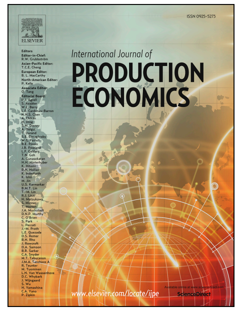

Contextual factors intervening in the manufacturing strategy and technology management-performance relationship

Iván Andrés Arana-Solares, César H. Ortega-Jiménez, Rafaela Alfalla-Luque, José Luis Pérez-Díez de los Ríos

PII: S0925-5273(18)30442-0

DOI: https://doi.org/10.1016/j.ijpe.2018.11.003

Reference: PROECO 7204

To appear in: *International Journal of Production Economics*

Contextual factors intervening in the manufacturing strategy and technology management-performance relationship

Abstract

The relationship between technology management (TM) and manufacturing strategy (MS) can be an important factor for increasing operational performance (OP) and contextual variables may affect this relationship. The purpose of this study is to empirically verify whether MS or/and TM improve OP and whether contextual variables influence OP in the electronics and machinery industrial sectors. A total of 231 firms from fourteen countries have been studied. Hierarchical regression analysis has been applied to test the formulated hypotheses. The findings show that MS significantly improves OP in both sectors, but TM only in the machinery sector. However, the MS-TM relationship is shown to have a significant interaction effect on OP in both types of industries. Additionally, the inclusion of contextual variables does not indicate any significant direct effect on OP. Finally, analysis results show that the greatest improvement in OP occurs in both sectors when MS, TM and contextual variables are included in the model. The evidence suggests that these industries should implement MS and TM to improve OP, while simultaneously considering contextual variables (indirect effect). Therefore, this paper also proposes that significant differences in OP are determined not only by the implementation of MS and TM practices, but also by contextual variables intervening in the relationships between these practices and OP. Overall, MS and TM should be considered important manufacturing practices by managers, who should take into account the interaction effects of contextual variables if they wish to be competitive in the global, dynamic market.

Keywords: Manufacturing strategy, Technology Management, Performance, Machinery sector, Electronics sector

1. Introduction

Manufacturers are under unprecedented pressure from new product introduction by competitors, rapid technological innovation, shorter product life cycles, constant changes to customer requirements, and advances in manufacturing and information technology. As a consequence, companies have taken to implementing operations programmes that have been successful in other firms. Operations programmes are sets of practices, techniques, improvements, etc., joint together for a common goal or a function of the plant for higher competitiveness (Koufteros et al., 2014; Lee et al., 2015; Schroeder and Flynn, 2001; Wang et al., 2015; Whybark and Vastag, 1993). The international high performance manufacturing (HPM) project considers operations programmes such as Lean Manufacturing, Technology Management (TM), Manufacturing Strategy (MS), Total Quality Management (TQM), Human Resources, Information Systems and others, in the belief that the roll out of these practices should lead to superior performance (Flynn et al., 1999; Schroeder and Flynn, 2001). However, superior performance requires the alignment of the manufacturing function and business strategy (Amoako-Gyampah and Acquaah, 2008). The strategic potential of the manufacturing function can be realized through the formulation of the MS, which can lead to superior competitiveness (Thun, 2008).Therefore, MS is commonly seen as an important operations programme that could enable a firm to attain high performance. For example, several studies have found a positive relationship between MS and operational performance (OP) in different types of industries and countries (e.g., Morita and Flynn, 1997; Devaraj et al., 2004; Corbett, 2008; da Silveira and Sousa, 2010, Acquaah et al., 2011; Machuca et al., 2011; Lee, 2014). So, MS is perceived as an operations programmes which, when implemented, improves both business and the relationships between MS and other operations programmes, working as a lever to further boost operational performance (OP) (Schroeder and Flynn, 2001).

In addition, TM is an immensely important operations programmes for companies today due to constant technological changes to both products and processes and their necessary management for business success. This practice comprises both hardware systems and human and organizational aspects (Heim *and* Peng, 2010). Nowadays, manufacturers are increasingly using advanced technologies. This trend is driven by the assumption that the use of TM will lead to improvements in OP. In the literature, there is evidence that TM has a positive effect on OP (Boyer *et al.*, 1996; Flynn *and* Flynn, 1999; Maier *and* Schroeder, 2001; Tsai, 2004; Raymond, 2005; Machuca *et al.*, 2011). However, there are also studies that conclude that the implementation of TM is not significantly related to improvements to OP (e.g., Beaumont *and* Schroeder, 1997; Boyer *et al.*, 1997; Swamidass *and* Kotha, 1998; Cagliano *and* Spina, 2000; Das *and* Jayaram, 2003) as the link between TM and OP could be influenced by contingent factors (Malhotra *et al.*, 2001) such as plant size, organization structure and plant focus (Das *and* Jayaram, 2003).

In spite of TM being able to provide a company with the required core competence (product and process technologies) in such a vastly changing world, it nonetheless requires an MS to be developed that links business strategy and manufacturing. Without such a strategy, it is highly likely that an organization’s core competencies could fragment, leaving business objectives unmet (Banerjee, 2000). MS implementation may help to identify the technologies needed to fulfill business needs. In fact, the MS-TM relationship may be an important factor in enhancing OP; for example, Machuca *et al.* (2011) show that the MS-TM relationship positively affects OP in the automotive components sector.

Thus, on its own, just implementing TM is not enough; it must be coherent with the MS and contingent variables in order to be effective (Schroeder *and* Flynn, 2001). From this it can be deduced that the impact of the MS-TM relationship on OP might depend on the context or conditions in which the company is operating. Consequently, companies should align these two practices (MS and TM) in order to achieve high performance manufacturing, and also adapt them to their own circumstances, which may vary from one industry to another, or depend on company size, amongst other things. Not only MS and TM, but also contextual factors may contribute to the explanation of performance variation, (Kotha *and* Orne, 1989).

MS, TM and OP interrelationships have only been studied to a limited extent (e.g., Machuca *et al.*, 2011; Garrido *et al.*, 2015) and there is still a lack of empirical work, especially regarding the inclusion of contextual variables (Heine *et al.*, 2003). In other words, MS and TM have been studied as the contribution of individual practices to performance on the one hand and the interaction between MS and TM on the other, but few studies have focused on the relationships between MS, TM and OP and contextual variables. As such, a research gap exists as to the impact that contextual variables have on the relationships between MS, TM and OP, and it is this gap that this paper seeks to fill. It is important to understand whether contextual variables have any effects on MS, TM and OP relationships, and whether their outcomes are positive or not.

There are several possible contextual variables, but this research focuses on plant size, environmental complexity, plant focus and plant description (see Annex F), which are all related to internal manufacturing processes and have been used in earlier research. For example, Das *and* Jayaram (2003) found a plan focus (make to stock (MTS) / make to order (MTO)) effect in relation to TM and OP. Likewise, Machuca *et al.* (2011) in the automotive components sector, and Garrido *et al.* (2015) in the machinery, electronics and automotive components sectors, found that plant size has no effect on MS, TM and OP relationships. Meanwhile, Garrido *et al.* (2015) found that environmental complexity and plant description differed in the machinery, electronics and automotive components sectors, which may explain the differences found in TM and MS implementation in their study. These authors suggested that implementing operations programmes can mask contextual effects on industries, so future studies should investigate the possible holistic effects of industrial contexts and production practices in technology, production strategy and other production programs on performance.

The main purpose of this study is, therefore, to empirically explore whether either MS or TM, or a combination of the two, improves OP, and whether contextual variables may also influence OP. This investigation focuses on two industrial sectors, the electronics and machinery industries, which were selected for four reasons: first, they are industries in transition and operate in global environments; second, they are industries with a substantial number of plants in America, Asia and Europe, the three geographical areas on which the HPM research project focuses; third, the two industries operate in different competitive environments; and fourth, they are industries with different characteristics in terms of products; for example, product life cycles are shorter in the electronics industry than in the machinery industry.

The results should provide a better understanding of MS and TM relationships and contextual variables, and guide practitioners who wish to pinpoint the manufacturing practices that are most relevant for their particular operating environment. This study also contributes to contingency theory (Lawrence *and* Lorsch, 1967) in Operations Management (Sousa *and* Voss, 2008) by showing that the effects of MS and TM practices on OP can depend on contextual factors.

The remainder of this paper is organized as follows. Section 2 analyzes the prior literature on this topic. Section 3 describes the methodology and hypotheses. Section 4 sets out the analysis and discussion of the results. Finally, conclusions and further research are presented, along with the implications of this study for practitioners and academics.

2. Theoretical background and hypotheses

2.1. Manufacturing strategy and operational performance

MS has come to play a major role in manufacturing companies due to constant changes in process technology, the need to address turbulent markets and the obligation for greater customer-supplier collaboration. This has led business units to become more aware of MS' importance in improving the company's competitive position. As such, operations managers have to juggle constant improvements to manufacturing processes with prudent investments in new processes, using capital and human resources to maintain their competitive position in the market. Consequently, for MS to be properly implemented and well-aligned in a plant, aspects should be included such as the anticipation of new technology, the link between MS and business strategy, the formal strategic planning process that involves the plant's management, and the right MS implementation (Schroeder *and* Flynn, 2001; Machuca *et al.*, 2011). The implications of these dimensions of MS may require integrating the functional areas of the company and being consistent with the business strategy, as well as anticipation of new technologies that could lead to improving competitiveness and operational performance (Sardana *et al.*, 2016; Yarbrough *et al.*, 2011; Bates *et al.*, 1995; Skinner, 1969).

Several studies in the literature that evaluates the effects of MS on OP have shown that MS is associated with a significant positive effect on OP (e.g., Milling *et al.*, 1999; Devaraj *et al.*, 2004; Amoako-Gyampah *and* Acquaah, 2008; Thun, 2008; da Silveira *and* Sousa, 2010; Machuca *et al.* 2011; Lee, 2014; Sardana *et al.*, 2016). Annex A summarizes the main previous research on this topic. Except for Machuca *et al.*, 2011, and Garrido *et al.*, 2015, these empirical studies have not paid much attention to the contextual variables or the sector type. Consequently, empirical evidence is needed on this topic and the following hypotheses will be tested:

Hypothesis 1a: MS implementation is positively associated with OP

Hypothesis 1b: MS implementation is positively associated with OP in the presence of contextual variables

2.2. Technology management and operational performance

Many companies have identified that manufacturing plays a critical role in effective process and product innovation. In order to bring products to market more quickly and cost-efficiently, it is important for manufacturing to understand product requirements, ensure that products are manufacturable (manufacturing and supplier involvement in product design), and provide suitable and capable process technologies. In addition, customers generate product customization, which implies the need for organizations to increase their product portfolios (Starr, 2010). In this context, product modularization is one possible strategy for increasing an organization's competitiveness (Piran *et al.*, 2016). In light of the above, product modularization, manufacturing involvement in product design, and supplier involvement can all be considered key TM dimensions affecting OP (Schroeder *and* Flynn, 2001; Machado *et al.*, 2017).

