Integration, uncertainty and information: how do they affect planning performance?

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Abstract

Purpose – Effective planning requires the participation of different functions and may be hampered by lack of integration and information quality (IQ). This paper aims to investigate the relationships among integration, uncertainty, IQ and performance, in the context of the production planning and control function. The literature lacks in-depth studies that consider these factors altogether, showing how they interact and how they contribute to improve business performance.

Design/methodology/approach – The authors introduce the variable of planning performance, which represents the quality of the production plans/planning process and is related to the frequency and causes of modifications to these plans. The relationships among the mentioned constructs are investigated by means of multiple case studies.

Findings – The results illustrate that integration is positively related to planning performance, and this relationship is mediated by IQ and moderated by uncertainty.

Originality/value – The presented analysis may help practitioners to foster interfunctional integration, better cope with uncertainty and improve information management, aiming to achieve better planning performance. The managers can choose integration and IQ improvement mechanisms that better fit to their environment/reality, using the four different cases as a benchmark. Moreover, this research contributes to the literature exploring this contingency perspective by means of in-depth case studies, considering that most of the existing research adopting this perspective is survey-based.

Keywords Integration, Uncertainty, Information sharing, Performance measures, Operations planning

Paper type Case study

1. Introduction

A myriad of methodologies and practices for operations management, supply chain management and continuous improvement arose over the last five decades. Several cases illustrate the success – and sometimes the failure – of these practices. As argued some time ago, they can be neither considered substitutes of a manufacturing strategy (Skinner, 1969; Hayes & Wheelwright, 1984) nor a panacea for managerial problems. The effective application of these methodologies, as seen in many cases, is hampered by organizational and cultural issues inside the companies as well as by environmental uncertainties.

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In this sense, the study of the internal integration and uncertainty remains relevant. The organizational integration supports the performance of the firm (Fabbe-Costes & Jahre, 2008; Sagawa & Nagano, 2015; Chang, Ellinger, Kim & Franke, 2016). Indeed, many of the studies in this area investigate dyadic relationships between integration and other organizational variables, such as business performance, manufacturing competitive priorities or information quality. The uncertainty is added as a moderating variable, and the level of analysis may consider specific processes and functions, the whole firm or the supply chain. In this paper, the production planning and control (PPC) function is chosen as the main point of investigation. In addition, a specific dimension related to the performance of the PPC function is considered: the planning performance, which represents the quality of the plans and planning process. It refers to the stability and responsiveness of the production plans and schedules, and it is related to the frequency and causes of modifications to these plans.

Given this overall context, the present research aims to answer the following research questions:

RQ1. How does the internal integration affect the planning performance?

RQ2. How do the uncertainty and the information quality (IQ) affect the relationship between internal integration and planning performance?

RQ3. Which are the internal integration mechanisms used in the companies, considering the production planning function, and how can they affect the planning performance or the competitive performance?

Therefore, the objective of this paper is to investigate the relationships among integration, uncertainty, IQ and performance, in the context of PPC function, considering the planning performance as a dimension of performance. More specifically, the study aims to observe how the level and the existing enablers of integration impact the effectiveness of the production planning, and how this relationship is influenced by the environmental uncertainty and intervened by the IQ available for planning.

As the scope of investigation encompasses multiple variables (instead of pair-wise correlations) and the intention is to describe "how" and "why" contemporary events occur, the research was conducted by means of multiple case studies. The review of literature also showed that there is room for in-depth studies to complement the existing survey-based studies with narrower focus.

In summary, the contributions of this research are as follows:

(1) to provide well-documented case studies showing the relationships among integration, information quality, uncertainty and performance, with the PPC as a focal function;

(2) to introduce the construct of planning performance in the above-mentioned relationship and

(3) to analyze different antecedents of integration used in the companies.

The structure of the paper is as follows. In the next section, the extant empirical research involving the variables of the study is reviewed. After that, the methodological structure is described. The individual analyses of the multiple cases are presented in Section 4, and the cross-case analysis and discussions are presented in Section 5. The last section summarizes the main findings.

2. Theoretical background

2.1 Empirical research on integration, information quality, uncertainty and performance

The empirical research involving the aforementioned constructs is continually increasing. The dyadic relationship between integration and performance is the most explored branch,

and many authors included in this dyad are moderating the influence of uncertainty. This relationship is analyzed in three levels: intrafunctional, interfunctional (internal integration) or supply chain level (external integration). In the supply chain level, external integration is usually divided into supplier integration and customer integration.

De Snoo, Van Wezel & Jorna (2011) and Gustavsson (2007) investigated the intrafunctional level, focusing the analysis on the production planning and control function. The perspective of interfunctional integration is considered in O'Leary-Kelly & Flores (2002) and Pagell (2004). The first ones have found that the integration of sales/marketing decisions in firms that were subjected to high levels of environmental uncertainty led to a better performance. Pagell (2004) presented the antecedents of internal integration, as they will be discussed in the next subsection.

In Gustavsson (2007), the integration is divided into organizational and technical dimensions. Organizational integration refers to the mechanisms, practices and culture that encourage collaborative and reciprocal relationships between the functions of an organization, e.g. working teams, standardized operating procedures and alignment of goals. On the other hand, technical integration or information system (IS) integration is associated to information and communication technology (ICT) processes by means of two dimensions: interface and compatibility. When the interface is manual or more dependent on people (fax, phone and e-mail), the technical integration is considered low, while automatic means (EDI, web, server and portals) characterize higher technical integration. In addition, ICT incompatibility among systems (such as the use of legacy systems or systems that do not support integration and automatic data transfer) characterize a low level of integration. Existing studies showed that IS integration is positively associated with cost and quality performance is indirectly associated to firm performance (Maiga, Nilsson & Ax, 2015).

This topic concerning information technology is also explored by Pérez-López *et al.* (2019). They present a structural equation model with five variables/constructs related to the integration of ICT in production systems and in the supply chain, namely: information exchange, operations management, production control, distribution activities and operational benefits. It was found that the implementation of information technologies facilitates the exchange of information, operations management and production control. ICT integration provides visibility for the supply chain and facilitates operation management in production lines and distribution activities. These benefits affect the operational performance, measured as flexibility, low cost and shorter cycle times for customers.

At the supply chain level, positive relationships between integration and performance were observed (Li, Ragu-Nathan, Ragu-Nathan & SubbaRao, 2006; Flynn, Huo & Zhao, 2010; Lee, Kim, Hong & Lee, 2010). Differences about the dimensions of integration and dimensions of performance adopted by each of the aforementioned authors are presented in Table A1 in the Appendix. While analyzing these relationships, some authors adopt a contingency perspective (Flynn *et al.*, 2010) or consider the moderating effect of environmental uncertainty (Wong, Boon-itt & Wong, 2011, Kalyar *et al.* 2020). The dyad integration–performance tends to be strengthened when the company is subjected to high uncertainty in accordance with the contingency theory (Donaldson, 2001). In this sense, Kalyar *et al.* (2020) have found that environmental uncertainty moderates the relationship of both internal integration and supplier integration with supply chain efficiency. Similarly, they observed that the relationship between internal integration and supply chain effectiveness as well as the relationship between customer integration and supply chain effectiveness are strengthened under high levels of environmental uncertainty. Different dimensions of uncertainty appear in empirical research. Mula, Poler, García-Sabater & Lario (2006) classify the disturbances that affect production systems into two groups: environmental and system uncertainty. Environmental uncertainty, as known, comprises factors that are beyond the production

system, such as uncertainty of external demand and external supply, and system uncertainty refers to the disturbances occurring within the production system, such as lead time uncertainty, machine breakdowns, operation yield uncertainty, quality uncertainty among others. De Snoo *et al.* (2011) refer to this last dimension as executional uncertainty, which corresponds to internal factors that prevent the plans to be executed as planned. Alternatively, the environment surrounding the organizations is divided by Vokurka & O'Leary-Kelly (2000) into three components: objects, perceived uncertainty and attributes. The objects correspond to the different uncertainties of the environment, such as customer demand patterns, suppliers' delivery reliability or products' life cycle. The perceived uncertainty is related to the ability of managers to accurately foresee future events in their environment. The last component, attributes, comprises three dimensions, namely: complexity, munificence and dynamism. Complexity is associated with the amount and diversity of factors affecting the organization, munificence refers to the resources available to support growth and dynamism regards to the turbulence or instability of the market.

