reviewed journals that have addressed challenges when conducting case-based research. The selection of articles helps navigate the subject and identify issues that need further attention in the IE context.

The search was carried out in the *Scopus* and *Web of Science* databases, as they are some of the most prominent ones for OM research (Thomé et al., 2016). The search was performed in the titles, abstracts, and keywords by using the following terms: *case study*, *case research*, *case-based approach*, combined with the terms *operations management*, *research methodology*, *research methods*, and *challenges*. This set of keywords was chosen based on other relevant publications covering the domains investigated in this study (e.g., Eisenhardt, 1989; Voss et al., 2002, and others). After reading the titles and abstracts, papers that were not aligned with the research purpose (identification of challenges and difficulties) were discarded, resulting in 28 articles for final analysis. More details of the selection and analysis of the papers can be found in Cauchick-Miguel et al. (2019).

Afterwards, a complementary search for methodological case research papers was conducted in the International Journal of Operations and Production Management (IJOPM), one of the most well-known journals in OM and which publishes a high number of qualitative research. Only two articles were found that have not been identified in the previous search.

3.2. Exploratory survey

The second step was to conduct an exploratory survey with Brazilian researchers mostly. This survey type may be carried out when the purpose is to gain preliminary insight on a subject (Forza, 2002). The author emphasised that exploratory surveys are relevant and extensively adopted in OM. Actually, this kind of survey does not necessarily demand a theoretical model, research hypotheses, non-probabilistic sample size, pre-test, or minimum response rate [for further details refer to Forza (2002), p.188-189]. Thus, to guide this step this work followed Forza's recommendations.

A sample of all authors' contacts of IE academics was used. Seventy experienced researchers were consulted. They were from a range of institutions (a purposive sample), who are usually interested in case research in OM. It considered a single open-ended question: *what are the main difficulties when conducting case studies?* In addition, the researchers were asked to list "*up to three difficulties when engaging in case studies*" they considered being the most limiting (difficulties) in adopting the case study as a research approach. The question was sent by email with subsequent two follow up messages. The results enable to raise the difficulties and from the analysis elements to mitigate them.

After 10 weeks of sending the email (response rate about 51%), with 116 statements (in total) were obtained, read, and grouped by an affinity diagram (Figure 4). From those, 8 statements had no direct relation to what had been requested, *i.e.*, they were could not be connected difficulties associated with case research and, thus, were discarded. This resulted in 108 statements for further analysis. According to their contents, the statements were assigned to each stage of the step-by-step framework for case study previously shown in Figure 1. More details on the survey design can be found in Cauchick-Miguel & Sousa (2018); Cauchick-Miguel et al. (2019).

The identified difficulties provided the basis for raising recommendations to address them and enhance the quality of the outputs of case research and theory-building process in OM. The recommendations were elaborated based on previous literature on case research. Those were particularly relevant concerning the data analysis stage, which was identified as one of the most critical stages when conducting case-based research, from the results of data collection and analysis (Cauchick-Miguel & Sousa, 2018).

Figure 4. Affinity diagram by grouping the statements (photo by the first author). Note: colors represent a main category (step in Figure 1) where the title is showed by the post-it; white statements have multi-steps.

4. Results: case research difficulties and recommendations for addressing them

A range of difficulties when conducting case study was identified from the literature search, as summarized in Table 5. Those are related to the required theoretical background, research design, data collection and analysis, and the research report in the case research stages of Figure 1.

Concerning the survey performed with researchers in the Brazilian IE scholarly to identify the main difficulties faced when engaging in case research, 116 aspects were obtained, as mentioned in the previous section. Those represent struggles when conducting case research. Those were clustered and organized following the stages of case research, as shown in Figure 1, apart from other categories of difficulties that emerged. Table 6 summarizes the identified difficulties.

As shown in Table 6, the difficulties raised by the researchers are not necessarily the same identified in the academic literature, as the ones related to data analysis, for example. Additionally, difficulties related to the pilot test step were not reported, possibly because this step is rarely performed by those who took part in the survey. At follows, the identified issues can be summarized in some categories and provide the basis to suggest improvements that may improve the methodological rigour when conducting case research.

Table 5. Some of the difficulties when conducting case-based research.

Related to	Difficulties	References
Scope definition	Case study design; define an appropriate research question	Rowley (2002); Barratt et al. (2011)
Number of cases	Definition of the appropriate number of cases	Eisenhardt (1989); Eisenhardt & Graebner (2007)
Selecting the cases	Definition of representative cases	Sousa-Zomer et al. (2022)
Data collection	Time for collecting data; access to organizations; researchers' skills	Darke et al. (1998); Baškarada (2014)
Data analysis	Organization of data; data coding, pattern matching, data triangulation	Rowley (2002); Barratt et al. (2011); Sousa-Zomer et al. (2022)
Generalization	Types of generalization; rationale of single case study adoption	Flyvbjerg (2006); Tsang (2014); Sousa-Zomer et al. (2022)

Note: contents sourced and adapted from Cauchick Miguel & Dresch (2018), Cauchick-Miguel et al. (2019), Sousa-Zomer et al. (2022).