However, not all companies have effectively involved their production personnel or modified their manufacturing practices to support process and product innovation (Henderson *and* Clark, 1990; Utterback, 1994, Prajogo, 2016). Despite the fact that both have a positive effect on business performance (Prajogo *and* Ahmed, 2007), there is only a limited understanding of the contextual variables under which these two different forms of innovation could be beneficial. While TM studies have shown the effectiveness of product and process innovation to be a competitive strategy, they also suggest that this effectiveness is influenced by the environmental context in which the firm operates and competes (Barney, 2001; Jansen *et al.*, 2006; Katila *and* Shane, 2005; Tsai *and* Yang, 2013). The reason for this is that although TM can be effective in improving performance in certain environments, it may not be as effective in others. This could be why the previous literature presents no conclusive findings as to the effects of TM on performance (see Annexes B and C). Some researchers have found that TM has positive and significant direct effects on OP (e.g., Boyer *et al.*, 1996; Flynn *and* Flynn, 1999; Fawcett *and* Myers, 2001; Maier *and* Schroeder, 2001; Tsai, 2004; Raymond, 2005; Fang, 2016; Prajogo, 2016) (see Annex B). However, empirical evidence also exists that does not support the TM–OP relationship (e.g., Beaumont *and* Schroeder, 1997; Boyer *et al.*, 1997; Swamidass *and* Kotha, 1998; Cagliano *and* Spina, 2000; Das *and* Jayaram, 2003, Machuca *et al.*, 2011; Jayaram *et al.*, 2014.; Bello *et al.*, 2015) (see Annex C). Some researchers have linked this pattern of inconclusive or varying results to the influence of contingency factors, such as plant size, manufacturing process type, work organization methods and competitive strategy (Sun *and* Gertsen, 1995, Swamidass *and* Kotha, 1998; Cagliano *and* Spina, 2000).

As a result, there is a need for more empirical evidence on the TM - OP relationship and the effects of contextual variables in said relationship. Therefore, the following hypotheses will be tested:

Hypothesis 2a: TM implementation is positively associated with OP

Hypothesis 2b: TM implementation is positively associated with OP when contextual variables are present

2.3. The relationships between MS and TM and operational performance

Organizations behave differently in stable and dynamic environments. Also, when they implement operations programmes to improve their competitive positions, organizations should not only consider contextual factors but also any interconnections among operations programmes (Schroeder *and* Flynn, 2001). Morita *et al.* (2001) assert that the interrelationship between practices must have a strategic objective. The strength of the relationship between practices will depend on how practices relate to each other and on how each is individually improved. If practice coverage and integration are appropriate, a plant will attain high performance.

Additionally, if capabilities for designing and managing the interrelationship are high, a plant will be able to realign the links between practices, even if the competitive situation changes. From this perspective, the effect of the MS - TM relationship on OP has been approached by different studies in the literature, as is shown in Annex D (e.g., Matsui, 2002; Sonntag, 2003; Ketokivi *and* Schroeder, 2004; Machuca *et al.*, 2011; Ortega *et al*,. 2012; Garrido *et al.*, 2015). In the same way, the presence or absence of contextual variables could materially affect the influence of MS and TM on OP outcomes (Im *and* Lee, 1989; Primrose, 1992; Groenevelt, 1993; Boyer *et al.*, 1997, Cagliano *and* Spina, 2000; Ahmad *et al.*, 2003).

Although the literature on this topic has studied the joint effect of MS and TM on OP, only Machuca *et al.* (2011) have undertaken research on the impact that the presence of contextual variables has on the relationship. This study suggests that MS is positively related to OP and that this continues to be the case when contextual factors are present. In the case of TM, their study showed no relationship with OP, even when contextual variables were included. While, the study focused on only one specific industry, namely, automotive components suppliers, it paved the way for future studies in other industries to address the question of whether the influence of both of the practice sets in question remains significant even after the inclusion of contextual variables.

This study continues this line of research and, therefore, the following hypotheses will be tested:

Hypothesis 3a: MS and TM in conjunction are positively associated with OP

Hypothesis 3b: MS and TM in conjunction are positively associated with OP when contextual variables are present

In other respects, it is possible that any relationship between TM and MS constitutes an interaction. In this sense, the most important reason why Japanese manufacturing companies have generated competitive advantages in the global market may be technological development in conjunction with an advanced MS (Matsui, 2002). This combination enables technological development to bring a set of competitive weapons to the plant (Itami *and* Numagami, 1992; Zahra *and* Covin, 1993). It can therefore be said that, in a way, a firm's technological resources regulate its failure or its competitive success, as TM is a manufacturing practice that could interact in the relationship between MS and OP. To the best of our knowledge, no studies found in the literature address the MS - TM interaction effect on OP or whether contextual variables contribute to improving this relationship. Thus, based on the arguments above, the following hypotheses are formulated:

Hypothesis 4a: MS -TM interaction positively affects OP

Hypothesis 4b: MS -TM interaction positively affects OP when contextual variables are present

2.4. Contextual variables and operational performance

When they seek to attain high performance manufacturing, companies should adopt the operations programmes that (adapted or not) jointly set the production plant on the path to high OP. The link between operations programmes and performance is highly influenced by contingent factors (Malhotra *et al.*, 2001; Schroeder *and* Flynn, 2001, Lam *et al.,* 2016). As Ketokivi *and* Schroeder (2004) mentioned, other contextual variables besides manufacturing practices can affect performance. Thus, the mere existence of operations programmes is not enough; they must be coherent with the contingent variables in order to be effective (Heine *et al.*, 2003, Schroeder *and* Flynn, 2001).

Notwithstanding, few studies have focused on the relationship between contextual variables and OP. Consequently, to date no research has been conducted into the influence of contextual variables on OP in the context of the electronics and machinery sectors. The environmental complexity, plant focus, plant size and plant description variables can have different impacts depending on the industry's distinctive features. This could be the case of the machinery and electronics sectors, where processes and product characteristics differ widely. For example, in the case of plant description, the machinery sector is characterized by low or single unit production volumes, whereas volumes are high in the electronics sector. Similarly, plant size could limit a company's flexibility to respond to any changes required to lot size.

Some empirical studies have considered contextual factors that influence the effectiveness of operations programmes, for instance: MS, TM practices and plant size; environmental complexity and plant description (e.g., Machuca *et al.*, 2011; Garrido *et al.*, 2015); and TM with plant size and plant focus (Das *and* Jayaram, 2003). Thus, contextual variables can have a significant effect on OP. The following hypothesis is therefore formulated:

H5.Contextual variables are positively associated with OP.

The research model has been represented in Figure 1.

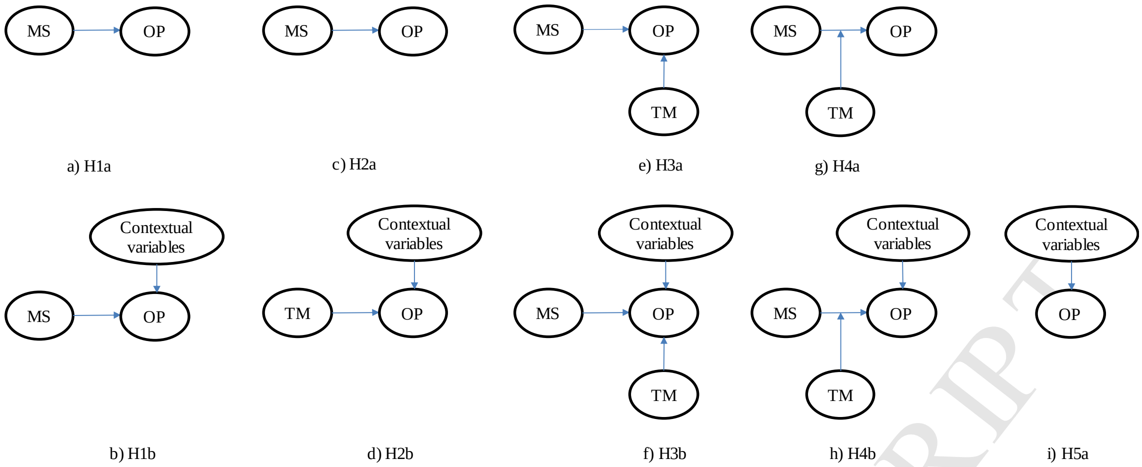

Figure 1 - Research model

3. Research methodology

3.1 Sampling and data collection

The empirical analysis was based on the current database of the fourth round of the international HPM (High Performance Manufacturing) project database (2016), which includes 309 manufacturing plants (auto supplier, machinery and electronics). The research technique used for data collection was the survey. The analytical unit was the plant. The HPM database covers the machinery and electronics industries in fourteen countries (Austria, Brazil, China, Finland, Germany, Israel, Italy, Japan, Korea, Spain, Sweden, Taiwan, UK and Vietnam), with data taken from 231 plants with 100+ employees, divided into 116 plants from the machinery sector and 115 plants from the electronics sector (see table 1).

Table 1 – Sample profile.

Country	Electronics Plants	Machinery plants	Total
Austria	1	6	7
Brazil	5	7	12
China	10	17	27
Finland	6	6	12
Germany	6	13	19
Israel	21	5	26
Italy	7	17	24
Japan	6	7	13
Korea	8	5	13
Spain	8	7	15
Sweden	4	4	8
Taiwan	19	10	29
UK	4	5	9
Vietnam	10	7	17
Total	**115**	**116**	**231**

Each questionnaire in this research study was tailored to the expertise of the focal informant following the key informant method (Bagozzi *et al.*, 1991). The items used in the present research were responded to by at least two different managers/workers (plant accounting managers, direct labor, human resource managers, inventory managers, process engineers, plant managers, quality managers, supervisors) in the plant for information to be triangulated. A total of 23 respondents per plant submitted their surveys. All the scales and measures of manufacturing practices considered in the HPM project were included in these questionnaires. Three different researchers developed and reviewed items for the scales to ensure the content validity of the questionnaires. The questionnaires were piloted using industry experts and academics, and items were included in at least two different questionnaires so information could be triangulated for greater reliability. This provided a cross-sectional image of the plants that prevented individual bias (Van Bruggen *et al.*, 2002; Sakakibara *et al.*, 1997) while simultaneously increasing validity.

3.2 Reliability of the scales

The items and questions in each scale were randomly listed in each of the questionnaires in order to prevent any respondent bias. The items were reviewed by a panel of experts, bibliographical review and structured interview, and piloted in several plants to improve content validity (Nunnally, 1967). The questionnaires were reviewed during the first, second and third rounds of the HPM project on the basis of the data collected and lessons learned from analyses, with invalid scales eliminated or modified to improve their reliability and validity. Other scales were also added to evaluate new concepts. The questionnaires were translated to local languages in non-English speaking countries and then back-translated by different individuals to check their accuracy. Any differences identified during this process were resolved before the surveys were launched. Questionnaires were also analyzed for reliability and construct validity using the usual statistical tests (including inter-correlation matrixes, Cronbach's alpha (Cronbach, 1951), factor analysis and canonical correlation). As a result, internal consistency, content validity and construct validity all achieved high values on the scales eventually used (Sakakibara *et al.*, 1999; Amahad *and* Schroeder, 2002; Schroeder *and* Flynn, 2001; Flynn *et al.*, 1995, Machuca et al., 2011).