Besides uncertainty, other variables are interposed in the relationship between integration and performance. Munir *et al.* (2020) found that supply chain risk management (SCRM) is a relevant mediating variable in the relationship between integration and operational performance. It partially mediates the relationship between internal integration and operational performance and fully mediates the association between supplier and customer integration and operational performance.

In addition, multidimensional constructs for integration and performance are usually employed. For instance, it was found that internal, customer and supplier integration affect financial performance by means of mediating variables of operational, relational and strategic performance (Chang *et al.* 2016) or by means of competitive advantage (Li *et al.* 2006). The construct of performance is usually defined in terms of competitive priorities, i.e. cost, flexibility, quality, delivery speed and timeliness, such as in Wong *et al.* (2011), Pérez-Lopéz *et al.* (2019) and Munir *et al.* (2020). In Kalyar *et al.* (2020), supply chain performance is subdivided into efficiency and effectiveness, but these two dimensions are still linked with the mentioned competitive priorities. Other works consider both the operational performance, which correspond to these competitive priorities, and the business performance, which is related to more global financial metrics, such as growth in sales, ROI, growth in profit and growth in market share (Flynn *et al.*, 2010).

Since the research on the dyad of external integration and performance is voluminous, efforts have been carried out to compile and generalize findings (Fabbe-Costes & Jahre 2008; Autry, Rose & Bell, 2014; Sagawa & Nagano 2015; Chang *et al.* 2016).

The dyad of IQ and performance has also been explored. Forslund & Jonsson (2007) investigated the impact of forecast information access and quality on supply chain performance. Further investigations showed that the impact of IQ on supply chain performance is mediated by the information sharing (Marinagi, Trivellas & Reklitis, 2015). Chavez, Yu, Gimenez, Fynes & Wiengarten (2015) also found that the IQ partially mediates the relationship between customer integration and quality, delivery and flexibility.

The relationship between integration and IQ is explored by Myrelid & Jonsson (2019). By means of case studies, they investigated how different determinants of IQ affect specific dimensions of it, when demand-related information is shared in the supply chain by means of dyadic relationships. Different factors, related to three categories (information sharing, interorganizational collaboration and intraorganizational process support), were chosen as IQ determinants. These three categories are closely related to integration. The results showed that these determinants affect five pragmatic IQ dimensions (relevance, accessibility, credibility, understandability and ease of operation) in different ways; that is, sometimes in a beneficial, detrimental or varying manner. It is shown how information sharing acts as both a determinant and moderator of pragmatic IQ.

Summarizing the presented discussions, it is possible to see that the constructs of integration, IQ and performance are usually analyzed in dyads, and the findings are fragmented, since they consider different mediating variables and moderating factors (Autry *et al.*, 2014; Sagawa & Nagano 2015; Chang *et al.* 2016). In this sense, the present research aims to consider these constructs altogether and observe their interrelations as an overall picture.

It is also worth mentioning that most of the empirical results discussed so far were derived from survey-based research. It was argued that there is a lack of in-depth studies about integration attempting to move from the descriptive to the prescriptive sphere (Pagell, 2004).

2.2 Antecedents of internal integration

The extensively discussed model of Pagell (2004) considers, as a starting point, the following antecedents of internal integration: organizational structure, measurement and rewards, cross-functional teams, job rotation, communication, information technology and top management support. From these factors, formal and informal communication as well as the measurement and reward systems were found to be the most relevant, which in turn are driven by organizational culture and structure.

This branch was further explored in the ambit of supply chain, with emphasis on the barriers that moderate the relationship between the drivers of integration and firm performance (Glenn Richey, Chen, Upreti, Fawcett & Adams, 2009). Too much emphasis on functional structures and metrics was emphasized again as an internal obstacle for integration. It was found that the barriers significantly strengthened the relationship between integration drivers and firm performance.

The crossfunctional integration processes between marketing and logistics were investigated by Pimenta, da Silva & Tate (2016) by means of in-depth studies. The existence of several integration factors was verified, namely adequate communication, trust, crossfunctional meetings, support from senior management, mutual evaluation and rewards system, non-conflicting functional objectives among others.

It was found that top management support plays an important role, and that a high level of integration is obtained when integration factors formally established by senior management coexist with trust, team spirit and other informal factors. Also, a holistic strategic approach, in which impacts on the firm as a whole are perceived as more important than functional impacts, fosters the level of integration (Pimenta *et al.*, 2016). This outcome is aligned with the findings of Pagell (2004).

The subjects of internal/interfunctional integration and sales and operation planning (S&OP) are to a high extent intertwined. S&OP is recognized as a relevant and powerful process to promote interfunctional integration. On the other hand, crossfunctional integration was observed to be a relevant enabler of S&OP process (Pedroso, da Silva and Tate 2016). This shows the mutual influence of these subjects on one another. Pedroso *et al.* (2016) raised several enablers of and barriers to the S&OP process, and many of these enablers also figure as integration antecedents in the literature concerning integration–performance relationships (e.g. Pagell, 2004), namely metrics and performance evaluation, information systems, organizational structure, top management support, consolidated company strategy and process coordination. Some S&OP enablers are also related to IQ, such as forecast accuracy and information flow management. On the other hand, some barriers for S&OP implementation (Pedroso *et al.*, 2016) also represent barriers for internal integration, such as silos culture, lack of incentives and penalties, inadequate technology and information systems, lack of top management support, rigid organizational structure and lack of organizational integration culture. By means of case research, the aforementioned authors found that some success factors such as top management support, metrics and performance monitoring, information systems and training are critical for the successfull

implementation of S&OP. These factors are aligned to the antecedents presented in the internal integration literature.

The procedural quality is related to the degree to which a process ensures sensible rules to validate information and make decisions. The alignment quality is defined as the degree to which a process ensures synchronized actions and support to organizational and functional goals. This constructive engagement is the active involvement of relevant participants in the process.

As well as there is a large body of knowledge concerning integration–performance relationships, and there is also a large body concerning S&OP with its own literature. The review of this extensive literature is not within the scope of this paper.

In addition to the presented enablers/antecedents of integration, there are other factors such as innovativeness, which, according to Kalyar *et al.* (2020), positively influences the dimensions of supply chain integration (SCI) (i.e. internal, supplier and customer integration) and affects the supply chain performance.

Table A1 in the appendix outlines the literature reviewed and discussed in this section.

3. Research method

The presented theoretical review has shown that (1) there is room for in-depth studies involving these constructs and its dimensions and (2) the constructs and dimensions must be carefully defined in order to avoid mixed findings.

In order to address the gap mentioned in the first topic, the method of multiple-case study was chosen. As known, case studies are suitable for theoretical construction in exploratory research (Eisenhardt, 1989; Voss, Tsikriktsis & Frohlich, 2002). Also, a special attention was given to the definitions of the constructs of the research, as it will be shown in the next subsection.

3.1 Constructs, propositions and data collection

This study analyzes the constructs of integration, uncertainty, IQ and performance in the context of PPC as focal function. Thus, some of the definitions discussed in Section 2 were translated to the specific context of the PPC, as presented in Table 1.

An important construct that has not been employed in the previous empirical research is the planning performance, defined herein as the accuracy of the original plan and necessary frequency of modifications. These modifications are related to the environmental uncertainty and system uncertainty, as discussed in Section 2. A distinction should be made between these two causes, since the latter should be the primary focus of the managerial actions. Low frequencies of modifications in the plans imply good coordination of resources and are related to more stable plans/higher planning performance.

The main proposition of the study, derived from the questions presented in the introduction, is that the internal integration, uncertainty and IQ affect the planning performance of PPC, measured in terms of frequency of rescheduling and modification of the plans. We suppose that the higher is the uncertainty faced by the firm, the higher the frequency of rescheduling and modifications in the plans. On the other hand, the internal integration and IQ must produce the opposite effect, i.e. to reduce the frequency of rescheduling.