Table 6. Summary of the main researchers' difficulties [adapted from Cauchick-Miguel et al. (2019)].

Category	Difficulties
Definition of the theoretical conceptual framework	Definition of the research opportunity
	Building up the theoretical framework
Case planning	Limited access to companies
	Definition of the ideal number of cases
	Development of the research protocol
Conducting the pilot test	No difficulties were pointed out
Data collection	Conducting the research protocol as planned
	Evaluation of the evidence sources quality
	Reduced access to different sources of evidence
Data analysis	Excessive volume of data
	Very descriptive results with limited analysis
Report writing	Failure to communicate the validity of the research findings
	Selection of relevant points that should be reported
Multi-stage	Low reliability of the information
	Choice of appropriate procedures for each step
Generalization	Lack of understanding of what is generalizing from case studies
Case study definition	Limited understanding of what a case study is
	Characterization of the case study in terms of its timing and type

4.1. Case research opportunities for improvement: Aquila's' hells in the Brazilian industrial engineering context

After reading, recording, and organizing the statements provided by survey participants, a content analysis was performed. Then, the main difficulties presented in the previous section, were further classified into three 'Aquila's hells', namely:

- Weak theoretical background, e.g., previous literature analysis that does not lead to a research opportunity or that identifies research gaps, as already identified by previous scholars as an essential step in any research effort (e.g., Eisenhardt & Graebner, 2007; Barratt et al., 2011; Cauchick Miguel & Dresch, 2018);
- Careless case study design/planning (Gerring, 2004; Eisenhardt & Graebner, 2007; Baškarada, 2014), e.g., selection of the unit of analysis; and
- Fragile/uncertain data analysis, e.g., definition of criteria for data analysis, description of the data analysis procedures, coding and analyzing the data in such a way that the research provides new insights instead of just a description of the data (Lu & Shulman, 2008; Barratt et al., 2011).

When revisiting previous studies that offer recommendations, those were related to the following actions and decisions in the case research (Cauchick Miguel, 2007; Cauchick Miguel & Dresch, 2018): (*i*) development of a theoretical background (e.g., identify research gaps, constructs, contradictions, etc.); (*ii*) define the type of research (e.g., exploratory, explanatory, etc.); (*iii*) planning the research (e.g., consider the types of validity; see section 6); (*iv*) establish criteria for case selection (e.g., access is essential but it is not enough to justify a choice); (*v*) data collection (e.g., develop a robust research protocol, take multiple sources of evidence into account); and (*vi*) data analysis (e.g., organize data, triangulate the data, code the data, identify patterns, cross-analysis in multiple cases, etc.); and (*vii*) correlate findings to existing literature and theory in order to move forward (i.e., create a new theory, test, or extend/refine it). Indeed, all of them are relevant to case research. Nevertheless, the data analysis stage was identified in the survey as one of the main constraints in the context of the Brazilian industrial engineering scholars. Thus, the recommendations here mainly addressed concerns regarding the data analysis stage. To illustrate that, a couple of examples of quotes from two respondents were:

> (i) Difficulty of analyzing the data, and this can lead to a text that is too descriptive,

and

> (ii) Difficulty of discussing the results and confronting them with the existing theory associated to the phenomenon or the investigated research problem.

As can be seen, the quotes are somewhat simple, suggesting that this stage of case research is still weakly addressed. This is concerning as the data analysis is a critical step in the case research and an appropriate step for generating new findings and theory development. Quote (*i*) is related to usual reported results on case-based research within the Brazilian IE scholar, *i.e.*, the results are too descriptive and less analytical. Actually, the 'how' description of data analysis is usually neglected in case research when the outlets from the Brazilian IE researcher are examined. The reports are often a storyline of what was collected in the field, and the methods usually focus on describing the data sources and collection procedures, with limited attention given to explaining 'how' the data has been triangulated and analyzed, indicating a poor use of data analysis strategies and techniques, e.g. coding.

Data analysis can range from a shallow description to a theoretical interpretation of data and facts. After collecting data in the field (considering multiple sources of evidence, as an example in Table 7), data reduction must be carried out (i.e., not 'all' data should be included in the analysis or the report).

The analysis should only consider data that is narrowly related to the research objectives and constructs. A narrative should be produced as early as possible. Actually, *a priori* theorization is essential to frame the research design (Ketokivi & Choi, 2014), allowing a deeper understanding of the narrative in the light of the literature, for instance. It is recommended to type up field notes as soon as possible both to maximize recall and to facilitate follow-up and filling of gaps in the data.