Additionally, Harman's single factor test was used to test the common method bias. This method is the most widely used in the literature (Podsakoff *et al*, 2003). For electronics the total variance explained by the first component was 30.919% and for machinery it was 25.754%. As the percentage of total variance explained was below 50% in both cases, nonsignificant common method bias effects existed.

MS and TM were measured perceptually on a seven-point Likert scale from 1= strongly disagree to 7 = strongly agree. Reliability was measured by Cronbach's alpha (Cronbach, 1951) and values were above 0.6 (Hair *et al.*, 2011), implying that they were internally consistent. Tables 2 and 3 show the Cronbach's alpha values obtained for each scale and industry and their confidence intervals (Koning *and* Franses, 2003). The MS construct achieved Cronbach's alphas of 0.732 and 0.822 in the machinery and electronics sectors, respectively.TM achieved Cronbach's alphas of 0.742 and 0.738 in the machinery and electronics sectors, respectively. The items corresponding to each of these subscales are given in Annex E. Additionally, convergent validity was tested for the average variance extracted (AVE). All AVE values were above the recommended threshold value of 0.5 (Fornell *and* Larcker, 1981).

OP was measured through 5 items (Tables 2 and 3). Respondents were asked to rate their plant's performance against its primary competitor in the industry on a five-point

Likert scale from "poor, low end of industry" (1) to "superior" (5). The OP construct achieved Cronbach's alphas of 0.834 and 0.829 respectively in the machinery and electronics sectors. In case of the AVE, all the values were above 0.5.

Composite reliability (CR) also was calculated and all the MS, TM and OP values were higher than the minimum recommended value for acceptable internal consistency (CR above 0.70) (Kline, 2011).

The contextual variables used in this research were: plant size (PS); environmental complexity (EC); plant focus (PF); and plant description (PD). Annex F lists the item measures for each of these contextual variables. Table 4 shows the average values of the contextual variables by sector.

Table2 – Reliability of scales in machinery sector

	Variable / Dimension	**Load Factor**	**Cronbach's α (Confidence intervals)**	**AVE**	**CR**
	MS		0.732 (0.639 – 0.801)	0.599	0.851
MS1	Formal strategic planning	0.852			
MS2	Anticipation of new technologies	0.488			
MS3	Implementation of manufacturing strategy	0.871			
MS4	Manufacturing-business strategy linkage	0.821			
	TM		0.742 (0.771 – 0.871)	0.664	0.855
TM1	Modularization of products	0.763			
TM2	Manufacturing involvement in product design	0.829			
TM3	Supplier involvement	0.850			
	OP		0.834 (0.778 – 0.875)	0.607	0.885
	Conformance to product specifications	0.744			
	Product capability and performance	0.790			
	On-time new product launch	0.738			
	Product innovativeness	0.823			
	Customer support and service	0.797			

Table 3 – Reliability of scales in electronics sector

	Variable / Dimension	**Load Factor**	**Cronbach's α (Confidence intervals)**	**AVE**	**CR**
	MS		0.822 (0.689 – 0.842)	0.677	0.891
MS1	Formal strategic planning	0.878			
MS2	Anticipation of new technologies	0.570			
MS3	Implementation of manufacturing strategy	0.900			
MS4	Manufacturing-business strategy linkage	0.896			
	TM		0.738 (0.640 – 0.809)	0.656	0.851
TM1	Modularization of products	0.827			
TM2	Manufacturing involvement in product design	0.788			

TM3	Supplier involvement	0.815			
	OP		0.829 (0.771 – 0.872)	0.600	0.882
	Conformance to product specifications	0.689			
	Product capability and performance	0.829			
	On-time new product launch	0.750			
	Product innovativeness	0.839			
	Customer support and service	0.756			

Table 4 - Descriptive information on the contextual variables

Variable	Machinery Mean	Electronics Mean
PS: Plant size	5.918	6.104
EC: Environmental complexity	3.171	3.348
PF: Plant focus (type of plants)	2.853	3.336
PD: Plant description	2.627	3.124

3.3 Model evaluation

Hierarchical regression analysis was used to test the hypothesis. This analysis allows the researcher to identify the percentage of variance explained by each independent variable in a separate mode (Pedhazur *and* Schmelkin, 1991; Cagliano, *et al.*, 2006). Division of variance by hierarchical regression analysis is the most appropriate methodology when there are correlations between the independent variables. Hierarchical regression analysis is also recommended over structural equations modeling (SEM) when the sample size is under 200 (Kline, 2011; Barrett, 2007). In this research, the samples are: 115 for electronics sector; and 116 for machinery sector.

Correlations between the variables considered in the analysis are shown in Table 5 (machinery plants) and Table 6 (electronics plants). It must be noted that significant correlations exist between contextual variables MS, TM and OP. These correlations should be considered for further analysis.

Table 5 - Correlation results for machinery plants

	Mean	S.D.	PS	EC	PF	PD	MS	TM	OP
PS	5.918	1.200	1	0.1	-0.059	0.065	0.170	0.259**	-0.150
EC	3.171	0.909		1	0.119	0.349***	0.024	0.030	-0.054
PF	2.853	0.831			1	0.131	-0.149	0.086	0.071
PD	2.627	1.188				1	0.182	0.089	0.050
MS	3.923	0.473					1	0.340***	.519***
TM	3.738	0.655						1	.380***
OP	3.713	0.644							1

**P≤0.1; **P≤0.05; ***P≤0.01*

Table 6 - Correlation results for electronics plants

	Mean	S.D.	PS	EC	PF	PD	MS	TM	OP
PS	6.104	1.161	1	0.100	-0.041	-0.080	0.451***	0.087	0.118
EC	3.348	0.771		1	-0.045	0.510***	0.087	0.128	0.026
PF	3.336	0.928			1	-0.062	0.129	0.051	0.042
PD	3.124	1.100				1	-0.049	0.085	-0.030

MS	4.004	0.542					1	0.376***	0.535***
TM	3.789	0.564						1	0.288***
OP	3.807	0.626							1

*P≤0.1; **P≤0.05; ***P≤0.01

The independent variables were included one by one to test the hypotheses, and in two stages depending on whether the contextual variables were present or not. In the first stage (not considering contextual variables), MS was included in isolation (Model 1; H1a); subsequently TM was included in isolation (Model 2; H2a); next both variables were included together (Model 3; H3a) and lastly the interacting effect of TM on the MS-OP relationship was included (Model 4; H4a).

In the second stage, first the control variables were included (Model 5; H5); then MS was included in isolation (Model 6; H1b); subsequently TM was included in isolation (Model 7; H2b); and lastly the two independent variables were included together (Model 8; H3b). Finally, Model 9 (H4b) included the MS - TM interaction effects. The contribution of each set of variables was evaluated by determining the significance of the F-statistic associated with the change in adjusted R^2 after including each set (Pedhazur *and* Schmelkin, 1991; Cagliano *et al.*, 2006).

The required sample size for testing an overall regression model is 50+8k (k is the number of predictors or independent variables). In models 1, 2 and 4 there is one predictor (k=1), thus requiring a sample of 50+8k=58 in order to contrast the regression model in full. For model 3, there are two predictors (k=2), resulting in a minimum sample of 66 companies, while model 5 requires four predictors (k=4) and a minimum sample of 82 companies. For models 6, 7 and 9 there are five predictors (k=5), which requires a sample size of 90. Finally, model 9 has six predictors (k=6) and requires a sample size of 98. For testing individual predictors, the required sample size is 104+k (Tabchnick *and* Fidell, 2013). According to individual predictors, the minimum sample in this research should be 110 because k = 6, considering the maximum number of independent variables to test (PS, EC, PF, PD, MS and TM). Therefore, the samples used of 115 for the electronics sector and 116 for machinery sector meet the minimum requirements satisfactorily.

4. Results and discussion

4.1. The machinery sector

The results obtained for the machinery sector using hierarchical regression analysis are given in Tables 7 and 8. In the first stage, when the contextual variables were not considered, the results showed that both MS and TM have relationships with OP that are positive and significant. Therefore, H1a and H2a are accepted. When both variables were included, results were again positive and significant for OP, with Model 3 achieving better results (adjusted R^2 = 0.302, F = 22.021, p <0.01) than the previous two models, thereby supporting H3a. This highlights the importance of having both of these advanced manufacturing practices implemented to improve OP in the machinery sector. Model 4, which included the interaction effect, was positive and significant for OP (adjusted R^2 =0.271, F = 37.016, p <0.01). H4a is therefore accepted. However, Model 3 was better with the joint inclusion of the two variables than when their interaction effect was analyzed (Model 4).

Table 7 – First stage: MS, TM and OP in machinery sector

	OP			
Factor	**Model 1**	**Model 2**	**Model 3**	**Model 4**
MS	0.519***		0.441***	
TM		0.380***	0.233**	
MS*TM				0.528***
F	35.668***	16.186***	22.021***	37.016***
R2	0.269	0.144	0.317	0.278
Adjusted R2	0.261	0.135	0.302	0.271

*P≤0.1; **P≤0.05; ***P≤0.01*

Contextual variables were added in the second stage. Model 5, which included only contextual variables, did not show any significant effect. Only environmental complexity presented a significant negative influence on OP; therefore, H5 is not supported. When MS was added to the linear regression (Model 6), the results showed a significant effect on OP while contextual variables continued to show no effect (adjusted R^2=0.261, F=5.095, p<0.05). In Model 7, TM showed a significant positive effect. This was not the case of any of the contextual variables (adjusted R^2 =0.180, F= 3.548, p < 0.01) except for EC, which presented a significant negative effect on OP. These results lend support to H1b and H2b. When MS, TM and the contextual variables were analyzed in conjunction (Model 8), MS and TM showed a significant positive effect on OP (adjusted R^2=0.348, F=6.155, p<0.01). The contextual variables continued to be non-significant except for EC, which had a significant negative effect. Therefore, H3b is supported. Finally, when the interacting effects of MS-TM were included (Model 9), the results showed a positive effect on OP (adjusted R^2=0.335, F= 6.847, p<0.01), supporting H4b. The highest adjusted R^2 level was in Model 8. This means that Model 8 predicts OP better than the other models and the contextual variables affect this improvement.