Moreover, the study aims to identify different causes for the rescheduling and to analyze how the planning performance is related to the operations performance objectives such as cost, dependability and flexibility. The propositions stated are represented in Figure 1.

The data collection was based on open-ended interviews with leaders and medium-level managers of the PPC function. They took from two to four hours. When possible, direct observations in the shop floor and in the office were made, and documental evidence was collected. For instance, in addition to understanding the production processes of the studied

Construct	Dimension	Definition
Internal integration	Organizational	Collaboration, stimulus for sharing decisions and coordinated actions
	Technical	ISs that support integration
	Intrafunctional	Integration and coherence among the hierarchical levels of planning (S&OP, MPS, MRP and scheduling)
	Interfunctional	Quality and intensity of the relationships between the PPC and the remaining functions (in special sales/marketing and operations)
	Enablers	Factors that enable/foster integration (communication, rewards systems and organizational structure)
Uncertainty	Environmental	(1) Demand uncertainty (volume and mix) (2) Problems with the supply of raw material and components (delays, quality problems and interruption) (3) Action of competitors in the industry
Information quality	Accuracy	Accuracy of the demand data available for planning (forecasts or customer orders)
	Credibility	Extent to which the planners see the information as trustable
Planning performance	Frequency of rescheduling	The amount of modifications in a fixed period of time
	Level of formality	(1) Formal: modifications made by the planners and registered (2) Informal: modifications made by the users of the plans
	Causes of rescheduling	(1) Variability of customer demand (2) Failures in external supply (delays, disruptions, etc.) (3) Deficiencies in internal supply (failures or delays in the internal processes and deficiencies of coordination) (4) Executional/behavioural: modifications made by the users, motivated by rewards or other advantages
Operations performance objectives/competitive priorities	Cost	Production/operational costs
	Quality	(1) Product quality: attending specifications and customer needs (2) Process quality: levels of scrap and rework
	Speed and dependability	(1) Speed of the process and throughput time of the orders (2) On-time delivery
	Flexibility	(1) Ability to make changes with acceptable penalties in time and cost
Business performance	Financial and strategic	Financial and strategic metrics such as profit, revenue, sales and market share

Table 1.
Constructs considered in the research

companies, the dynamics of the office activities was sometimes observed in order to see how the communication among actors really is. Examples of documents presented by the interviewees include organograms, product routings, plans, schedules and product structures. The interface and functions of information systems was also demonstrated in some cases.

In order to avoid inconsistencies in the data collection, a case study protocol was proposed. Mechanisms for validating the data collection procedure were employed. The interviewees were asked to review the condensed transcription of the interviews and to correct and add information if necessary. The preliminary analysis of the transcriptions has also raised few additional questions that were later answered. At the end of the analyses, a closed-ended questionnaire was elaborated and also sent to the interviewees in order to confirm the information. Examples of questions included in this instrument are as follows: questions where the respondent has to set the priority of different sources of uncertainties, of different

performance indicators applied to PPC and of different competitive priorities for the company. These answers were confronted to the answers given in the semistructured interviews in order to check for consistency.

3.2 Basic characteristics of the selected companies

The selection of the companies for our study was based on three criteria: the companies should belong to the industrial sector, should hold a position of leadership in the industry in which they compete and should have a PPC function with well-structured activities. In total, four companies with this profile in Brazil were selected, all of them belonging to multinational corporations. The basic characteristics of these companies are presented in Table 2.

As limitations, the chosen sample includes companies with plants/business units in a specific geographic region of Brazil (Southeast), and the relationships of these units with the headquarters in other countries (e.g. USA or Germany) were not considered. Thus, the sample does not allow a comparative analysis of different cultural and regional factors affecting the

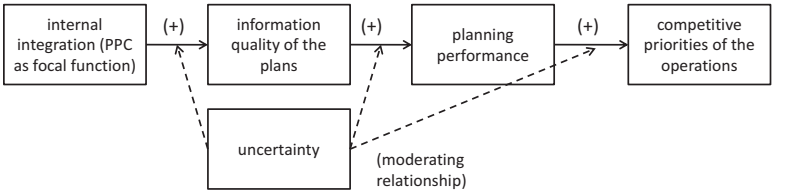

Figure 1.
Propositions of the multiple case study

Company		A	B	C	D
Size		Medium	Large	Large	Large
Type of production system	Policy of attending the demand	MTO and few items of MTS	MTS (40%) and MTO (60%)	MTS, MTO, ATO and ETO*	MTS (most of the volume) and MTO
	Production flow	Job shop, customized items and functional layout	Assembly: batch shop	Different configurations, depending on the BU	Assembly: Flow shop
Number of SKUs (variety)		Medium/high	Medium	Very high	Low
Activities of the production planning and control function		To define or confirm due dates for the customer orders; to elaborate the MPS, MRP and schedule operations and to formulate the aggregate and strategic plans	To elaborate the aggregate plan and MPS and to define stock policies and levels (Manufacturing function is in charge of the operations scheduling)	To lead the S&OP; to elaborate the MPS and MRP and to define stock policies and levels (the responsibility for the operations scheduling is shared with the manufacturing department)	To define stock policies and levels; to analyze the capacity; to elaborate the MPS and MRP and to schedule the operations (the S&OP is elaborated by another function)

Table 2.
Basic features of the selected companies

Note(s): *depending on the product line and on the business. The analyzed business units operated according to an MTS policy with some assembled-to-order (ATO) products

findings. In addition, the companies analyzed are manufacturers of tangible goods. So, the observations are related to this context and not to the context of service companies or manufacturers of less tangible goods (e.g. software companies). Based on the sample, the study considers the perspective of PPC/manufacturing leaders not the point of view of leaders operating in other functions (e.g. marketing or finance).

4. Case studies

4.1 Observations in company A

Company A is a make-to-order (MTO) contract manufacturer (CM) that serves multiple overall equipment manufacturers (OEMs) using the same production system and resources. When the interview was carried out, a system for capacity reservation had recently been implemented, supporting sales and PPC staff. It showed the firm orders and allowed reserving capacity for a given order from the moment that the customer had requested a quote. This reservation was based on the probability of winning each individual order, which should be estimated by the sales team.

The main problem reported by the interviewee was the absence of a robust PPC system to take the several planning variables, associated to highly customized products, into account. Company A did not present a structured process of S&OP. Although belonging to a well-established corporation, the company had entered in a new branch, and this interview was specifically carried out in this new business unit, where the strategic and tactical planning was still incipient.

The following factors may be highlighted as integration mechanisms in company A:

(1) IS: the previously described system for capacity reservation was designed to be a mechanism of technical integration in the interface of the PPC and sales functions. One weaknesses of this integration is the lack of compatibility between the system and the spreadsheets used for scheduling. Due to this and mainly to organizational factors, the system could not be deployed.

(2) Communication and meetings: meetings involving the PPC, the operations and the sales functions take place to correct scheduling deviations and mitigate the effects of uncertainties as well as to define priorities.

(3) Standardization of activities and assignment of responsibilities: due to an expressive growing that imposed a triplication in the production volume, the extant systems could not adequately support the planning and scheduling activities. A restructuration and standardization of activities was responsible for an improvement in the service level and a decrease in the frequency of rescheduling. As a result, an OTIF (on time in full) of 95% was achieved.

(4) Size: the size of the business unit under study was highlighted as an integration factor. Although the total production volume of the unit is considerably high, the unit has few employees. According to the interviewee, this factor enabled them to work in close proximity.

At first, problems related to IQ were regarded as the main causes of poor planning performance, e.g. inaccurate information regarding set up times, process routings, etc. Then, two initiatives of improvement were carried out. In a second moment, quality problems that resulted in high scrap rates were pointed out as a relevant cause. The data collected in company A are outlined in Table 3.