Interviews should be conducted by at least two of the authors, in order to enhance the information gathering's reliability (Dubé & Paré, 2003), especially for data analysis. In addition, idiosyncratic responses should be disregarded in the interest of focusing on dominant patterns among interviewees (Tortorella et al., 2021).

If interviews were audio-recorded, information should be fully transcribed and subsequently analyzed qualitatively and discussed by the authors. Summaries should be then consolidated after reaching a consensus on the main findings (Miles & Huberman, 1994; Miles et al., 2014). The transcriptions should be also made as shortly after as possible, for instance, to remember details of the interview environment such as interviewees' reactions. The same procedure is true for field observations. Observations, however, have their potential drawbacks. A researcher may give meaning to a situation based on observation without checking out that meaning with participants (Corbin & Strauss, 2008). Thus, it is important to triangulate the different data sources, so the findings of the case study will be supported by multiple sources of evidence. Other information like secondary data should also be considered to support the analysis in addition to internal documents that the researchers managed to have access. All of this data documentation produces a case narrative made up of the transcriptions of notes, all data sources, and ideas and insights. Narrative accuracy may be enhanced by letting key informers assess draft reports.

As mentioned earlier, data reduction of the raw data is necessary. After the data collection, the first step is to convert these data into text files organized in a case study database. However, just transcribing the data and building a narrative considering all sources of evidence is not enough. According to Yin (1994), data analysis involves examining, categorizing, tabulating, testing or recombining evidence to produce findings that contribute to existing literature. It is important to highlight that any scientific research should contribute to the scholarly literature, and this contribution should be evident from the research findings.

The researcher can start the analysis process by playing with the data. Some options to start manipulating the data include (Miles & Huberman, 1994): (i) developing a matrix of categories and placing the evidence within the established categories; (ii) creating data displays such as flowcharts and other graphics, (iii) tabulating the frequency of different events, and (iv) using a temporal scheme to describe the events. Table 8 presents an example of display organizing the collected data for a modularity study. If multiple cases are investigated, a display summarizing the data for each case should be developed, and a cross-case analysis should be performed afterwards to identify convergent and divergent aspects across the cases and data sources. A display is an example of a data organizing technique that can help to identify patterns and relationships in the data and to develop a clear chain of evidence that will lead to robust findings supported by the data. A clear chain of evidence is one of the conditions to increase the validity of the research.

Table 7. Data collection details from various sources of evidence in multiple cases.

	Data collection sources		
Case	**Interviewers**	**Observation (visits)**	**Analysis of documents**
Company A	Quality manager	Production line	Digital documents
	Purchasing manager	Administrative sector	Criteria for suppliers' selection
	RandD leader	Product engineering	ISO 9001 procedures
	Training and developing supervisor	Customer support	Customer records (public)
		Human resources section	Documents obtained at the site
Company B	Business unit director	Business unit	ISO 9001 procedures
	Purchasing supervisor	Administrative sector	Digital documents
	Production manager	First tier suppliers	Criteria for suppliers' selection
Company C	Personnel supervisor	Administrative sector	Financial balance sheet
	Quality management supervisor and production manager	Production line I and II	ISO 9001 procedures
		Assembly line	Performance report
		Human resources section	Digital documents
	Production manager	Suppliers (2nd tier)	Criteria for suppliers' selection
Company D	RandD manager	Research center	Digital documents
	Project leaders	Product engineering	ISO 9001 procedures
	Business unit director	Business unit	Performance report

Note: table constructed and adapted from one of the authors' research actual data (not published).

Preliminary analyses after manipulating the data can then support moving towards an analytical strategy. According to Yin (1994), the researcher can use four different analytical strategies in the data analysis process:

- Relying on theoretical propositions: if theoretical propositions were identified in the literature review and the objectives and design of the case study were defined based on such propositions, those should be the focus and guide the data analysis;
- Working the data from the 'ground up': this strategy is the opposite of working with propositions; instead of analyzing the data with a preliminary view of the propositions, this strategy consists of finding new insights and developing concepts from the data, i.e., inductively;
- Developing a case description: this strategy consists of organizing the case study data according to some descriptive framework; and
- Analyzing rival explanations: this strategy defines and tests rival explanations and can be applied with the three previous strategies.

A detailed description of each of those strategies can be found in Yin (1994). The point is that the researcher should be aware that a procedure should be followed for the data analysis, and a strategy should be adopted, depending on the purpose of the study.