The results of the second stage in machinery plants showed that the presence of contextual variables influenced the improvement of OP, except for EC, which had a significant negative effect in the model. In other words, the contribution of the contextual variables (except EC) examined is, in general, a positive but non-significant effect on OP, which results in an increase in the coefficients that measure the MS - OP relationship (Model 1, β = 0.519 vs. Model 6, β = 0.538) and TM (Model 2, β = 0.380 vs. Model 6, β = 0.430). Likewise, TM made a greater contribution to OP in the presence of the contextual variables and MS (Model 3, β = 0.233 vs. Model 8, β = 0.322). The impact of the TM interaction effect on the MS-OP relationship was observed to increase in the presence of the contextual variables (Model 4, β = 0.528 vs. Model 9, β = 0.590). These results show that joint MS and TM implementation and interaction have an effect on OP even in the presence of contextual variables. This means that in the joint implementation model (8), both of the independent variables, MS and TM, have effects on OP that are not conditional on the value of the other independent variables, and the value of the independent variable itself is not conditional on OP or on any other independent variable. In the case of the interaction model (9), it is implied that the form and/or strength of the effect that a plant's MS has on its effectiveness is contingent on TM and, at the same time, the form and/or strength of the effect that a plant's TM has on its effectiveness is contingent on MS. In simpler terms, the interactive effect of a plant's MS and TM will impact OP.

Therefore, machinery plants have to implement both operations programmes together. This means that joint and interactive implementation of the two practices will result in higher performance than the implementation of either of the two practices individually. In other words, when the two practices are implemented in interrelation with one another, they result in higher performance when the company context is considered in terms of PS, PF and PD.

Hierarchical regression analysis results showed that the variable EC has a significant negative effect on OP. One possible explanation for this is that machinery plants that opt for jobbing and project processes are often found in the engineer to order (ETO) or make to order (MTO) sectors. Thus, these plants seek the ability to customize and to reduce their operating expenses. This is particularly difficult in this sector, as these firms are not always able to adopt mass production processing efficiencies (Hendry, 2010).

Table 8 – Second stage: contextual variables, MS, TM and OP in machinery sector

	OP				
Factor	**Model 5**	**Model 6**	**Model 7**	**Model 8**	**Model 9**
PS	0.034	-0.131	-0.074	-0.186	-0.138
EC	-0.283**	-0.218	-0.308**	-0.247**	-0.270**
PF	0.063	0.156	0.050	0.132	0.112
PD	0.095	0.040	0.133	0.077	0.097
MS		0.538***		0.454***	
TM			0.430***	0.322***	
MS*TM					.590***
F	1.154	5.095**	3.548***	6.155***	6.847***
R2	0.079	0.325	0.251	0.415	0.392
Adjusted R2	0.011	0.261	0.180	0.348	0.335

*P≤0.1; **P≤0.05; ***P≤0.01*

4.2. The electronics sector

The first stage results for the electronics sector with the inclusion, first of MS in isolation, and subsequently of TM in isolation, are given in Table 9. First (Model 1) the effect of MS on OP was tested and the result was positive and significant (adjusted R^2 = 0.279, F = 36.976, p <0.01), so H1a is supported. Next (Model 2) the effect of TM on OP was tested and a significant positive relationship was also obtained (adjusted R^2 = 0.072, F = 7.610, p <0.01). Hence H2a is supported. Then, the combined effect of the two variables was tested; MS was observed to remain positive and significant, whereas TM had a positive but non-significant effect on OP (adjusted R^2 = 0.272, F = 16.913, p <0.01). Finally (Model 4) the interaction effect of the two variables was tested, resulting in a significant positive effect on OP (adjusted R^2 = 0.230, F = 26.352, p <0.01). Therefore, H3a is not supported while H4a is.

Table 9 – First stage: MS, TM and OP in the electronics sector

	OP

Factor	Model 1	Model 2	Model 3	Model 4
MS	0.535***		0.495***	
TM		0.288***	0.092	
MS*TM				0.489***
F	36.976***	7.610***	16.913***	26.352***
R2	0.287	0.083	0.290	0.239
Adjusted R2	0.279	0.072	0.272	0.230

*P≤0.1; **P≤0.05; ***P≤0.01*

In this first stage, it was observed that in the case of the electronics industry the effects of the two studied variables independently had significant positive impacts on OP. Notwithstanding, when the two variables were included together, the effect of TM on OP decreased and ceased to be significant, while MS remained positive and significant. However, the interaction effect between the two variables showed a significant positive relationship with OP. One possible reason for these results could be industry-specific characteristics, such as short product life cycles, volatile markets and high global competition, all of which require an MS that guides these types of industries toward OP improvement and the preservation or generation of competitive advantages. Thus, it can be seen that TM must be present for the MS-OP interaction relationship to be competitive.

Contextual variables were included in the second stage of the analysis (Table 10). In the first instance (Model 5), only the effects of the contextual variables were measured and a weak relationship with OP was observed. Therefore H5 is not supported. When MS was added to the analysis (Model 6), it significantly affected OP (adjusted R^2 =0.284, F=4.731, p<0.01), while the contextual variables did not (H1b supported). However, when TM was added to the analysis (Model 7), neither TM nor the contextual variables showed significant relationships with OP, so H2b is not supported. When MS, TM and the contextual variables were included together (Model 8), only MS continued to be significant (adjusted R^2=0.229, F=3.176, p<0.05). These results do not support H3b. Finally, when the interaction effect was included (Model 9), the results showed a positive effect on OP (adjusted R^2=0.162, F=2.703, p<0.05), supporting H4b. This provides some support for the assertion that there is an interaction relationship between the two practices.

These results show that the effects of contextual variables are nuanced depending on the operations programmes with which they are associated. For example, in Model 6 the contribution of the contextual variables in the electronics sector can be observed to have nonsignificant negative coefficient values, which may result in an increase in the positive impact of the MS coefficients on OP (Model 1, β = 0.535 vs. Model 6, β = 0.621). Similarly, the contribution of MS to OP increases in the presence of the contextual variables and TM (Model 3, β = 0.495 vs. Model 8, β = 0.571). This suggests that electronics companies must implement MS to improve OP, irrespective of PS, CE, PF and PD. To the contrary, TM's contribution to OP decreases and ceases to be significant in the presence of the contextual variables (Model 2, β = 0.288 vs. Model 7, β = 0.251). However, the impact of the TM interaction effect on the MS-OP relationship is observed to decrease in the presence of the contextual variables (Model 4, β = 0.489 vs. Model 9, β = 0.458). This means that TM is sensitive to plant characteristics such as plant size, type of manufacturing process, etc.

Table 10 – Second stage: contextual variables, MS, TM and OP in electronics sector

	OP				
Factor	**Model 5**	**Model 6**	**Model 7**	**Model 8**	**Model 9**
PS	0.111	-0.153	0.106	-0.107	-0.020
EC	0.013	-0.002	-0.003	0.012	-0.018
PF	-0.010	-0.062	0.004	-0.050	-0.020
PD	-0.212	-0.126	-0.241	-0.137	-0.188
MS		0.621***		0.571***	
TM			0.251	0.018	
MS*TM					0.458***
F	0.661	4.731***	1.313	3.176**	2.703**
R2	0.058	0.360	0.144	0.334	0.257
Adjusted R2	-0.030	0.284	0.034	0.229	0.162

*P≤0.1; **P≤0.05; ***P≤0.01*

Therefore, companies in the electronics sector should consider that MS has a greater impact on OP than TM. However, TM is considered a common practice in this type of industry, and its implementation can interact with the MS - OP relationship. Specifically, implementing an MS via strategic planning and anticipation of new technologies can provide the means to respond to rapidly evolving technology and short product life time in this type of industry and ultimately to improving OP (Liu *and* Liang, 2015).

5. Conclusions and final considerations

5.1 Empirical evidence and previous literature

Organizations are increasingly implementing MS and TM practices to improve performance (e.g., Matsui, 2002; Ketokivi *and* Schroeder, 2004; Prajogo, 2016). However, the literature shows mixed results when examining the relationship between MS and TM practices and OP (Matsui, 2002, Machuca *et al.*, 2011). Some studies have found that MS and TM practices together can lead to higher performance than when they are implemented individually (Matsui, 2002; Sonntag, 2003; Machuca *et al.*, 2011). However, joint MS and TM implementation is related to OP, but not in the same way in different industries (Garrido *et al.*, 2015). Nevertheless, the literature has provided little explanation as to how the MS and TM relationship affects OP when different contextual factors exist. Drawing on contingency theory, this paper tests whether the relationship between MS and TM is affected by contextual factors in two industrial contexts, the electronics and machinery sectors. These sectors have different competitive environments and characteristics in terms of products and processes.

The results show a positive effect of MS on OP for the two sectors studied and that this effect improves in the presence of contextual variables. These results corroborate earlier studies, such as Machuca *et al.* (2011), which concluded that MS has a positive relationship with performance in the automotive components sector and continues to do so even in the presence of contextual factors. Therefore, empirical evidence has been found that indicates that MS is an essential practice in the machinery, electronics and automotive components sectors and that it must be implemented for OP to improve (Machuca *et al.*, 2011; Garrido *et al.* 2015).

With respect to TM, this practice significantly impacts OP in the machinery sector, but not in the electronics sector. The results obtained in the electronics sector are in line with Machuca *et al.* (2011), who did not find any empirical evidence for a positive TM-OP relationship in the automotive components sector, either. These results seem to be incompatible with the characteristics of the electronics sector: for example, fast technological evolution and short product life time; or the automotive components sector, which needs to rapidly adapt to technological changes in the automobile industry. Furthermore, these two sectors have to contend with fierce global competition. According to these results, TM might be considered a practice that is a requisite for survival in the electronics and automotive components sectors, i.e., a minimum requirement, an order qualifier. As a result, TM has little influence on OP. However, in a sector such as the machinery industry, characterized by less repetitive processes, complex information exchanges with the customer, and sporadic customer orders, TM can be a differentiating practice capable of becoming an order winner. As such, the results reveal differences between sectors in the TM-OP relationship and this creates a new research gap with further evidence needed of the effect of TM on OP in other sectors.

Likewise, when a plant seeks to implement only one of the two practices (MS or TM), the benefits are maximized when the plant also implements the basic techniques of the other practice, and this is even more pertinent in global markets, where there is a dynamic and highly competitive environment (Karim *et al.*, 2008). In line with the above, the results of this research in the machinery sector show that the joint implementation of MS and TM practices and their interaction can produce a greater improvement to OP than implementing either of the two practices individually. However, the results reveal certain nuances in the improvements to OP in the electronics sector when either MS or TM is implemented in isolation compared to when the joint effect is analyzed or the two practices interact. In other words, MS is observed to make a greater individual contribution to OP than when it is linked with TM. This is in line with the Machuca *et al.* (2011) study on the automotive components sector, which shows that the joint MS - TM effect does not produce a significant improvement to OP. This creates a gap in research with research needed on these two practices' joint and interaction effects in other types of industrial sector.