The most relevant source of uncertainty faced by the analyzed business unit was a fast and pronounced increase in customer demand, which was mitigated by strengthening

Problems related to the PPC function	Deficiencies in the planning system to consider the variety of routings and absence of a system to integrate the hierarchical levels of planning
Organizational structure	Functional structure
S&OP	Not implemented
Extant integration mechanisms	(1) IS for reservation of capacity (2) Communication and meetings (3) Standardization of the PPC activities and assignment of responsibilities (4) Size of the unit
Level organizational integration	(1) Communication and meetings: Medium; meetings with no fixed schedule (2) Shared decisions and plans: High; plans agreed by all the ones involved (3) Frequency of S&OP meetings and adjustments: No formal process (4) Stimulus for exchanging ideas: High; team working in close proximity (5) Common understanding of the important objectives: medium; cultural factors preventing the full implementation of the reservation system
Level of technical integration	(1) Interface: medium; many scheduling activities in spreadsheets (2) Compatibility: medium; ERP not integrated with the reservation system
Level of uncertainty	(1) Changes in the customer demand: low (MTO) (2) Problems with supply or suppliers: low (3) Actions of the competitors: low; the company is leader in the industry (4) Changes in the process technologies: low (5) Other relevant source of uncertainty: Fast increase in the demand, equivalent to three times the initial volume produced in the plant
Planning performance	(1) Frequency of the modifications in the schedules/plans: not informed (2) Level of formality: not informed (3) Causes of the modifications in the plans: Lack of a structured planning system and clearly defined responsibilities; lack of adherence between the planning system and the shop floor constraints (previous scenarios); scrap and rework
Competitive priorities and performance measures	(1) 1. Cost; 2. delivery performance; 3. flexibility (2) Performance measures of the PPC: Delivery performance measured by the OTIF metric

Table 3.
Data collected in company A

integration, as will be further discussed in Section 5. Company A manufactures some functional products (Fisher, 1997) not only with longer life cycles but also innovative products with high customization. Even considering the innovative products, the demand uncertainty is minimized (i.e. the demand is more predictable) due to some factors, namely (1) there is high integration with the customer (OEM) during product development, and the allowed time-to-market is relatively large; (2) after product development, the supply is performed on a MTO basis; (3) the lead time that the customer is willing to wait (called in the company "technical lead time") is of six weeks; it is considered relatively loose in comparison to the lead time for manufacturing the products according to the respondents.

4.2 Observations in company B

The PPC function in company B executes the conventional activities of the hierarchical planning structure, namely aggregate planning, master schedule, MRP and definition of inventory policies. The organizational structure of the company is functional.

The integration mechanisms that could be identified, based on the answers of the PPC manager and on direct observations, are presented as follows:

(1) Communication and meetings: the manufacturing manager, the supervisors and the planners agree on the PPC plans in a monthly meeting. According to the PPC manager, the plans are not imposed or informed but discussed and agreed.

(2) Positions with integrating function: one of the members of the PPC team is held responsible for verifying the fulfillment/status of the orders. Weekly or biweekly meetings are arranged with the team of supervisors in order to find solutions for deviations.

(3) Organizational culture: the manufacturing and the PPC teams are prone to collaboration and teamwork. There is certain mutual confidence and partnership between the two groups.

The level of organizational integration between PPC and manufacturing and between PPC and sales/marketing differs. To improve that, a middle-level manager was assigned to establish the S&OP process.

The frequency of changes to the plans, in this company, was related to seasonality of the industry and to the type of policy adopted, i.e. MTO or make-to-stock (MTS). According to Fisher's (1997) classification, company B manufactures not only functional products with long life cycle but also introduces some innovations. On the other hand, the margins of the functional products are not low because there is product differentiation based on quality and image of the brand. The diversity/variety of products is also high, which is not usually a feature of the products classified as "functional". Due to these mixed features, the level of demand uncertainty/predictability may be considered medium. According to the respondents, the rescheduling mainly occurred due to the variability of customer demand, delays of suppliers and delays in order release. The lack of integration of PPC and sales functions impacted the IQ (of forecast), leading to poor planning performance.

The collaborative values involving the relationship between the manufacturing and PPC functions were incorporated in the company's organizational culture. Thus, the organizational culture arose in this case as an integration factor and was not explicitly mentioned in the remaining ones. An outline of the observations made in company B is shown in Table 4.

4.3 Observations in company C

This company has multiple plants/business units. The respondents were two leaders responsible for the PPC in two different business units. The key issues related to the PPC routine were the lack of synchronization between PPC and sales/marketing function (see Table 5), which lead to high working pressure on the PPC team. This topic is directly related to the organizational and interfunctional integration, and the respondents pointed it spontaneously before they were asked about integration.

In total, four different enablers of integration were identified in company C and are presented as follows:

(1) Organizational structure: the business units of company C in Brazil are geographically spread out. The structure of the PPC function, previously decentralized, became corporative, with the PPC teams responding to one single director. The main advantage of this change, as pointed by the respondents, regards to the agility in the decision-making and unity of command. Each planner of the PPC team is assigned to work with a member of the marketing team of a specific business unit.

(2) ISs (technical integration): at the time when the interviews were carried out, the PPC team was implementing a new piece of software for demand forecasting and was encouraging the involved parts – planning and marketing employees – to revise the forecast process and to become more committed to it.

Problems related to the PPC function	Forecast accuracy; responsiveness of the PPC/manufacturing function and estimation of the available to promise quantities
Organizational structure	Functional structure
Process of S&OP	Not implemented and ongoing project
Extant integration mechanisms	(1) Communication and meetings: monthly meeting involving PPC and manufacturing, including managers and biweekly meetings for correcting deviations (2) Position with integrating function (3) Organizational culture: Attitude of collaboration and partnership between the manufacturing and the PPC function
Level of organizational integration	(1) Communication and meetings: High communication with the manufacturing function (workgroups and fixed schedule) and low with the sales function (2) Shared decisions and plans: Idem (see preceding topic) (3) Frequency of S&OP meetings and adjustments: low (4) Stimulus for exchanging ideas: High exchange with the manufacturing function; mutual attitude of collaboration and low exchange with the sales function (5) Common understanding of the important objectives: Idem (see preceding topic)
Level of technical integration	(1) Interface: low; aggregate plan and scheduling in spreadsheets and MPS/MRP in the ERP (2) Compatibility: low; spreadsheets and ERP not integrated
Level of uncertainty	(1) Changes in the customer demand: High and biweekly (2) Problems with supply or suppliers: low; 10% of the deliveries with delay and high vertical integration (3) Actions of the competitors: low; the company is leader (80% of market share) (4) Changes in the process technologies: low
Planning performance	(1) Frequency of the modifications in the schedules/plans: more than once a week (2) Level of formality: 10% of the plans are informally changed by the users (3) Causes of the modifications in the plans: 1. Demand variability; 2. Failures/delays in external supply and 3. Failures/delays in internal supply
Competitive priorities and performance measures	(1) 1. Process quality; 2. delivery performance and 3. cost; different prioritization over time (2) Performance measures of the PPC: service level and inventory level

Table 4.
Data collected in company B

(3) S&OP process: it has been carried out in company C for 15 years, with fixed schedules set in advance and defined responsibilities. The meetings are split in monthly executive S&OP meetings and preS&OP meetings to discuss capacity, bottlenecks and technological restrictions of the machinery related to existing and new products.

(4) Top management support: in addition to the preS&OP and S&OP meetings, a top management executive meeting his/her monthly frequency is led by the CEO and includes all directors. They must present the status of the key performance indicators (KPI) of their respective units. The interviewees emphasized the importance of the severe attitude of the CEO in promoting these meetings, since they compelled the sales/marketing function to share with the PPC function the responsibility for the inventory levels and demand forecasts. They did not exist when the former CEO ruled the company.