Additionally, it is important to highlight that coding the data is a common practice when employing analytical strategies. Coding the data is, actually, the first step in the data reduction process (Sousa, 2005). It consists of highlighting parts of the texts and developing codes that might represent pre-defined categories (e.g., when adopting a deductive approach and, for example, working with pre-established propositions) or that will support the development of new themes and concepts (i.e., when working on the data from the 'ground up' or conducting an inductive analysis). The codes can be seen as 'blocks' that represent the data related to what has been explored, related to either the research question or the constructs identified in the literature. Table 9 shows an example of codes and their meaning for a previous work looking at modularity.

Table 8. Example of a display for organizing collected data and constructs.

Evidence	Conceptual elements		
	Product modularity	Production modularity	Modules supply
Interview (13/04/09)	The modules are divided into M1- Driver's Station; M2 – Front Axle; M3 – Transport Module; M4 – Rear Axle and 3rd Axle; M5 – Power train	The automaker held a competition to select the supplier for the instrument panel design (process engineer – assembly line manager 1) The modules are divided into M1- Driver's Station; M2 – Front Axle; M3 – Transport Module; M4 – Rear Axle and 3rd Axle; M5 – Power train	Some suppliers deliver assembled modules such as seats and wheels with the tires already installed and calibrated
Interview (07/05/09)	The definition of a module in our company is having a common interface ... (Product manager; platform manager)	To facilitate the assembly of the truck body, they are mounted upside down (...) there are two lines in parallel, one that assembles the body and the other that then turns the body into its normal position and completes the assembly of the truck (fits the cabin, banks, etc.). The door is mounted in the cab and its components installed in it, without removing it from the cab, as there is no space for a sub-assembly of the doors outside the cab.	The company had a project for the instrument panel to be assembled by the supplier, but it didn't work out, as the sub-suppliers of panel components would charge a higher value for the parts than the value they sell to the company
Reports (report of qualified suppliers) Document Analysis (Minutes)	Not available (no access)	Not available (no access)	The subassembly suppliers are responsible for the quality of the products they buy from other suppliers (2nd tier supplier)
Plant visit (07/05/09)			Instrument panel: delivered disassembled, but with all components delivered by the supplier; It is mounted without the steering and the assembly is installed on the truck

Note: this example (unpublished data) is based on the research project "Contingency factors in the modularity adoption in companies from the automotive sector".

After analyzing the data, for instance, the findings and conclusions could be compared with the existing theory, and the researcher should elaborate on how the findings contribute to the existing literature. In addition, it is important to highlight that the data analysis procedures should be planned ahead of time and explicitly reported later in any kind of work (e.g., dissertations, thesis, articles, etc.). This also provides traceable research evidence.

Overall, the quality of outputs of case research is heavily based on the quality of the data analysis process. Thus, it is important that the Brazilian research moves towards improving rigour in the methodological approaches as that would increase the impact and international recognition of national research outputs.

5. Moving forward: next stage in enhancing case research quality

From the authors' observations, there is another issue that the vast majority of publications from the Brazilian scholarly community simply omit: research validity. Table 10 shows the types of validity that should be considered in case-based research, including a brief definition of the different validity types, as well as an overall assessment of how developed each type of validity is within the Brazilian IE scholarly community.

When conducting case research, the researcher should be concerned with the study's validity in terms of the methodological procedures and its results. The researcher should reflect on: (i) *what are the main concerns regarding the validity of this study?* and (ii) *how can I control the quality of the research and its outputs?* In order to ensure the validity and quality of the research procedures and outputs, the researcher should carefully consider the quality criteria and respective aspects as described in Table 11.

Research impact cannot be achieved without adequately addressing the different types of validity and reliability of case research. This is an essential issue that should be taken further in the efforts of the Brazilian IE community to improve methodological rigor in the domestic context.

Table 9. Example of codes (meaning) for highlighting in the evidence (interview transcription, company internal document, etc.).

Code	Brief description
INT	Driver related to the modular interfaces
TYPMODTAWARE	Organizational awareness regarding modularity practices adoption
TYPMOD	Type of modularity (product, production, and organizational) and their relationship
EXTMOD	External drivers of modularity
HISTORYMOD	Historical evidence of modularity

Note: those codes come from the research project "Contingency factors in the modularity adoption in companies from the automotive sector" (unpublished data).

Table 10. Types of validity (Croom, 2005).