In other respects, when contextual variables were included in the models, the results showed certain differences between sectors. Some contextual variables (PF and PD) did not have a positive relationship with OP in the electronics sector (Model 5) and none was significant. However, when they were included with MS, only Model 6 improved slightly on Model 2. In all other cases, none of the models considering contextual variables improved. In the case of the machinery sector, of all the contextual variables only environmental complexity had a significant negative effect and the model improved overall. Furthermore, the results of Models 6 through 9 showed improvements in the presence of the contextual variables compared to when they were not included (Models 1 through 4).

In other respects, MS - TM interaction showed a significant positive effect on OP in both sectors, both in the presence of the contextual variables were present and when they were not included (Models 3 and 8). The joint implementation of the two practices only had a significant positive effect on OP in the machinery sector (Model 4), and this was even greater when the contextual variables were included (Model 9). Therefore, this paper also posits that there are significant differences in performance that depend not only on the implementation levels of MS and TM practices in plants, but also, to a certain degree, by the contextual variables that are included in each specific case.

5.2. Theoretical implications

This paper looks beyond the challenges that plants face when implementing MS and TM. It considers the specific challenges to contingency theory in Operations Management with respect to the influence of contextual variables on MS and TM practices in two different industries, electronics and machinery, in 14 countries on three continents (America, Asia and Europe). Research proposals are developed through a survey of research questions, enabling this study to offer some theoretical contributions.

First, and most importantly, the paper identifies various degrees of MS and TM implementation that enhance OP for manufacturers in both of the studied industries. Thus, these findings contrast with previous widely accepted views that internal practices and techniques provide a better explanation of performance than the context in which plants operate by supporting an alternative view that the joint implementation of manufacturing practices and contextual factors contributes to the explanation of OP (Schroeder *and* Flynn, 2001; Sousa *and* Voss, 2008). In addition, further research is needed to identify whether a more holistic multivariate fit model with several operations programmes requires contextual factors to allow for industry constraints.

The second contribution identifies that performance appears to be a function of interaction in the MS-TM relationship. This observation suggests that overcoming challenges may well involve studying these practices together on the bivariate level, which may help to identify and structure future understanding of the areas that researchers ought to consider when trying to understand the connection between MS-TM and OP outcomes for other types of industries. In support of this suggestion, the study argues that decisions and activities are likely to be embedded in plants considering well-integrated practices that contribute to competitiveness in conjunction. Taking this broad, integrative perspective of the practices in question should enhance understanding of the way that manufacturers of different products implement such practices and overcome, or fail to overcome, key challenges as they attempt to manufacture. Manufacturing in both our selected industries is likely to involve MS processes that are based on, and linked to, TM processes. These processes run in parallel, with important points of contact between the practices involved in both processes that appear vital to successful product manufacture. Although this approach can generate some bureaucratic issues, in contrast to prior research (Sonntag, 2003), it appears to also possibly mean that firms adopt a common manufacturing process that plant employees understand, despite the potential change that the interaction brings. This common understanding may thus be an important factor in whether or not manufacturing practices or initiatives are successful. Managerial implications emerge with regards to the responses adopted to overcome key interaction challenges across two types of industries with differing products. This suggests that manufacturers should not uncouple their established MS-TM integration, despite some calls to do so (Matsui

2002). Instead, manufacturers with strong interactions should attempt to create new system fits in parallel with, and in support of, their other existing practices, recognizing that retaining one focused interaction may ultimately risk limiting their ability to successfully compete. If disruptive manufacturing threatens to destroy their existing market completely, then a more radical shift toward a more holistic focus may be preferable. Plants attempting to build new manufacturing models face challenges around key practices, needing to provide incremental support, while attempting to deliver step changes in OP. Plants may need to have lines of communication, reduce conflict, enhance learning, and understand issues to respond to these challenges. Structures also need to be put in place to support clearer interaction acknowledgement and to help with the constraints in many plants that hinder implementation efforts. This paper's findings suggest that contextual factors do not improve OP when this interaction is implemented.

The study's third and final contribution focuses on the processes and actions identified in this research that clarify and deepen the evidence on the importance of the two relationships, MS and TM, with performance. Specifically, findings show that MS improves OP in both sectors. However, TM is only significant in the machinery sector. Furthermore, the empirical evidence clarifies the interplay among these practices and illustrates which are essential when seeking a universal fit between either MS or TM and OP.

5.3 Managerial implications

The outcomes of this paper can guide managers seeking to define TM and MS and their implementation options in their plants. Specifically, this paper provides valuable information for industrial plant managers by identifying some relevant practices that must be considered when integrating manufacturing programs. The usual implementation of MS and TM (joint implementation and interaction) results in significant differences in effectiveness outcomes in sectors with short life cycle products, such as the electronics sector, and those with longer life cycle products, such as the machinery sector. Further, although we initially agree and have discussed that contextual factors may also contribute to the explanation of competitiveness variation, they resulted few to none: contextual factors such as PS, CE, PF and PD were believed to affect performance, none did so. Moreover, any possible environmental effects (whether positive or negative) are minimized when MS and TM are integrated.

For manufacturers at more mature stages of MS and TM implementation, these results may offer guidelines for reshaping their implementation in operations management. This part of the paper indicates that even in such different sectors as machinery and electronics, plants' internal practices may provide a better explanation of their effectiveness than the context in which they operate. This also further supports the theory that well-integrated manufacturing programs can lead to significant improvements in competitiveness. Nevertheless, managers have to be aware that the different implementation options afforded by such programs are never free of contradictions.

5.4. Limitations and further research

The exploratory nature of this study means that limitations exist with regard to its generalizability. This paper has attempted to distinguish manufacturers with particular approaches identified in the worldwide HPM project that have chosen to focus not only on MS and TM, but on several other practices, such as TQM, Total Productive Maintenance, Supply Chain Management, Lean Manufacturing, Information Systems, as well as on more of a “rifle approach”. Two specific industries (machinery and electronics) were selected rather than making an indiscriminate approach with data collected from a wide range of industries, since the results were expected to be more generalizable and readily interpretable. However, future research could consider additional variables and industries that might impact the effectiveness of responses to various fit approaches, such as interaction, combination, and universal fit (i.e., only one program influencing performance) in challenges to practice implementation, such as differences in gender or age or length of service**.** Future research should also test the impact and challenges posed by the implementation of the identified practices, and the types of responses adopted, using large samples of manufacturers in other industries. Another potential limitation relates to the heterogeneity of the industries. Although further exploration is required, the present paper’s approach has provided important insights into the commonality of practices across very different plants within industries and, thanks to its integrative approach to research, can be seen to also give interesting insights into common issues that many manufacturers face.

Further studies in the future can approach and evaluate MS, TM and contextual variables for each OP scale separately to determine which variables have a direct effect on specific operational measures. This analysis of contextual variables should also provide guidance for researchers looking to increase the practical relevance of their research and the depth of their analysis by enabling them to focus sharply on the contextual variables that are of paramount importance. This study can also be extended to other contextual variables, manufacturing practices and industries to ascertain what effect they have on OP. Similarly, the intervening effects of contextual variables on MS and TM relationships or other manufacturing practices should be analyzed in detail using the fit concept; both the bivariate perspective, such as mediation and interaction, or the systems perspective, such as covariation, etc. Lastly, it would be interesting to conduct longitudinal studies to determine whether the interrelationships of advanced manufacturing practices must change or evolve in line with market changes. In this regard, projects such as the HPM project, with many iterations over a number of years, provide a good basis for research (Hallgren *and* Olhager, 2006).

Acknowledgements

This study has been conducted within the frameworks of the following projects: “Acción especial SGUIT-2015 (SBAPA2015-06) HPM-(Project 2015/148 U.S.)”, Junta de Andalucía (Spain); “PAIDI Excellence Project P08-SEJ-0384”, Junta de Andalucía (Spain); and “DPI2009-11148”, Spanish National Program of Industrial Design and Production. The authors wish to acknowledge the helpful comments and suggestions of Victor A. Villegas Solorio regarding this paper.

References

Acquaah M, Amoako-Gyampah K, Jayaram J., 2011. Resilience in family and nonfamily firms: an examination of the relationships between manufacturing strategy, competitive strategy and firm performance. International Journal of Production Research, 49, (18), 5527.

Amahad, S., and Schroeder, R., 2002.Refining the product-process-matrix. International Journal of Operations & Production Management, 22, (1), 103-124.

Ahmad, S., Schroeder, R., Sinha, K., 2003. The role of infrastructure practices in the effectiveness of JIT practices: implications for plant competitiveness. Journal of Engineering and Technology Management, Vol.20, 161–191.

Amoako-Gyampah, K., and Acquaah, M., 2008. Manufacturing strategy, competitive strategy and firm performance: An empirical study in a developing economy environment. International Journal Production Economics, 111, 575-592.

Ang, J.S.K.,Shimada,T.,Quek,S.-A.,Lim,E.,2015.Manufacturingstrategyand competitiveperformance – an ACEanalysis. International Journal Production Economics, 169,240–252.

Bagozzi, R.P., Yi, Y.J., Phillips, L.W., 1991. Assessing construct-validity in organizational research. Administrative Science Quarterly, 36 (3), 421–458.

Banerjee S.K., 2000. Developing manufacturing management strategies: Influence of technology and other issues. International Journal of Production Economics, 64, 79-90.

Barrett, P., 2007. Structural equation modeling: Adjudging model fit. Personality and Individual Differences,42, 815-824.

Bates, K, Blackmon, K., Flynn, E.J. and Voss, C., 2001.Manufacturing Strategy: Building Capability for Dynamic Markets. In R. G. Schroeder & B. B. Flynn Eds.. High Performance Manufacturing-Global Perspectives 59-72. New York: John Wiley & Sons, Inc.

Bates, K. A., Amundson, S. D., Schroeder, R. G., Morris, W. T., 1995.The crucial interrelationship between manufacturing strategy and organizational culture. Management Science, 41 (10), 1565–1580.

Beaumont, N.B. and Schroder, R.M., 1997. Technology, manufacturing performance and business performance amongst Australian manufacturers.Technovation 17, (6), 297-307.

Beede, D. N. and Young, K. H., 1998.Patterns of advanced technology adoption and manufacturing performance. Business Economics, 33, 43–48.

Bello Pintado, A., Kaufmann, R. and Merino Diaz-de-Cerio, J., 2015. Advanced manufacturing technologies, quality management practices, and manufacturing performance in the southern cone of Latin America. Management Research: Journal of the Iberoamerican Academy of Management, 13, (2), 187–210. doi: 10.1108/mrjiam-03-2015-0580.

Boyer, K.K., Ward, P.T. and Leong, K.G., 1996. Approaches to the factory of the future: an empirical taxonomy. Journal of Operations Management, 14, 297–313.

Boyer, K.K., Leong, K.G., Ward, P.T. and Krajewski, L.J., 1997.Unlocking the potential of advanced manufacturing technologies. Journal of Operations Management, 15, (4), 331-347.