The frequency of changes in the plans is higher for the lower levels of the planning hierarchy, as expected. The sales and operation plan is seldom modified, while at the level of master production schedule (MPS), most of the changes are caused by urgent orders of clients that cannot wait for the standard delivery time. At the shop floor level, the rescheduling occurs in

Problems related to the PPC function	Involving the marketing/sales in the S&OP; motivating the PPC team; asserting the importance of the PPC and coping with conflicting functional metrics
Organizational structure	PPC is a corporate division
Process of S&OP	Carried out for 15 years
Extant integration mechanisms	(1) Organizational structure: Corporate PPC function enables agility, unity of command and autonomy (2) S&OP process (3) Top management support: Assures the involvement of the areas in the S&OP and solves discrepancies caused by conflicting objectives
Level of organizational integration	(1) Communication and meetings: Medium – high; high frequency but depend on the initiative of the planner (2) Shared decisions and plans: High; workgroups (3) Frequency of S&OP meetings and adjustments: High; two monthly meetings (preS&OP and corporate S&OP) (4) Stimulus for exchanging ideas: medium; optimization of functional objectives (5) Common understanding of the important objectives: High; understanding of the trade-offs
Level of technical integration	(1) Interface: Medium; some plans in spreadsheets (2) Compatibility: Medium high; planning software integrated to the ERP
Level of uncertainty	(1) Changes in the customer demand: High; once a week or higher (2) Problems with supply or suppliers: Medium; 25% of delay (3) Actions of the competitors: Low or medium (4) Changes in the process technologies: Low (5) Other relevant sources of uncertainty: Managerial complexity due to high variety (pulverized demand) and fast and pronounced increase in the demand (10 to 15% per month)
Planning performance	(1) Frequency of the modifications in the schedules/plans: Daily; plans for 2–3 days (2) Level of formality: Not informed (3) Causes of the modifications: 1. Demand variability; 2. deficient communication; 3. failures/delays in external supply and 4. failures/delays in internal supply
Competitive priorities and performance measures	(1) Cost and delivery performance (2) Performance measures of the PPC: Service level and inventory level and forecast accuracy being monitored

Table 5.
Data collected in company C

a daily basis, mainly due to machine breakdowns, delay of suppliers, lack of raw material, delay in the procedures of importation of goods and quality problems.

The performance indicators of the PPC function of company C are at the service level and inventory level. The inventory level was also included in the scorecard of the marketing/sales function but with very low priority. Moreover, the rewards that apply to the sales team were not related to any extent to the accuracy of the demand forecasts, as recommended in the literature. The reason for that is related to the highly diversified portfolio that must be sold by each salesperson which, according to the respondents, would prevent the accurate forecast of each SKU (stock keeping unit)/individual product. In summary, the measurement and reward system hindered internal integration in the company analyzed.

An outline of the findings related to company C is shown in Table 5.

The changes in customer demand were considered the most relevant source of environmental uncertainty. This factor is magnified by the high diversity of products, which adds complexity to the management of the system. This complexity is highlighted in the literature as one of the dimensions of uncertainty, as presented in Section 2. Company C has multiple plants and business units. On the one hand, it manufactures some functional

products with long-life cycles in high volumes. For these products, it is usually the leader of the market or segment, and margins are not so low because products are differentiated based on quality or image. On the other hand, most of the products are innovative, and innovation is a relevant component of company C's business strategy. Thus, demand uncertainty tends to be high, customer demand is pulverized among a wide range of products and market mediation (Fisher, 1997) is a critical point.

This case raised some interesting points. One of them is that the respondents narrated occurrences that illustrated some of the investigated dimensions and could be considered stronger evidence than only answers to direct questions. The most important point, however, is that the information provided about two different points in time helped to reveal some relationships among the constructs.

In total, four years before the conduction of our study, the service level of a given business unit was 85%, and the back orders corresponded to almost 750,000 dollars. In the following years, although the sales increased significantly (10 to 15% per month), an increase in the service level with controlled inventory was achieved. This is attributed to the strengthening of internal integration.

A decrease in the frequency of rescheduling was achieved after the change of the CEO, the remodeling of the organizational structure and the improvement of IQ of the S&OP process. In one of the analyzed business units, the inventory level was even reduced, as shown by the historical series of this performance indicator. The importance of top management support corroborates the previous findings discussed in Section 2.

In summary, the high variety of items and a fast and pronounced increase in sales were relevant factors of uncertainty faced by the company, which responded to that by strengthening the internal integration; as a result, the service level increased 10% whilst the inventory level was kept under control. The top management support and organizational structure were the most relevant integration enablers, compensating the influence of conflicting functional objectives. In other words, the measurement and rewards system of the company studied by the aforementioned authors also discouraged integration, leading to local goals optimization instead. In company C, we realized that S&OP and top management executive meetings enabled the procedural and alignment quality (constructs presented in Section 2.2), thus mediating integration. The concept of constructive engagement (Section 2.2) is also present in company C. The respondents clearly showed that the attitude of the new CEO fostered constructive engagement from the participants. The importance of this top management support and of the integration factors formally established by senior management is also highlighted by Pimenta *et al.* (2016). Therefore, the findings of this case are aligned with the previous literature.

The company was subjected to higher levels of uncertainty, since the need of abruptly increasing the production volume engenders higher management complexity and intensifies the use of the existing resources. The results shows that the relationship between integration and performance is moderated by uncertainty, as discussed in Section 2.

4.4 Observations in company D

In company D, the S&OP is carried out by a corporate planning team, separated from the local PPC function that is in charge of short term plans. The manager and one employee of the local PPC team from one of the plants were interviewed. Based on their answers, five integration enablers were identified, as follows:

(1) Communication system: there is a well-defined communication system around the production planning and control activities, which involves the relevant players. Formal meetings also occur with a predefined frequency.

(2) Organizational structure and culture: the organizational structure is seen as a factor of integration between the PPC and the S&OP teams, since it engenders a "healthy conflict", i.e. a positive antagonism between the demand-side and the supply-side. Although geographically separated, both teams are situated at the same hierarchical level, report themselves to the same corporate manager and work cooperatively (e.g. the S&OP team tries to influence the future demand in order to comply with the capacity constraints). In company C, on the contrary, the PPC leaders perceive that the importance of these two sides is uneven.

(3) Meetings: meetings to discuss and define the plans occur on a weekly basis. The chief of PPC and the chief of the S&OP team attend these meetings twice a month, approximately.

(4) Position with integrating function in the interfaces: one employee with integrating function was designated to work in the interface between the PPC and engineering functions in order to improve the accuracy of the data related to machine utilization, process routings, processing and queuing times.

(5) Position with integrating function inside the PPC: there are two planners in the considered plant; one is responsible for the short-term plan and the other for the medium-term plan. The latter analyzes the impact of a proposed rescheduling (i.e. a short-term change) in the medium term, being also in charge of the communications with the S&OP team located in the company headquarters.

Most of the products manufactured by company D may be considered functional. Although the company launches some innovative products and most of the products of the portfolio present a degree of differentiation, the life cycle is usually medium or long, and the margins are low. Thus, customer demand tends to be more predictable (i.e. uncertainty related to the demand tends to be lower) in comparison to company C, for instance.

The interviewees estimated that about 30% of the production plans are modified or rescheduled. These changes are registered in the information system, allowing its monitoring. The changes in the customer demand in terms of product mix are classified as the first cause, and the failures in internal supply as the second. IQ and communication problems were mainly affecting the planning performance due to a lack of accuracy of inventory records; quality problems and unexpected events (e.g. machine breakdowns leading to insufficient parts in stock) also affect the reliability of this internal supply. Informal rescheduling executed by production supervisors was a problem in the past and was mitigated by the implementation of a more rigid system to track the manufacturing execution.

The specific performance indicators of the PPC function, according to the interviewee, are the inventory level and the production costs. In contrast to company C, the performance of the marketing/sales function in company D is indeed measured by means of forecast accuracy and inventory level, and the sales efforts are also driven by these indicators. This alignment and coherence among functional performance measurements is a relevant integration enabler in company D and is aligned with the literature.

Table 6 presents an outline of the findings related to company D.

The study illustrated the dyadic relationships among integration, IQ and planning performance. The presence of an employee with integrating function in the interface of the PPC and the engineering departments enabled an improvement in the IQ available for planning, in terms of process routings, machine utilization and queue times. This improvement, on its turn, prompted a decrease in the frequency of rescheduling, i.e. contributed to a higher stability of the plans. It also allowed distinguishing two types of causes for rescheduling, as will be discussed in the next section.