Validity	Definition	'Assessment' (authors' observations)
Internal	Level of confidence regarding cause and effect; it is also defined as the "*approximate validity with which we infer that a relationship between two variables is casual*" (Cook & Campbell, 1979, p. 37)	No development
External	The general applicability of the conclusions and their reflection of reality, i.e.. it has to do with the degree to which the results of a study can be generalized to populations of unit of analysis (e.g., people, settings, times, etc.)	Moderate development
Construct	Extent to which an observation measures the concept it is intended to measure, i.e. the researcher must clearly specify the way the construct was represented in order for the reader of a report to understand what was done and to evaluate the quality of the measure	No development
Descriptive	Extent to which the research reported is accurate, i.e. it refers to the degree that the account reported by the researcher is accurate	Moderate development
Interpretative	Extent to which the research portrays the subject's meaning i.e. is present to the degree that the researcher accurately portrays the meaning given by participants to what is being studied	No development
Theoretical	Extent to which the data fits the theory postulated, i.e., the extent that a theoretical explanation provided by the researcher fits the data	No development

Note: the original source is the work of Croom (2005). In addition, a table in Cauchick-Miguel et al. (2019, p. 142) was adapted by including more information on the types of validity as well as the 'development assessment' column, by using a simple scale: 'no development'; 'moderate development'; 'well-developed'.

Table 11. Quality criteria that should be considered in case research and how to address it.

Quality criteria	How to address it?
Construct validity	Clear chain of evidence - Does the paper provide a clear chain of evidence allowing the readers to reconstruct how the researcher went from the initial research questions to the final conclusions?
	Data triangulation - Does the paper adopt different angles from which to look at the same phenomenon, does it use different data collection strategies and different data sources?
Internal validity	Research framework - Does the paper formulate a clear research framework, which demonstrates that variable x leads to outcome y, and that y was not caused spuriously by a third variable?
	Pattern matching - Does the paper compare empirically observed patterns with either predicted ones or patterns established in previous studies and in different contexts?
	Theory triangulation - Does the paper address theory triangulation and verify the findings by adopting multiple perspectives?
External validity	Cross-case analysis - Does the paper adopt multiple case studies (case studies of different organizations) or different case studies within one organization?
	Rationale for case study selection - Does the paper provide an explanation for why the particular case study was appropriate based on the research question?
	Case study context - Does the paper provide details on case study context?
Reliability	Case study protocol - Does the paper report on a research protocol?
	Case study database - Does the paper provide evidence of a case study database with the available documents, transcripts, archival data, etc?

Note: adapted from Sousa-Zomer et al. (2022) and developed based on Cook & Campbell (1979), Eisenhardt (1989), Yin (1994), Gibbert et al. (2008).

6. Concluding remarks

This research aimed to create awareness among the Brazilian community in industrial engineering on the importance of addressing existing weaknesses related to methodological rigor when conducting case research. While case research is a methodological approach that has been widely adopted among the Brazilian community of IE scholars, it remains poorly executed in practice, especially regarding critical steps such as the data analysis stage. The results reveal that there is recognition in the community that difficulties should be addressed. Those were summarized as the main 'Aquila's hells', namely: (i) weak theoretical background, (ii) careless case study design/planning, and (iii) fragile/uncertain data analysis. Suggestions for dealing with current flaws in the data analysis stage are proposed. The paper also draws the attention of researchers to the need to address research validity to increase the quality of the research outputs and recognition of national outputs in international journals.

As every research work, this paper does suffer from limitations too. The principal one may be related to the Aquila's' hells, besides data analysis. Theoretical background as well as careless design and planning in case-based research are also a crucial to achieve more rigour and research recognition.

Faced with the current state of case research adopted in the Brazilian IE scholars, this paper may offer practical contributions in a couple of points. The first one is related to the whole structure. To develop a case study, there is no short cut, especially if the intend is towards a theoretical contribution, e.g., as in a doctorate circumstance. The second one is the point explored in more details in this paper: data analysis. Practically, it is of paramount importance to reduce studies that are merely descriptive, confirmatory, and non-causal. Of course, not only data analysis can assist in achieving that but also a more robust design of other stages. Finally, the third point is related to rigour. There is no rigour if the irregularities persist. A truly incorporation of the types of validity is needed and researchers should emphasize them in their case research.

While addressing research quality is a need, the authors recognize the existing limitations in terms of guidance in the national context on how to conduct a valid and reliable study. Further research will provide more detailed suggestions and recommendations on how the different types of validity and reliability should be considered along the stages of case research.

References

Barratt, M., Choi, T. Y., & Li, M. (2011). Qualitative case studies in operations management: trends, research outcomes, and future research implications. *Journal of Operations Management*, *29*(4), 329-342. http://dx.doi.org/10.1016/j.jom.2010.06.002.

Baškarada, S. (2014). Qualitative case study guidelines. *Qualitative Report*, *18*(4), 1-18.

Benvenuti, E. W., Oliveira, P. T., & Cauchick-Miguel, P. A. (2011). Preliminary diagnostic of knowledge areas in production engineering and research approaches adopted in publications of an important national journal. In *Anais do XVII Simpósio de Engenharia de Produção*. Bauru, Brazil: UNESP. In Portuguese.