Cagliano, R., and Spina, G. 2000. Advanced manufacturing technologies and strategically flexible production. Journal of Operations Management 18, (2), 169-190.

Cagliano, R., Caniato, F. and Spina, G., 2006. The linkage between supply chain integration and manufacturing improvement programmes. International Journal of Operations and Production Management, 26, nº 3, 282-299.

Corbett, L. M., 2008. Manufacturing strategy, the business environment, and operations performance in small low-tech firms.International Journal of Production Research, 46, (20), 5491-5513.

Cronbach, L.J., 1951. Coefficient alpha and the internal structure of tests.Psychometrika, 16, 297-334.

Da Silveira, G. J.C. and Sousa, R. S., 2010. Paradigms of choice in manufacturing strategy: Exploring performance relationships of fit, best practices, and capability-based approaches. International Journal of Operations & Production Management, 30 (12), 1219-1245.

Das, A., and Jayaram, J., 2003. Relative importance of contingency variables for advanced manufacturing technology. International Journal of Production Research 41, (18), 4429-4452.

Devaraj, S., Hollingworth, D., and Schroeder, R. G., 2001. Generic manufacturing strategies: an empirical test of two configurational typologies. Journal of Operations Management, 19, 427–452.

Devaraj, S., Hollingworth, D., and Schroeder, R. G., 2004.Generic manufacturing strategies and plant performance. Journal of Operations Management, 22, 313–333.

Díaz, E., Garrido, L. Mart M, and García-Muiña F., 2007. Structural and infrastructural practices as elements of content operations strategy. The effect on a firm's competitiveness. International Journal of Production Research, 45, (9), 2119.

Fang, E. A., Li, X., & Lu, J., 2016.Effects of organizational learning on process technology and operations performance in mass customizers. International Journal of Production Economics, 174, 68-75.

Fawcett, SE, & Myers, MB., 2001. Product and employee development in advanced manufacturing: implementation and impact'. International Journal of Production Research, 39, (1), 65-79.

Fine, C.H., 2000.Clockspeed-based strategies for supply chain design. Production and Operations Management, 9, (3), 213-21.

Flynn, B.B., and Flynn, E.J., 1999. Information-processing alternatives for coping with manufacturing environment complexity. Decision Sciences, 30, (4), 1021-1052.

Flynn, B.B., Sakakibara, S., and Schroeder, R.G., 1995. Relationship between JIT and TQM: Practices and Performance. Academy of Management Journal, 38, (5), 1325-1360.

Flynn, B.B., Schroeder, R.G. and Flynn, E.J. (1999), "World class manufacturing: an investigation of Hayes and Wheelwright's foundation", Journal of Operations Management, 17, 249-69.

Fornell, C., &Larcker, D. F. (1981).Evaluating structural equation models with unobservable variables and measurement error. JMR, Journal of Marketing Research, 18, 39–50.

Frohlich, M.T. and Dixon, J.R. (2001), "A taxonomy for manufacturing strategies revisited", Journal of Operations Management, 19 (5), 541-558.

Garrido-Vega, Pedro, Ortega Jimenez, Cesar H., Díez Pérez de los Ríos, José Luis, Morita M., 2015. Implementation of technology and production strategy practices: Relationship levels in different industries. International Journal of Production Economics, 161, 201-216, ISSN 0925-5273, http://dx.doi.org/10.1016/j.ijpe.2014.07.011.

Groenevelt, H., 1993. The just-in-time system. In: Graves, S.C. Ed..Handbooks in Operations Research and Management Science.Elsevier, New York, NY, 4.

Gyan-Baffour, G., 1994.Advanced manufacturing technology, employee participation and economic performance: an empirical analysis. Journal of Managerial Issues, 6, 491–505.

Hallgren, M., and Olhager, J., 2006. Quantification in manufacturing strategy: A methodology and illustration. International Journal of Production Economics, 104, (1), 113-124.

Hair, J.F. Jr, Black,W.C., Babin, B.J. and Anderson, R.J., 2011. Multivariate Analysis, Prentice-Hall, Upper Saddle River, NJ.

Heim, G.R., Peng,D.X., 2010. The impact of information technology use on plant structure, practices, and performance: an exploratory study. Journal of Operations Management, 28 (2), 144–162.

Heine, M. L., Grover, V., and Malhotra, M. K., 2003. The relationship between technology and performance: a meta-analysis of technology models. OMEGA, 31, 189-204.

Henderson, R., Clark, K., 1990. Architectural innovation: the reconfiguration of existing product technologies and the failure of established firms. Administrative Science Quarterly 35 (1), 9–30.

Hendry, L.C., 2010. Product customisation: an empirical study of competitive advantage and repeat business. International Journal of Production Research, 48, (13), 3845-3865.

Hilmola, O., Lorentz, H., Hilletofth P. and Malmsten J., 2015.Manufacturing strategy in SMEs and its performance implications, Industrial Management & Data Systems, 115 (6), 1004-1021.

Itami, H., and Numagami, T., 1992. Dynamic Interaction Between Strategy and Technology. Strategic Management Journal, 13, 119–136.

Jayaram J, Oke A, Prajogo D., 2014. The antecedents and consequences of product and process innovation strategy implementation in Australian manufacturing firms.International Journal of Production Research, 52, (15), 4424.

Karim, MA, Smith, AR, &Halgamuge, S., 2008.Empirical relationships between some manufacturing practices and performance. International Journal of Production Research, 46, (13), 3583-3613.

Ketokivi, M., and Schroeder, R.G., 2004. Manufacturing practices, strategic fit and performance. A routine-based view. International Journal of Operations & Production Management, 24, (2), 171-191.

Kline, R.B., 2011. Principles and Practice of Structural Equation Modeling. Guilford Press, New York.

Koning, A. J. and Franses, P. H., 2003.Confidence Intervals for Cronbach's Coefficient Alpha Values. ERIM Report Series Reference (ERS-2003-041-MKT). Available at SSRN: http://ssrn.com/abstract=423658.

Kotha, S., and Orne, D., 1989. Generic manufacturing strategies: A conceptual synthesis. StrategicManagement Journal, 10, 211–231.

Koufteros, X., Lu, G., Peters, R., Lai, K. and Wong, C., 2014. Product development practices, manufacturing practices, and performance: A mediational perspective. International Journal of Production Economics, 156, 83–97.

Lam H.K.S., Yeung A.C.L., Cheng T, Humphreys P.K., 2016. Corporate environmental initiatives in the Chinese context: Performance implications and contextual factors. International Journal of Production Economics, 180, (1), 48-56.

Lawrence, P.R., Lorsch, J.W., 1967. Organization and Environment. Harvard University Press, Cambridge.

Lee, Wonhee; Rhee, Seung-Kyu and Oh Joongsan, 2014. The relationships between manufacturing strategy process, manufacturing-marketing integration, and plant performance: an empirical study of Korean manufacturers. Operation Management Research, 7, 117–133.

Lee, D., Rho, B. and Yoon, S., 2015. Effect of investments in manufacturing practices on process efficiency and organizational performance. International Journal of Production Economics, 162, 45-54.

Liu, Y. & Liang, L., 2015. Evaluating and developing resource-based operations strategy for competitive advantage: an exploratory study of Finnish high-tech manufacturing industries. International Journal of Production Research, 53, (4), 1019.

Machado-Barbosa, L., Pacheco-Lacerda, D., SartoriPiran F. A., Dresch A., 2017.Exploratory analysis of the variables prevailing on the effects of product modularization on production volume and efficiency, International Journal of Production Economics, 193, 677-690.

Machuca, J.A.D, Ortega-Jiménez, C.H., Garrido-Vega, P., and Ríos, José Luis Pérez Diez de los., 2011. Do technology and manufacturing strategy links enhance operational performance? Empirical research in the auto supplier sector. International Journal of Production Economics, 133, (2), 541-550.

Maier, F.H. and Schroeder, R.G., 2001. Competitive product and process technology. In R. G. Schroeder & B. B. Flynn Eds. High Performance Manufacturing: Global Perspectives 96-116. New York: John Wiley & Sons, Inc.

Malhotra M.K., Heine M.L., and Grover V., 2001. An evaluation of the relationship between management practices and computer aided design technology. Journal of Operations Management; 19, 307–33.

Mallick, D. N. and Schroeder, R. G., 2005.An Integrated Framework for Measuring Product Development Performance in High Technology Industries. Production and Operations Management, 14, (2), 142-158.

Matsui, Y., 2002. Contribution of manufacturing departments to technology development: An empirical analysis for machinery, electrical and electronics, and automobile plants in Japan. International Journal of Production Economics, 80, 185–197.

Miller, J.G. and Roth, A.V. (1994), “A taxonomy of manufacturing strategies”, Management Science, 40 (3), 285-304

Milling, P.M., Maier, F.H. and Mansury, D., 1999. Impact of manufacturing strategy on plant performance – insights from the international research project: world-class manufacturing. Paper presented at the Managing Operations Networks EurOMA Conference, Venice, Italy, 573-580.

Morita, M. and Flynn, E. J., 1997.The linkage among management systems, practices and behaviour in successful manufacturing strategy. International Journal of Operations & Production Management, 17 (10), 1997, 967-993.

Morita, M., Flynn, E.J.and Milling, P., 2001. Linking Practices to Plant Performance High Performance Manufacturing-Global Perspectives. New York: John Wiley & Sons, Inc.

Nunnally, J.C., 1967. Psychometric Theory. McGraw-Hill, New York.

Oltra, M.J. and Flor, M.L., 2010. The moderating effect of business strategy on the relationship between operations strategy and firms’ results. International Journal of Operations & Production Management, 30, (6), 612-638.

Ortega, C. H., Garrido-Vega, P. and Machuca, J.A.D., 2012. Analysis of interaction fit between manufacturing strategy and technology management and its impact on performance. International Journal of Operations & Production Management, 32, 958-981. doi:10.1108/01443571211253146.

Ortega, C. H., Garrido-Vega, P. Díez Pérez de los Ríos, J. L. and Garcia-Gonzalez, S., 2011. Manufacturing strategy–technology relationship among autosuppliers.International Journal of Production Economics,133, 508–517.

Papke-Shields KE, Malhotra MK, and Grove V., 2006.Evolution in the strategic manufacturing planning process of organizations. Journal of Operations Management, 24, 421–439.

Pedhazur, E. and Schmelkin, L., 1991. Measurement, Design and Analysis: An Integrated Approach. Ed. Lawrence Erlbaum Associates, Hillsdale, NJ.

Piran, F.A.S., Lacerda, D.P., Camargo, L.F.R., Viero, C.F., Dresch, A., Miguel, P.A.C., 2016. Product modularization and effects on efficiency: an analysis of a bus manufacturer using Data Envelopment Analysis (DEA). International Journal of Production Economics, 182, 1–13.

Podsakoff, P. M., MacKenzie, S. M., Lee, J., &Podsakoff, N. P. (2003). Common method variance in behavioral research: a critical review of the literature and recommended remedies. Journal of Applied Psychology, 88(5), 879-903.