Problems related to the PPC function	Extension of the pull system; definition of stock levels (raw materials, components) and capacity analysis considering spare parts
Organizational structure	Corporative and local PPC teams
Process of S&OP	Consolidated S&OP process
Extant integration mechanisms	(1) Organizational structure: Existence of two PPC teams at the same hierarchical level seen as positive (2) Communication and meetings (3) Positions with integrating function inside the PPC and in the interface with the Engineering function
Level of organizational integration	(1) Communication and meetings: High; high frequency and fixed schedule (2) Shared decisions and plans: Medium; workgroups (3) Frequency of S&OP meetings and adjustments: High; monthly meeting for adjustments and quarterly S&OP corporate meeting (4) Stimulus for exchanging ideas: Medium (see item "shared decisions and plans") (5) Common understanding of the important objectives: Medium; understanding of the trade-offs
Level of technical integration	(1) Interface: High; use of ERP, servers, integrated platforms and intranet (2) Compatibility: High; integrated software for each level of hierarchical planning (including S&OP)
Level of uncertainty	(1) Changes in the customer demand: High; daily to weekly (2) Problems with supply or suppliers: Medium; 25% of the deliveries with delay (3) Actions of the competitors: low; the company is leader (4) Changes in the process technologies: medium high; frequent changes to reduce cost
Planning performance	(1) Frequency of the modifications in the schedules/plans: Daily, one non-scheduled set up/day and 30% of the plans changed (2) Level of formality: Informal rescheduling occurred in the past and was controlled (3) Causes of the modifications in the plans: 1. demand variability; 2. failures/delays in internal supply and 3. failures/delays in external supply
Competitive priorities and performance measures	(1) No explicit prioritization (2) Performance measures of the PPC: Inventory level and production cost and service level for the sales and logistic functions

Table 6.
Data collected in company D

5. Crosscase analysis and discussions

A cross-case analysis was carried out aiming at identifying common patterns or divergences among the cases and, especially, to observe the relationships among the investigated constructs.

Several enablers of integration were found in the companies, and some of them are common to more than one company. A comparison is presented in Table 7. These results are aligned with previous findings. The factors 1, 2, 5 and 7, 8 and 10, were discussed by Pagell (2004), and the factors 2, 5, 6, 8 and 10 were highlighted by Pimenta *et al.* (2016).

The level of integration of the companies and the level of uncertainty to which they were subjected were also assessed. These classifications were based not only on the direct answer of the respondents but also on the indirect comments made by them and on the direct observations of the researchers. The results are shown in Table 7 and will be discussed over the next paragraphs.

In company A, some disconnections in the interface between the PPC and the sales department were found. Organizational barriers prevented technical integration (i.e. integration by means of information systems) and also ICT incompatibility among different information systems (as discussed in Section 2.2) hindered integration. The production schedules were elaborated using spreadsheets, and it was not possible to automatically gather data from the

Integration enablers	Company A	B	C	D
1. ISs	x			
2. Communication and meetings	x	x	x	x
3. Standardization of tasks and clear definition of responsibilities	x			
4. Size of the company	x			
5. Organizational culture		x		
6. Positions with integrating function		x	x	x
7. Organizational structure			x	x
8. Top management support			x	
9. S&OP process			x	
10. Strategic fit/ alignment of functional metrics				x
Organizational integration	Medium	High*/Low**	High	High
Technical integration	Medium low	Medium	High	High
Uncertainty (demand)	N.A.	High	High	High
Uncertainty (suppliers)	Low	Low	Low	Low
Uncertainty (competitors)	Low	Low	Low	Low
Uncertainty (technology)	Low	Low	Low	Medium
Uncertainty (variety/ customization)	High	low	Very high	Low
Uncertainty (accelerated growth)	High	Low	High	Low
IQ (forecasts)	N.A.	Low	Medium high	Medium high
Planning performance (rescheduling frequency)	N.I.	Biweekly to weekly	Daily	Weekly to daily
Planning performance (causes of rescheduling)	1. Internal supply	1. Demand variability/ forecast accuracy 2. External supply	1. Demand variability/ forecast accuracy 2. Communication	1. Demand variability/ forecast accuracy 2. Internal supply
Performance metrics (PPC)	OTIF (service level)	N.I.	Inventory level and service level	Inventory level and cost
Business performance (competitive priorities)	Delivery (speed and dependability)	Quality	Cost and dependability	No prioritization
Performance: Actual × goal	Goal achieved (95% OTIF)	Achieved	Goals achieved (95%)	Goals achieved

Note(s): *high integration in the PPC–manufacturing interface; **low integration in the PPC–sales/marketing interface; N.A.: not applied and N.I.: not informed

Table 7. Summary of the comparative results

capacity reservation system to serve as input to the schedules. In addition, the sales representatives were not used to keep the information updated in the system. This low organizational integration was caused by the lack of formal an informal communication between functions which, in turn, is driven by organizational culture and structure, as highlighted by Pagell (2004). According to Gustavsson (2008) and Myrelid & Jonsson (2019), low integration results in IQ deficiencies, especially regarding some dimensions of it. In company A, some respondents pointed out a lack of accessible, reliable/credible and timely information for planning. Pérez-Lopéz (2019) also showed that information exchange and ICT support operation management and facilitate production control. The presented discussions show that the results of this case study are aligned to the findings of the authors mentioned herein.

The level of technical integration was considered higher in companies C and D because the different information systems used presented a higher degree of compatibility, with little or none parallel information (such as data in spreadsheets are in parallel to the ERP platform, for instance).

In company B, the integration of the PPC with the manufacturing area was high and based on a relationship of trustworthiness while the integration with the marketing/sales department was low due to the lack of communication (e.g. direct communication and a more effective S&OP process). Once again, these results corroborate previous reports in the literature. Trustworthiness and team spirit are regarded as relevant for crossfunctional integration (Pimenta *et al.*, 2016) as well as communication (Pagell, 2004) in its formal or informal mode (Pimenta *et al.*, 2016).

The changes in the customer demand were highlighted as the main source of uncertainty. This affects the three MTS companies, as expected. Divergences of real and forecasted demand are related first to deficiencies in the integration of PPC and sales/marketing function and, second, to deficiencies in the internal supply. The uncertainty associated to the external supply was not considered relevant because these companies had already developed improvement programs with their suppliers. Moreover, as each company is the leader of the respective industry in which they operate, the uncertainty derived from the movements of the other competitors was considered not relevant.

In total, two dimensions of uncertainty that were originally not in the research protocol were included: the high diversity of products/items and the growth rate of the company/business. The high diversity of products that was observed in company C, in terms of effect on planning, may be considered similar to the high customization of the products in company A. This diversity or customization is related to the dimension of "complexity" defined by Vokurka & O'Leary-Kelly (2000) and discussed in Section 2.1. It implies higher variation in the customer demand patterns and, therefore, is also associated to the component "objects". The rate of sales growth was included in the studies because both companies A and C had been subjected to a period of consistent sales increase when the interviews were carried out. This situation increases the level of uncertainty to which the companies are subjected and is related to turbulences in the market (i.e. to the dimension "dynamism" defined by Vokurka & O'Leary-Kelly (2000)). Consequently, the frequency of rescheduling (instability of the plans) also tends to increase. These dimensions of uncertainty appear in the top of Figure 2, which will be discussed later in this section.