Berto, R. M. V. S., & Nakano, D. N. (2000). Scientific publications in the proceedings from the National Congress of Production Engineering: a study of research types and methods. *Production*, *9*(2), 65-76. http://dx.doi.org/10.1590/S0103-65131999000200005. In Portuguese.

Berto, R. M. V. S., & Nakano, D. N. (2014). Revisiting scholarly output in the records of the Brazilian Meeting of Industrial Engineering. *Production*, *24*(1), 225-232. http://dx.doi.org/10.1590/S0103-65132013005000007. In Portuguese.

Bertrand, J. W. M., & Fransoo, J. C. (2002). Operations management research methodologies using qualitative modeling. *International Journal of Operations & Production Management*, *22*(2), 241-264. http://dx.doi.org/10.1108/01443570210414338.

Boyer, K. K., & McDermott, C. (1999). Strategic consensus in operations strategy. *Journal of Operations Management*, *17*(3), 289-305. http://dx.doi.org/10.1016/S0272-6963(98)00042-4.

Carter, N., Bryant-Lukosius, D., DiCenso, A., Blythe, J., & Neville, A. (2014). The use of triangulation in qualitative research. *Oncology Nursing Forum*, *41*(5), 545-547. http://dx.doi.org/10.1188/14.ONF.545-547. PMid:25158659.

Cauchick Miguel, P. A. (2007). Case study in production engineering: structure and recommendations for its conduction. *Production*, *17*(1), 216-229. In Portuguese.

Cauchick Miguel, P. A. (2010). *Research methodology in production engineering and operations management*. Rio de Janeiro: Campus-Elsevier. Case study adoption in production engineering, pp. 129-144. In Portuguese.

Cauchick Miguel, P. A. (2011). Qualitative research approach in production engineering: an assessment of a research project and a sample of master of science dissertations. *Exacta*, *9*(2), 197-206. http://dx.doi.org/10.5585/exacta.v9i2.2503.

Cauchick Miguel, P. A., & Dresch, A. (2018). Difficulties when conducting case studies in operations management: analysis and recommendations. In P. Demartini, M. Marchiori (Eds.), *17th European Conference on Research Methodology for Business and Management Studies*. Reading, United Kingdom: Academic Conferences and Publishing International Limited.

Cauchick-Miguel, P. A., & Sousa, R. (2018). The method of case study in production engineering. In P. A. Cauchick-Miguel (Ed.), *Research methodology in production engineering and operations management* (3rd ed., pp. 130-146). Rio de Janeiro: Campus-Elsevier. In Portuguese.

Cauchick-Miguel, P. A., Sousa-Zomer, T. T., & Dresch, A. (2019). Difficulties when adopting case study in engineering. In P. A. Cauchick-Miguel (Ed.), *Scientific methodology for engineering* (pp. 189-214). Rio de Janeiro: Elsevier. In Portuguese.

Childe, S. J. (2011). Case studies in operations management. *Production Planning and Control*, *22*(2), 107-107. http://dx.doi.org/10.1080/09537287.2011.554736.

Cook, T. D., & Campbell, D. T. (1979). *Quasi-experimentation: design and analysis issues for field settings*. Chicago: Rand McNally.

Coombs, H. (2022). *Case study research: single or multiple*. Retrieved in 2023, July 26, from https://haydencoombs.files.wordpress.com/2022/09/case-study-research-coombs-2022-3.pdf. White paper.

Corbin, J., & Strauss, A. (2008). *Basics of qualitative research*. Thousand Oaks: Sage.

Corrêa, H. L. (1992). *The links between uncertainty, variability of outputs and flexibility in manufacturing systems* (Ph.D. thesis). University of Warwick, Warwick.

Correa, H. L. (2020). *Milestones of research methodology in IE in Brazil*. Personal communication by email message with Professor Henrique Correa, 3rd October, 2020.

Coughlan, P., & Coghlan, D. (2002). Action research for operation management. *International Journal of Operations & Production Management*, *22*(2), 220-240. http://dx.doi.org/10.1108/01443570210417515.

Creswell, J. W., & Poth, C. N. (2018). *Qualitative inquiry and research design: choosing among five approaches*. London: Sage.

Croom, S. (2005). Topic issues and methodological concerns for operations management research. In European Institute for Advanced Studies in Management (Org.), *EDEN Doctoral Seminar on Research Methodology in Operations Management*. Brussels, Belgium: EIASM.

Darke, P., Shanks, G., & Broadbent, M. (1998). Successfully completing case study research: combining rigour, relevance and pragmatism. *Information Systems Journal*, *8*(4), 273-289. http://dx.doi.org/10.1046/j.1365-2575.1998.00040.x.