Prajogo Daniel I., 2016. The strategic fit between innovation strategies and business environment in delivering business performance. International Journal of Production Economics, 171, 241-249, ISSN 0925-5273, http://dx.doi.org/10.1016/j.ijpe.2015.07.037.

Prajogo,D.I.,Ahmed,P.K.,2007.The relationships between quality, innovation and business performance: an empirical study. International Journal Business Performance Management, 9,405–426.

Primrose, P.L., 1992.Evaluating the introduction of JIT. International Journal of Production Economics, 27, 9–22.

Raymond, L., 2005. Operations management and advanced manufacturing technologies in SMEs: A contingency approach. Journal of Manufacturing Technology Management; 16, (7/8), 936-955.
Rose, R.C., Kumar, N., and Ibrahim, H.I., 2008. The Effect of Manufacturing Strategy on Organizational Performance. Performance Improvement, 47, (1), 8-25.
Sakakibara, S., Flynn, B.B., Schroeder, R.G., and Morris, W.T., 1997.The Impact of Just-In-Time Manufacturing and its Infrastructure on Manufacturing Performance. Management Science, 43, (9), 1246-1257.
Sardana, D., Terziovski, M., & Gupta, N., 2016. The impact of strategic alignment and responsiveness to market on manufacturing firm's performance. International Journal of Production Economics, 177, 131-138.
Schroeder, R. G., and Flynn, B., 2001. High Performance Manufacturing-Global Perspectives. New York: John Wiley & Sons, Inc.
Schroeder RG, Bates KA, and Junttila M.A., 2002. A resource-based view of manufacturing strategy and the relationship to manufacturing performance. Strategic Management, 23, 105–117.
Sharma, B., 2008.Technology Strategy, Contextual Factors and Business Performance: An Investigation of Their Relationship. South Asian Journal of Management, 15 (3).19-39.
Sila, I., 2007. Examining the effects of contextual factors on TQM and performance through the lens of organizational theories: an empirical study. Journal of Operations Management 25 (1), 83–109.
Skinner, W., 1969.Manufacturing missing link in corporate strategy. Harvard Business Review, 136–145.
Sonntag, V., 2003.The role of manufacturing strategy in adapting to technological change.Integrated Manufacturing System, 14, (4), 312-323.
Sousa, R., Voss, C.A., 2008. Contingency research in operations management practices. Journal of Operations Management 26 (6), 697–713.
Swamidass, P.M., and Kotha, S., 1998.Explaining manufacturing technology use, firm size and performance using a multidimensional view of technology. Journal of Operations Management, 17, (1), 23–37.
Sun, H., and Gertsen, F., 1995. Organizational changes related to advanced manufacturing technology in the production area. International Journal of Production Economics, 41, 369–375.
Tabchnick, B.G. – Fidell, L.S. (2013). Using Multivariate Statistics. Pearson, New York.
Thun, J.H., 2008. Empirical analysis of manufacturing strategy implementation. International Journal of Production Economics, 113, 370–382.
Tsai, K.H., 2004. The impact of technological capability on firm performance in Taiwan's electronics industry. Journal of High Technology Management Research, 15, 183–195.
Utterback, J. M., 1994. Radical innovation and corporate regeneration. Research-Technology Management, 37(4), 10.
Van Bruggen,G.H., Lilien,G.L., and Kacker,M., 2002.Informants in organizational marketing research: why use multiple informants and how to aggregate responses. Journal of Marketing Research, 39, (4), 469-478.
Wang, Z., Subramanian, N. and Gunasekaran, A., 2015. Composite sustainable manufacturing practice and performance framework: Chinese auto-parts suppliers′ perspective. International Journal of Production Economics, 170, (A), 219–233.
Whybark, D.C. and Vastag, G. 1993. Global Manufacturing Practices : A Worldwide Survey of Practices in Production Planning and Control. Elsevier.
Yarbrough, L., Morgan, N. A., Vorhies, D. W., 2011. The impact of product market strategy organizational culture fit on business performance. Journal Academic Marketing Science, 39 (4), 555–573.
Zahra, S., &Covin, J., 1993.Business Strategy, Technology Policy, and Firm Performance. Strategic Management Journal, 14, 451–478.
Zhang, D., Linderman, K. and Schroeder, R. G., 2012. The moderating role of contextual factors on quality management practices, International Journal of Operations Management, 30, (1–2), 12-23, ISSN 0272-6963, https://doi.org/10.1016/j.jom.2011.05.001.

Annex A - Studies on the relationship between MS and OP.

Author	Sample	Objectives	Results
Morita *and* Flynn, 1997	46 Japanese factories in the machinery,	To examine whether MS is related to best advanced manufacturing practices and	Positive relationship found between implementation of best practices and performance.

Author	Sample	Objectives	Results
	electronics and automotive industries.	performance.	
Milling *et al.*, 1999	164 machinery, electronics and automotive industries in Germany, Italy, Japan, the UK and the USA.	To investigate the relationship between MS and plant performance.	Timely delivery and MS have a weak relationship while cost efficiency and MS show a positive relationship.
Bates *et al.*, 2001	164 machinery, electronics and automotive industries in Germany, Italy, Japan, the UK and the USA.	To analyze MS dimensions in their two perspectives (market-based view (MBV) and resource-based view (RBV)).	Focus on long-term investments in manufacturing process through the consistent adoption of MS. The authors suggest implementing initiatives to improve the manufacturing process.
Ketokivi *and* Schroeder, 2004	164 machinery, electronics and automotive industries in Germany, Italy, Japan, the UK and the USA.	Having a better understanding of the contingency strategic argument in MS studies.	Operations programmes and contingency arguments' influence on OP; contingency has a greater impact.
Devaraj *et al.*, 2001	164 machinery, electronics and automotive industries in Germany, Italy, Japan, the UK and the USA.	Comparative empirical study of two types based on process-product matrix configuration and generic manufacturing strategies with the performance of the company.	Generic manufacturing strategies are related to several measures of performance, such as cost, cycle time / inventory, quality and innovation.
Devaraj *et al.*, 2004	143 machinery, electronics and automotive industries in Germany, Italy, Japan and the USA.	To examine the effects of the fit between generic manufacturing strategies and manufacturing objectives on higher levels of plant performance.	Analysis reveals a significant relationship between generic manufacturing strategies and plant performance.
Amoako-Gyampah *and* Acquaah, 2008	126 manufacturing companies in Ghana.	To examine the relationship between MS and competitive strategy and its influence on firm performance.	Significant positive relationships found between competitive strategy and MS. Additionally, quality is the only MS component that influences performance.
Corbett, 2008	10 manufacturing companies in New Zealand.	To examine the stability of MS in turbulent environments, with emphasis placed on improvement initiatives and the impact that these decisions have on OP.	Strategy configurations were not stable and many firms moved towards a price-based configuration. The most successful firms invested more in their operations strategy's infrastructural categories in line with the resource-

Author	Sample	Objectives	Results
			based view. OP indicators showed some improvement in manufacturing costs but other indicators showed no real pattern.
Rose *et al.*, 2008	121 electrical and electronics firms in Malaysia.	To investigate the effect of MS on organizational performance.	Cost-based strategy shows a significant impact on firm performance, while speed strategies show a nonsignificant relationship with organizational performance.
Thun, 2008	235 machinery, electronics and automotive industries in Austria, Finland, Germany, Italy, Japan, South Korea, Sweden and the USA.	To close the gap between theoretical approaches concerning MS and empirical analysis.	General implementation of an MS leads to better performance and fosters the implementation of special manufacturing strategies; i.e., a resource-based, a market-based, or an integrated manufacturing strategy.
Oltra *and* Flor, 2010	76 Spanish ceramic companies.	To examine the influence of business strategy on the relationship between MS and business results from the contingency perspective.	Business strategy has a moderating effect in the relationship between MS and company results.
da Silveira *and* Sousa, 2010	697 manufacturers of metal products, machinery, equipment, and instruments in 22 countries.	To test relationships between performance improvements and three classical MS paradigms of fit, best practices and capabilities.	Capability learning and best practices are positively related to performance improvements in quality, flexibility, and dependability, whereas internal fit appears to be negatively related to improvements in flexibility.
Acquaah *et al.et al.*, 2011	122 manufac-turing firms in Ghana.	To compare the relationship between MS, competitive strategy and performance in family and non-family firms.	Family and non-family firms in Ghana use different manufacturing components to improve performance.
Machuca *et al.*, 2011	90 auto supplier companies in Austria, Finland, Germany, Italy, Japan, South Korea, Spain, Sweden and the USA/Canada.	To examine the relationship between MS and TM and its effect on OP; likewise in the presence of contextual variables.	MS has a positive relationship with performance, and continues to do so even in the presence of contextual factors. However, TM does not have a positive relationship with performance in either case.
Lee, 2014	221 machinery, automotive and electronics manufacturers in South Korea	To examine the interrelationships between MS process manufacturing-marketing integration and plant performance.	Positive relationships were observed between the MS process, manufacturing marketing integration and plant performance. Although MS formulation does not directly affect plant performance, its influence on plant performance is transmitted through MS implementation and manufacturing marketing integration.

Author	Sample	Objectives	Results
Ang et al, 2015	163 manufacturing plants in the machinery, electronics and auto supplier industries in Brazil, China, Germany, Japan, and the USA.	To investigate the relationships between the competitive dimensions of manufacturing strategy and competitive performance in two clusters: 1) Brazil and China; 2) Germany, Japan and USA.	The strategic orientation of the firm has a positive impact on competitive performance.
Garrido *et al.*, 2015	267 auto supplier, machinery and electronics plants in Austria, Finland, Germany, Italy, Japan, South Korea, Spain, Sweden and the USA/Canada	To examine whether there are differences in the ways that TM and MS are implemented in different sectors, whether implementation is linked to performance, and whether contextual factors explain the differences.	Joint MS and TM implementation is related to OP but not in the same way in the three sectors because of the influence of contextual variables.
Sardana *et al.*, 2016	58 Indian manufacturing firms.	To examine the influence of manufacturing operations' functioning, strategic alignment and responsiveness to market need for customization and firm performance.	Manufacturing operations' strategic alignment to the business plan positively and significantly improves the firm's performance. Plant technology capability shows a positive but nonsignificant relationship with firm performance. The presence of Strategic Alignment in the regression caused the solution to be positioned in such a way that the Plant Technology Capability was in a weaker significant, negative position.

Annex B - Studies on the positive relationship between TM and OP.

Author	Sample	Objectives	Results
Boyer *et al.*, 1996	202 US metallurgical companies.	To examine whether investment in advanced manufacturing technology (AMT) improves performance.	There is an important interaction between AMT and investment in infrastructure. Performance improvement in firms that implement both practices instead of one.
Flynn *and* Flynn, 1999	164 machinery, electronics and automotive industries in Germany, Italy, Japan, the UK and the USA.	To evaluate the role of various alternatives for information processing in complex manufacturing environments.	In a complex environment, information processing is related to improvement of OP.