It is also worth mentioning that, according to Fisher (1997), Companies B and D should have presented lower levels of uncertainty related to customer demand than Companies A and C, since they manufacture a significant percentage of functional products. However, the results shown in the row "uncertainty (demand)" of Table 7 were based on the perception of the PPC managers or leaders, indicating that some of them have a biased view regarding demand predictability, i.e. the view that "customer demand is always changing". In addition, this relationship proposed by Fisher (1997) (i.e. functional products – more predictable demand and innovation products – less predictable demand) is likely to be reflected in other

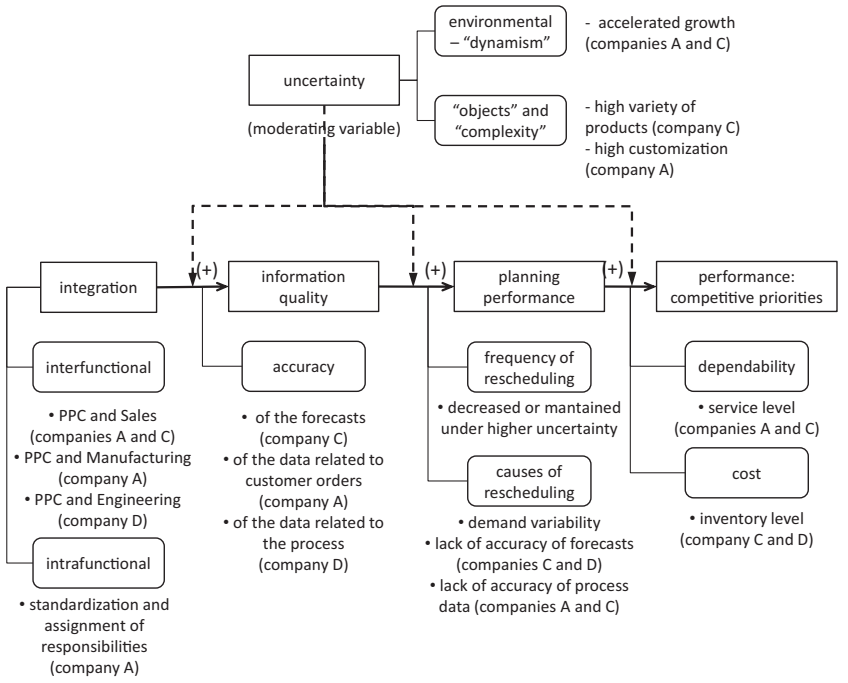

Figure 2.
Relationships among the investigated constructs

rows of Table 7, namely "variety/customization" and "accelerated growth". It is seen that companies B and D (with functional products) present low uncertainty regarding these dimensions, while companies A and C, relying on innovation, present high uncertainties.

Inventory and/or service levels were found to be the main performance metrics associated to the PPC function of companies. In only one of them, the forecast accuracy was monitored. In Grimson and Pyke's (2007) five-stage S&OP maturity model, the sales function is measured on forecast accuracy in stage 3, that is, in organizations that have a standard S&OP process. This shows the opportunity of improving the S&OP process in the companies studied as an important way to achieve internal integration.

The individual and cross analysis of the cases presented evidence of the relationships among the investigated constructs (Figure 2), which will be discussed in the following paragraphs.

As presented in the theoretical section, the uncertainty construct may be divided into environmental and executional dimensions (De Snoo *et al.*, 2011). The observations gathered in company D allowed dividing the causes of rescheduling into two categories: causes derived from environmental uncertainty and causes derived from execution uncertainty. The first ones tend to be less controllable than the latter. But for some aspects, these two dimensions are tightly intertwined. Especially when it comes to attending customer demand, it is not trivial to distinguish which fraction of the rescheduling was performed due to the natural variability of the demand and which was caused by inaccurate forecasts or deficiencies in the forecasting process. In general terms, however, the manager of PPC in company D had a clear perception of this distinction, so that the PPC was oriented toward treating the executional causes as first concern, and a certain level of rescheduling was understood as ineluctable in order to attend changes in customer demand due to environmental uncertainty.

As one of the main results, the crosscase analysis illustrated the existence of a positive relationship between integration and performance in companies A, C and D, which is moderated by uncertainty in the case of companies A and C. This is shown in Figure 2, in the lower part, first and last columns of blocks. The moderating effect of uncertainty is represented by a dashed line. In these companies, an abrupt raise in the sales/production volume led to increased uncertainty, since it required all the resources to operate at the border of their capacities. This situation destabilized the operations and deteriorated the planning performance. The companies addressed such matter by developing new integration enablers or strengthening the existing ones, being able to keep the levels of performance or even to raise them. In the case of company C, not only the service level was improved but also the inventory level was kept under control. As discussed in the literature review section, the relationship between integration and performance moderated by uncertainty was plentifully reported in the previous research (Li *et al.* 2006; Flynn *et al.*, 2010; Lee *et al.* 2010; Wong *et al.*, 2011; Kalyar *et al.* 2020).

Thus, the results presented herein corroborate previous findings. A distinctive element of our research, however, is the use of case studies to better understand how this relationship occurs and what are its relevant antecedents (e.g. integration antecedents)? The authors cited in this paragraph present survey-based results, which are generalizable but not always may be converted into specific prescriptive directions for managers. The integration antecedents developed or strengthened by the companies to reach better performance are the ones previously shown in Table 7. The description of the cases, presented in Section 4, helps to show some ways to deploy/achieve integration or to cope with certain types of uncertainty, aiming to reach better performance.

In the existing empirical research, integration, IQ and performance are defined as multidimensional constructs, as presented in Section 2.1. In our work, as mentioned in the introduction and Section 3, the concept of planning performance is introduced, referring to the stability and responsiveness of the production plans and schedules and related to the frequency and causes of modifications to these plans. Thus, we imply that integration positively affects planning performance, which in turn affects performance in terms of competitive priorities (see Section 2.1), as shown in Figure 2.

The situation observed in companies A, C and D also allowed identifying the IQ as an intervening element in the dyadic relationship between integration and performance. This is in accordance with the study of Myrelid & Jonsson (2019). As IQ determinants, they defined factors related to information exchange, interorganizational collaboration and intraorganizational process support. These factors, on their turn, may be seen as dimensions of internal and external integration. The authors observed that these determinants affect some pragmatic dimensions of IQ, such as accessibility, ease of operation, relevance, credibility, etc. Similarly, in the analyzed cases (companies A, C and D), the integration engendered the improvement of the IQ available for planning as an immediate result. For company A, it meant more credibility in the data related to firm orders and production processes (i.e. routings, set up and processing times, etc.); for company C, it represented demand forecasts with higher accuracy. In company D, the improvement in IQ concerned the process routings, processing times of operations and machine utilization data, achieved by means of strengthening the integration between the PPC and engineering. As a consequence, the frequency of rescheduling caused by failures in internal coordination and inexact information decreased in all cases, yielding a better performance. These relationships are also depicted in Figure 2. This positive relationship between IQ and performance corroborate with the study of Marinagi *et al.* (2015), which has found that information sharing is the link (i.e. the mediating variable) between IQ and supply chain performance. In other words, increased information reliability and quality are facilitated by information sharing and lead to higher overall performance.

The chosen set of companies is relatively homogeneous in terms of business performance, since all companies are leaders in their respective industries in Brazil. This aspect was important to ground the research; given that these companies have a superior business performance, it was possible to observe how or why the investigated constructs enabled such performance level. The PPC functions on the studied companies were also well structured; the processes were well defined, and specific responsibilities were assigned to the players. On the other hand, the selected set is relatively heterogeneous: each company presented an unlikeness/a peculiarity regarding the size, the variety of items or the organizational structure, for instance. Hence, different antecedents of integration could be observed.

Ivert (2015) and Kaipia, Holmström, Småros & Rajala (2017) highlight that there is a lack of research concerning the sales and operation planning (S&OP) with a focus on a contingency perspective; that is, considering the planning environment variables as contingency/contextual factors for the design of the S&OP process. Here, this view is extended, considering that the contingency factors related to the planning environment and the company should be used to shape the process of internal integration and IQ improvement.

Thus, as practical implications, our study exposes different integration mechanisms linked to four different realities, which managers may implement in their companies depending on the context. Concerning contextual factors, determined mechanisms would be more suitable and determined uncertainty factors, or IQ deficiencies would be more relevant. Thus, the integration processes should be driven toward a specific direction, depending on the contingencies. For instance, if high product variety is an issue and the functional indicators and incentives are misaligned (as in company C), the managers should focus on top management support strongly promoting a process perspective (formal meetings, with defined and shared responsibilities, in order to generate informational, procedural and alignment quality). On the other hand, if product variety is relatively reduced and demand uncertainty is lower (like in company D), a person with integrating function between the tactical planning and manufacturing areas would be an adequate and more cost-effective solution. Managers can use the results presented herein as a benchmark to focus their efforts on developing specific integration mechanisms and improving specific points regarding information quality, for instance. This way, they can choose mechanisms that better fit their environment/reality.