Drejer, A., Blackmon, K., & Voss, C. (2000). Worlds apart? A look at the operations management area in the US, UK and Scandinavia. *Scandinavian Journal of Management*, *16*(1), 45-66. http://dx.doi.org/10.1016/S0956-5221(99)00002-0.

Dresch, A., Lacerda, D. P., & Cauchick-Miguel, P. A. (2015). A distinctive analysis of case study, action research and design science research. *Revista Brasileira de Gestão de Negócios*, *17*(56), 1116-1133. http://dx.doi.org/10.7819/rbgn.v17i56.2069.

Dubé, L., & Paré, G. (2003). Rigor in information systems positivist case research: current practices, trends and recommendations. *Management Information Systems Quarterly*, *27*(4), 597-635. http://dx.doi.org/10.2307/30036550.

Eisenhardt, K. M. (1989). Building theories from case study research. *Academy of Management Review*, *14*(4), 532-550. http://dx.doi.org/10.2307/258557.

Eisenhardt, K. M., & Graebner, M. E. (2007). Theory building from cases: opportunities and challenges. *Academy of Management Journal*, *50*(1), 25-32. http://dx.doi.org/10.5465/amj.2007.24160888.

Eisenhardt, K. M., Graebner, M. E., & Sonenshein, S. (2016). Grand challenges and inductive methods: rigor without rigor mortis. *Academy of Management Journal*, *59*(4), 1113-1123. http://dx.doi.org/10.5465/amj.2016.4004.

Filippini, R. (1997). Operations management research: some reflections on evolution, models and empirical studies in OM. *International Journal of Operations & Production Management*, *17*(7), 655-670. http://dx.doi.org/10.1108/01443579710175583.

Filippini, R., & Voss, C. (1997). Editorial. *International Journal of Operations & Production Management*, *17*(7), 653-654.

Flyvbjerg, B. (2006). Five misunderstandings about case-study research. *Qualitative Inquiry*, *12*(2), 219-245. http://dx.doi.org/10.1177/1077800405284363.

Forza, C. (2002). Survey research in operations management: a process-based perspective. *International Journal of Operations & Production Management*, *22*(2), 152-194. http://dx.doi.org/10.1108/01443570210414310.

Gerring, J. (2004). What is a case study and what is it good for? *The American Political Science Review*, *98*(2), 341-354. http://dx.doi.org/10.1017/S0003055404001182.

Gibbert, M., Ruigrok, W., & Wicki, B. (2008). What passes as a rigorous case study? *Strategic Management Journal*, *29*(13), 1465-1474. http://dx.doi.org/10.1002/smj.722.

Grodal, S., Anteby, M., & Holm, A. L. (2021). Achieving rigor in qualitative analysis: the role of active categorization in theory building. *Academy of Management Review*, *46*(3), 591-612. http://dx.doi.org/10.5465/amr.2018.0482.

Hatchuel, A. (2009). A foundationalist perspective for management research: an European trend and experience. *Management Decision*, *47*(9), 1458-1475. http://dx.doi.org/10.1108/00251740910995666.

Hussein, A. (2009). The use of triangulation in social sciences research: can qualitative and quantitative methods be combined? *Journal of Comparative Social Work*, *4*(1), 106-117. http://dx.doi.org/10.31265/jcsw.v4i1.48.

Hyer, N. L., Brown, K. A., & Zimmerman, S. (1999). A social-technical systems approach to cell design: case study and analysis. *Journal of Operations Management*, *17*(2), 179-203. http://dx.doi.org/10.1016/S0272-6963(98)00034-5.

Ketokivi, M., & Choi, T. (2014). Renaissance of case research as a scientific method. *Journal of Operations Management*, *32*(5), 232-240. http://dx.doi.org/10.1016/j.jom.2014.03.004.

Larsson, R. (1993). Case survey methodology: quantitative analysis of patterns across case studies. *Academy of Management Journal*, *36*(6), 1515-1546. http://dx.doi.org/10.2307/256820.

Leonard-Barton, D. (1990). A dual methodology for case studies: synergistic use of a longitudinal single site with replicate multiple sites. *Organization Science*, *1*(3), 248-266. http://dx.doi.org/10.1287/orsc.1.3.248.

Lu, C., & Shulman, S. W. (2008). Rigor and flexibility in computer-based qualitative research: introducing the Coding Analysis Toolkit. *International Journal of Multiple Research Approaches*, *2*(1), 105-117. http://dx.doi.org/10.5172/mra.455.2.1.105.

Martins, R. (1999). *Measuring performance systems: a model to structure the use* (Doctoral dissertation). University of São Paulo, São Paulo. In Portuguese.

McLachlin, R. (1997). Management initiatives and just-in-time manufacturing. *Journal of Operations Management*, *15*(4), 271-292. http://dx.doi.org/10.1016/S0272-6963(97)00010-7.