Author	Sample	Objectives	Results
Fawcett *and* Myers, 2001	158 US manufacturing firms	To examine interrelationships between four manufacturing practices: (1) integrated product development; (2) employee development; (3) just-in-time manufacturing; and (4) manufacturing automation and firm performance.	All four manufacturing practices have significant, positive impacts on firm performance.
Maier *and* Schroeder, 2001	164 machinery, electronics and automotive industries in Germany, Italy, Japan, the UK and the USA.	To analyze the impact of TM on competitive performance.	Introduction of technology, anticipation of new technologies and effective implementation are the key to improving competitive performance. TM is an important manufacturing practice for achieving high performance.
Tsai, 2004	45 Taiwan electronics firms.	To examine the impact of technological capability on firm performance.	Technological capability has a significant effect on productivity growth and firm performance.
Raymond, 2005	118 Canadian manufacturing firms.	To examine the fit or alignment between the critical success factors (CSF) of operations management in small and medium–sized enterprises and their degree of AMT implementation.	As the implementation levels of AMT and CSF increase, OP improves, but it decreases significantly when there is a mismatch between the two.
Fang, 2016	211 manufacturing and service organizations in China.	To investigate the role of organizational learning and process technology in the implementation of mass customization.	This study confirms that process automation is significantly connected to throughput; however, process flexibility does not contribute to throughput.
Prajogo, 2016	207 manufacturing firms in Australia.	To examine the role of business environments (in terms of dynamism and competitiveness) as contingency factors that affect the effectiveness of innovation strategies (such as product and process) in delivering business performance.	Dynamic environments strengthen the effect of product innovation on business performance. Competitive environments strengthen the effect of process innovation on business performance and weaken the effect of product innovation on business performance.

Annex B- Studies on no positive relationship between TM and OP.

Author	Sample	Objectives	Results
Beaumont *and* Schroeder, 1997	962 Manufacturing firms in Australia.	To examine the links between AMT use, manufacturing performance and business performance.	There is no relationship between AMT and performance.
Boyer *et al.*, 1997	202 manufacturing plants in USA.	To examine whether the investment in AMT improves performance.	Interaction between AMT and infrastructure programs is significantly related to company performance but not flexibility.
Swamidass *and* Kotha, 1998	160 manufacturing firms in USA	To examine the relationship between AMT, plant size and performance.	AMT use shows no direct impact on business results. Plant size weakly moderates the AMT - performance relationship.

Author	Sample	Objectives	Results
Cagliano *and* Spina, 2000	392 manufacturing firms in the metal-working industry operating in 20 countries in Europe, North and South America, and Japan.	To investigate the relationship between the use and effectiveness of various technologies and OP.	AMT *per se* does not imply higher OP.
Das and Jayaram, 2003	309 manufacturing plants in the USA.	To evaluate a set of contingent variables that influence the AMT-OP relationship.	Lean manufacturing and work organization practices are the primary contingency variables that affect the AMT-OP relationship.
Machuca *et al.*, 2011	90 auto supplier companies in Austria, Finland, Germany, Italy, Japan, South Korea, Spain, Sweden and the USA/Canada.	To examine the relationship between MS and TM and its effect on OP; likewise in the presence of contextual variables.	MS has a positive relationship with performance, and continues to do so even when contextual factors are present. However, TM does not have a positive relationship with performance in either case.
Jayaram *et al.*, 2014.	207 manufacturing firms in Australia.	To investigate the effect of product and process innovation strategy on product innovation performance and product quality performance.	Product innovation strategy is positively related to product innovation performance, while process innovation strategy implementation positively affects product quality performance. Both strategies are found to positively affect business performance.
Bello *et al.*, 2015	301 manufacturing firms in Argentina and Uruguay.	To examine the effect of the relationship between AMTs and quality management practices on manufacturing performance.	QM practices have a direct effect on manufacturing performance, while AMTs are significant only in the presence of QM practices.

Annex D- Studies on the relationships of MS and TM on OP.

Author	Sample	Objectives	Results
Matsui, 2002	164 machinery, electronics and automotive industries in Germany, Italy, Japan, the UK and the USA.	To analyze the role of manufacturing departments in product and process technology development and their relationship with other main fields of production management.	Involvement in technology development is strongly influenced by human resource management, information systems, quality management, and MS, and the fact that it plays a decisive role in determining the competitive performance of the manufacturing plants.
Sonntag, 2003	21 interviews with technology users, suppliers and service providers in the countries of the European Union.	To develop an MS model to explain how companies adapt to technological change and what the source of that change is.	The MS model indicates that it is critical not only for companies to be able to adapt to technological change, but also for their ability to adapt to changes in the future.
Ketokivi *and*	164 machinery, electronics and	To move toward better-informed empirical inquiry of	There is merit in best practice and strategic contingency arguments

Author	Sample	Objectives	Results
Schroeder, 2004	automotive industries in Germany, Italy, Japan, the UK and the USA.	the strategic contingency argument in MS research.	explaining OP; however, the contingency argument has stronger support.
Machuca *et al.*, 2011	90 auto supplier companies in Germany, Italy, Japan, South Korea, Spain, Sweden and the USA/Canada.	To examine the relationship between MS and TM and its effect on OP; likewise in the presence of contextual variables.	MS has a positive relationship with performance, and continues to do so even when contextual factors are present. However, TM does not have a positive relationship with performance in either case.
Ortega *et al.*, 2012	90 auto supplier companies in Austria, Finland, Germany, Italy, Japan, South Korea, Spain, Sweden and the USA/Canada.	To examine the interaction fit between a set of MS managerial practices and a TM set and the link between this fit and OP.	No significant deviation in OP from high and low implementation levels of the MS / TM relationship.
Garrido *et al.*, 2015	267 auto supplier, machinery and electronics plants in Austria, Finland, Germany, Italy, Japan, South Korea, Spain, Sweden and the USA/Canada	To examine whether there are differences in the ways that TM and MS are implemented in different sectors, whether implementation is linked to performance, and whether contextual factors explain the differences.	MS and TM implementation is related to OP but not in the same way in the three sectors because of the influence of contextual variables.

ANNEX E. Items related to MS, TM and OP scales.

Manufacturing Strategy (MS) Adapted from: Schroeder *and* Flynn (2001), Matsui (2002), Machuca *et al.* (2011), Ortega *et al.* (2012) and Garrido *et al.* (2015).
MS1: Formal strategic planning
• Our plant has a formal manufacturing strategy process, which results in a written mission, goals and strategies. • This plant has a manufacturing strategy, which is put into writing. • Plant management routinely reviews and updates a long-range manufacturing strategy.
MS2: Anticipation of new technologies
• We pursue long-range programs in order to acquire manufacturing capabilities in advance of our needs. • We make an effort to anticipate the potential of new manufacturing practices and technologies. • Our plant stays on the leading edge of new technology in our industry. • We are constantly thinking about the next generation of manufacturing technology.
MS3: Implementation of Manufacturing Strategy
• The improvement programs that we pursue to improve operations are based on our manufacturing strategy.

• Improvement programs are an essential element of our manufacturing strategy. • Changes to the manufacturing strategy are deployed in the entire manufacturing area. • The plant's performance measures clearly reflect the plant's goals. • What the strategy says and what we pursue on the shop floor are two different things. • Corporate decisions are often made without consideration of the manufacturing strategy
MS4: Manufacturing-business strategy linkage
• We have a manufacturing strategy that is actively pursued. • Our business strategy is translated into manufacturing terms. • Potential manufacturing investments are screened for consistency with our business strategy. • At our plant, manufacturing is kept in step with our business strategy.
Technology Management (TM) Adapted from: Schroeder *and* Flynn (2001), Matsui (2002), Machuca *et al.* (2011), Ortega *et al.* (2012) and Garrido *et al.* (2015).
TM1: Product modularization
• Our products are modularly designed so they can be rapidly built by assembling modules. • We have defined product platforms as a basis for future product variety and options. • Our products are designed to use many common modules.
TM2: Manufacturing involvement in product design
• Manufacturing engineers are heavily involved prior to the introduction of new products. • New product design teams have frequent interaction with the manufacturing function. • Manufacturing is involved at the early stages of new product development. • The manufacturing function is the key to improving new product concepts.
TM3: Supplier involvement
• Suppliers are involved early in product design efforts. • We partner with suppliers for the design of new products. • Suppliers are frequently consulted during the design of new products. • Suppliers are an integral part of new product design efforts.
Operational Performance Adapted from: Miller and Roth (1994), McKone *et al.* (2001), Schroeder *and* Flynn (2001); Ketokivi *and* Schroeder(2004), Ahmad *et al.* (2010), Machuca *et al.*(2011), Phan *et al.* (2011) and Hilmola *et al.*(2015)
• Conformance to product specifications. • Product capability and performance. • On-time new product launch. • Product innovativeness. • Customer support and service.

ANNEX F. Items on contextual variables scales.

Contextual variables Adapted from: Schroeder *and* Flynn (2001), Ahmad *et al.* (2003), Das *and* Jayaram, (2003), Machuca *et al.* (2011) and Garrido *et al.* (2015)
PS: Plant size (number of employees) PS = natural logarithm (number of employees)
EC: Environmental complexity. Percentage of production volume manufactured in each of the ways listed below. The sum of the five items must be 100%. • Dedicated flow line(s). • Assembly line. • Mixed model line(s). • Manufacturing cells. • Job shop. • Other ways. CE = 5/600 x (1 x "other ways" + 2 x "job shop" + 3 x "manufacturing cells" + 4 x "mixed model line" + 5 x "assembly line" + 6 x "dedicated flow line(s)")
PF: Plant focus (type of plant). Percent of plant production manufactured according to the strategies listed below (total sum must be 100%): • Engineer to order. • Make to order. • Assemble to order. • Make to stock. PF = 5/400 x (1 x "engineer to order" + 2 x "make to order" + 3 x "assemble to order" + 4 x "make to stock")
PD: Plant description. The production processes in this plant are best characterized as follows (total sum must be 100%): • One of a kind. • Small batch. • Large batch. • Repetitive/line flow. • Continuous. PD = 1/100 x (1 x "one of a kind" + 2 x "small batch" + 3 x "large batch" + 4 x "repetitive/line flow" + 5 x "continuous")

This article was pre-selected from the highest evaluated papers presented at the 5th World Conference on Production and Operations Management (P&OM Havana 2016), co-organized by the European Operations Management Association (*EurOMA*), the Production and Operations Management Society (*POMS*) and the Japanese Operations Management and Strategy Association (*JOMSA*). The original paper has followed the standard review process for the *International Journal of Production Economics* and was managed by Afonso Fleury and Gerald Reiner, as co-Editors, and supervised by Peter Kelle (IJPE's Editor America).