This is an indirect result of this paper, in the sense that only uncertainty was considered an explicit contingency variable. However, the study of different cases showed that there are other potential contingency factors related to the company and the planning environment that can shape the integration and IQ improvement processes, such as company geographic configuration (distributed multi-plant and concentrated plant), company size, PPC organizational structure, product variety, product customization level, product's demand profile and variability and so on. These contextual factors could be investigated in a more systematic manner in future research.

Moreover, the extant research on integration, uncertainty and performance is usually survey based and focuses more on proving and generalizing the relationships among these constructs than on observing how the integration mechanisms are linked to the contextual factors and how they generate IQ and better performance. This is a contribution of this work to the literature and for future works aiming at further exploring this contingency perspective on how the context shapes integration/IQ improvement mechanisms resulting in better performance.

Even though the observations may not be generalized, evidence of the positive relationship between integration, IQ and performance, moderated or not by uncertainty, was found in all the case studies analyzed.

6. Final remarks

In this paper, the relationship between organizational integration, environmental uncertainty IQ and planning performance was investigated by means of descriptive multiple case studies. The research focused on the context of the PPC function and its interfaces. A comparative analysis of the cases allowed to

(1) Highlight some differences among organizational structures of the PPC function and to observe the impacts of these differences on interfunctional integration;

(2) Identify ten different integration enablers present in companies, linked to different contexts/realities;

(3) Evaluate the level of internal integration in the companies, taking the technical and organizational dimensions into account;

(4) Identify sources of uncertainty and performance indicators that are relevant for the PPC function;

(5) Identify the causes of rescheduling or low planning performance in the companies and

(6) Contrast different priorities set by the companies to the performance objectives of cost, quality, speed, dependability and flexibility.

The main remarks that could be drawn from the study are summarized as follows:

(1) Among the analyzed companies, common integration enablers were found, and the findings are aligned with previous studies.

(2) The companies presented a medium or high level of organizational integration, which was obtained by means of the integration enablers found. This may help to explain the high business performance of the companies, which are leaders in the industries they compete.

(3) The changes in customer demand were regarded as the main source of uncertainty for MTS companies, as expected. In total, two additional sources of uncertainty, not initially considered in the case study protocol, were identified, namely, the high variety of produced items and the fast and pronounced increase of the sales.

(4) The deficiencies in internal supply or the deficiencies in the communication between the PPC and the sales/marketing functions were pointed out as the most relevant causes of poor planning performance. The latter cause was associated to the information quality, since it generated inaccurate information for planning.

(5) Service level and inventory level were found to be the main performance measures of the PPC function. The accuracy of the forecasts was directly monitored in only one of the companies.

(6) Evidence that indicated a positive relationship between internal integration and planning performance was collected in three of the companies under study. In two of them, this relationship was moderated by uncertainty, since they were being pushed to abruptly increase their production volumes and venues. Thus, the uncertainty acted as a contingency variable, strengthening the internal integration.

(7) The IQ was also identified as an intermediate result of the dyadic relationship between internal integration and planning performance.

(8) The evidence also illustrated the relationship among integration, IQ and planning performance in the opposite way, i.e. lack of integration resulting in poor planning performance. Most of them were based on portrayed episodes rather than on answers for direct questions.

As practical implications, the presented analysis may help practitioners to foster interfunctional integration, to better cope with uncertainty and to improve information quality, aiming to achieve better planning performance. The managers can choose to deploy the integration mechanisms and the initiatives of IQ improvement that better fit their reality, using the situations and solutions presented herein for the four different companies as a benchmark. Moreover, this research contributes to the literature with a contingency perspective, presenting indirect results about how the contextual factors of the planning environment shape the process of internal integration and IQ improvement. The study presents in-depth case studies, and thus distinguishes itself from the existing research that adopts this contingency view, which is mostly survey based.

As known, qualitative methods of analysis do not allow statistical-based generalization. However, the analyzed situations, characteristics and context may apply not only to the studied companies, considering the fact that the set of cases chosen is relatively heterogeneous and formed by multinational organizations. The results presented in this paper regarding the contingency perspective are somewhat indirect, in the sense that the contingency variable considered explicitly is uncertainty. However, as a spin-off, the study showed that other variables related to the company and the planning environment are potential contingency factors that shape the integration mechanisms and the IQ improvement initiatives in the companies, leading to a better performance. As an opportunity for future research, these variables could be considered in an explicit and more systematic manner, either in qualitative in-depth studies or in survey-based studies.

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Appendix

Authors	Contribution/topic treated
De Snoo *et al.* (2011)	Uncertainty and its impact on scheduling (i.e. in the context of – PPC and intrafunctional level)
Gustavsson (2007)	Technical and organizational integration and its impact on IQ in the context of PPC (intrafunctional level)
O'Leary-Kelly & Flores (2002)	Integration between sales/marketing decisions and manufacturing/purchasing decisions
Maiga *et al.* (2015)	Relationship between IS integration and performance
Pérez-López *et al.* (2019)	Structural equation model related to the integration of ICT in production systems and in the supply chain
Li *et al.* (2006)	Relationship between SCM practices, competitive advantage and organizational performance (five dimensions of SCM practice are considered: strategic supplier partnership, customer relationship, level of information sharing, quality of information sharing and postponement) and higher levels of SCM practice can lead to enhanced competitive advantage and improved organizational performance
Flynn *et al.* (2010)	Relationship between three dimensions of SCI (customer, supplier and internal integration), operational and business performance from both a contingency and a configuration perspective; hierarchical regression is used for the contingency approach, and cluster analysis is used for the configuration approach
Lee *et al.* (2010)	Antecedents of information sharing and collaboration; relationship between information sharing and collaboration and performance; factors/antecedents that influence the level of operational and strategic information sharing and collaboration: trust, interdependency and rate of technological change
Wong *et al.* (2011)	Relationships between three dimensions of supply integration and four dimensions of operational performance, moderated by environmental uncertainty (EU); under high EU, the associations between suppler/customer integration and delivery and flexibility performance are strengthened, as well as the associations between internal integration and product quality and production cost
Kalyar *et al.* (2020)	Innovativeness as an antecedent of SCI, i.e. positively related to SCI (internal, supplier and customer integration and external integration orientation); SCI positively related to supply chain performance; supply chain innovativeness directly related to supply chain performance and EU as a moderating factor of the SC integration–performance relationship
Donaldson (2001)	Contingency theory
Vokurka & O'Leary-Kelly (2000), Mula *et al.* (2006), De Snoo *et al.* (2011)	Different dimensions of uncertainty
Kalyar *et al.* (2020), Munir *et al.* (2020)	Other variables mediating the relationship between integration and performance (innovativeness and SCRM, respectively)
Glenn Richey *et al.* (2009)	Barriers that moderate the relationship between the drivers of integration and firm performance
Li *et al.* (2006), Wong *et al.* (2011), Chang *et al.* (2016), Pérez-López *et al.* (2019), Kalyar *et al.* (2020), Munir *et al.* (2020)	Performance measured as a multidimensional construct related to the competitive priorities (cost, quality, delivery and flexibility)

Table A1.
Outline of the reviewed literature

(*continued*)

Authors	Contribution/topic treated
Flynn *et al.* (2010), Chang *et al.* (2016)	Performance measured as operational and business performance
Fabbe-Costes & Jahre (2008), Autry *et al.* (2014), Sagawa & Nagano (2015), Chang *et al.* (2016)	Literature review about integration and performance relationships
Forslund & Jonsson (2007)	Relationship between forecast information access/quality and supply chain performance
Marinagi *et al.* (2015)	Relationship between IQ and supply chain performance mediated by information sharing
Chavez *et al.* (2015)	Relationship between customer integration and performance (in terms of quality, delivery and flexibility) partially mediated by IQ
Myrelid and Jonsson (2019)	Relationship between IQ/integration determinants (information sharing, interorganizational collaboration and intraorganizational process support) and IQ dimensions (relevance, accessibility, credibility, understandability and ease of operation)
Pagell (2004), Pimenta *et al.* (2016)	Antecedents of internal integration, involving marketing and logistic functions
Pedroso *et al.* (2016)	Interfunctional integration as a promoter of S&OP and enablers and barriers for S&OP

Table A1.

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