Mello, C. H. P., Turrioni, J. B., Xavier, A. F. X., & Campos, D. F. (2012). Action research in production engineering: a structure proposal for its conduction. *Production*, *22*(1), 1-13. http://dx.doi.org/10.1590/S0103-65132011005000056. In Portuguese.

Meredith, J. (1998). Building operations management theory through case and field research. *Journal of Operations Management*, *16*(4), 441-454. http://dx.doi.org/10.1016/S0272-6963(98)00023-0.

Meredith, J., & Vineyard, M. (1993). A longitudinal study of the role of manufacturing technology in business strategy. *International Journal of Operations & Production Management*, *13*(12), 3-14. http://dx.doi.org/10.1108/01443579310048182.

Miles, M., & Huberman, M. (1994). *Qualitative data analysis: an expanded sourcebook*. Thousand Oaks: Sage.

Miles, M., Huberman, A. M., & Saldana, J. (2014). *Qualitative data analysis: a methods sourcebook*. London: Sage.

Narasimhan, R., & Jayaram, J. (1998). Causal linkages in supply chain management: an exploratory study of North American manufacturing firms. *Decision Sciences*, *29*(3), 579-605. http://dx.doi.org/10.1111/j.1540-5915.1998.tb01355.x.

Pannirselvam, G. P., Ferguson, L. A., Ash, R. C., & Siferd, S. P. (1999). Operations management research: an update for the 1990s. *Journal of Operations Management*, *18*(1), 95-112. http://dx.doi.org/10.1016/S0272-6963(99)00009-1.

Rowley, J. (2002). Using case studies in research. *Management Research News*, *25*(1), 16-27. http://dx.doi.org/10.1108/01409170210782990.

Saunders, M., Lewis, P., & Thornhill, A. (2012). *Research methods for business students* (6th ed.). London: Pearson Education Limited.

Scudder, G. D., & Hill, C. A. (1998). A review and classification of empirical research in operations management. *Journal of Operations Management*, *16*(1), 91-101. http://dx.doi.org/10.1016/S0272-6963(97)00008-9.

Slack, N., Lewis, M., & Bates, H. (2004). The two worlds of operations management research and practice: can they meet, should they meet? *International Journal of Operations & Production Management*, *24*(4), 372-387. http://dx.doi.org/10.1108/01443570410524640.

Soltani, E., Ahmed, P. K., Liao, Y. Y., & Anosike, P. U. (2014). Qualitative middle-range research in operations management: the need for theory-driven empirical inquiry. *International Journal of Operations & Production Management*, *34*(8), 1003-1027. http://dx.doi.org/10.1108/IJOPM-11-2012-0486.

Sousa, R. (2005). Case research seminar. In European Institute for Advanced Studies in Management (Org.), *EDEN Doctoral Seminar on Research Methodology in Operations Management*. Brussels, Belgium: EIASM.

Sousa-Zomer, T. T., Abreu, J. L., Cauchick-Miguel, P. A., Tortorella, G. L., Piran, F., & Lacerda, D. P. (2022). What passes as a rigorous case research in operations management: an analysis of two decades of empirical research. In European Operations Management Association (Org.), *29th International EurOMA Conference*. Brussels, Belgium: EurOMA.

Thomé, A. M. T., Scavarda, L. F., & Scavarda, A. J. (2016). Conducting systematic literature review in operations management. *Production Planning and Control*, *27*(5), 408-420. http://dx.doi.org/10.1080/09537287.2015.1129464.

Tortorella, G. L., Fogliatto, F. S., Cauchick-Miguel, P. A., Kurnia, S., & Jurburg, D. (2021). Integration of Industry 4.0 technologies into Total Productive Maintenance practices. *International Journal of Production Economics*, *240*, 108224. http://dx.doi.org/10.1016/j.ijpe.2021.108224.

Tsang, E. W. K. (2014). Generalizing from research findings: the merits of case studies. *International Journal of Management Reviews*, *16*(4), 369-383. http://dx.doi.org/10.1111/ijmr.12024.

Voss, C. (2009). Case research in operations management. In C. Karlsson (Ed.), *Researching operations management*. London: Routledge.

Voss, C., Johnson, M., & Godsell, J. (2015). Revisiting case research in operations management. In European Operations Management Association (Org.), *22nd International EurOMA Conference*. Brussels, Belgium: EurOMA.

Voss, C., Tsikriktsis, N., & Frohlich, M. (2002). Case research in operations management. *International Journal of Operations & Production Management*, *22*(2), 195-219. http://dx.doi.org/10.1108/01443570210414329.

Yin, R. (1994). *Case study research: design and methods*. London: Sage.