The mediating effect of Employees' Involvement on the relationship between Industry 4.0 and operational performance improvement

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Abstract

This study aims at investigating whether EI constitutes the mediating link relating Industry 4.0 technologies to operational performance improvement in emerging countries. When manufacturing companies within this socio-economic context adopt Industry 4.0 technologies, they may either reinforce or undermine the importance of practices related to EI, hence affecting the level of operational performance improvement. In this sense, we carried out a survey with 147 Brazilian manufacturers that have already started to implement Industry 4.0 technologies concurrently with their existing continuous improvement programs, which are highly based on EI practices. Findings indicate the EI indeed has a positive mediating effect on the relationship between Industry 4.0 adoption and operational performance improvement. This outcome suggests that the high-tech movement promoted by Industry 4.0 advent does not disregard the need for empowering and committing employees. This fact is also true even in contexts where employees' condition may rise additional barriers for Industry 4.0 implementation, such as emerging economies. Therefore, the implementation of Industry 4.0 seems to be a promising approach for assisting employees on continuous improvement and reinforcing the need for their participation and engagement, especially in manufacturers from sectors with higher levels of technological intensity.

Keywords: *Employees' involvement, Industry 4.0, Mediating effect, Emerging economies, Operational Performance.*

1. Introduction

Employees' Involvement (EI) has been described as empowering employees to make decisions regarding problem-solving at their level in the organization (Welikala and Sohal, 2008). Such involvement is beneficial to organizations since employees, who are actually involved in the job, are able to suggest and implement improvements in face of their expertise (Thomas et al., 2009). In fact, Marodin et al. (2017) argued that a key factor for the success of any continuous improvement initiative lies on properly involving employees so that they own the process and contribute to its sustainability. Hence, continuous improvement efforts are mainly characterized by a low-tech and human-centered approach and consolidate various management principles and practices (Seppälä and Klemola, 2004; Spear, 2009).

In turn, the term 'Industry 4.0' denotes an industry whose main features comprehend connected machines, smart products and systems, and inter-related solutions. These characteristics are incorporated towards the achievement of intelligent production units based on integrated computer and digital components that monitor and control physical devices (Lasi et al., 2014). Thus, such technological advances are claimed to lead to a novel manufacturing approach (Ashton, 2009). However, the integration of Industry 4.0 technologies into existing production environments and how they can support continuous improvement is still under investigation (Kolberg et al., 2016). For instance, Weyer et al. (2015) claimed that, although Industry 4.0 enables smarter management of resources and production processes, an increased level of automation will not lead to less human interaction or worker-less production facilities.

In this sense, requirements on employees' knowledge and skills may change and become even more specialized (Dworschak and Zaiser, 2014). These specialization demands may become a specific barrier for manufacturers located in emerging countries, where the existing low-cost labor force together with lower educational levels raise different challenges for Industry 4.0 adoption (Ministry of Economy, 2016; Tortorella and Fettermann, 2017). Therefore, there is a clear need for developing a framework that supports the adoption of Industry 4.0 while considering aspects of technology, organization and human (Kolberg and Züehlke, 2015).

This study aims at investigating whether EI constitutes the mediating link relating Industry 4.0 technologies to operational performance improvement in emerging countries. When manufacturing companies within this socio-economic context adopt Industry 4.0 technologies, they may either reinforce or undermine the importance of practices related to EI, hence affecting the level of operational performance improvement. In this sense, we carried out a survey with 147 Brazilian manufacturers that have already started to implement Industry 4.0 technologies concurrently with their existing continuous improvement programs, which are highly based on EI practices. We postulate one operational construct comprised of 4 inter-related and internally consistent EI practices, which have been suggested by Shah and Ward (2007). Further, with regards to Industry 4.0 we use ten technologies that are most likely to be implemented in manufacturing companies in an emerging country (Brazil's National Confederation of Industry, 2016). We empirically validate these constructs in our study sample and further investigate their concurrent effect on operational performance improvement.

Besides its theoretical contribution, our research provides managerial implications that may support leaders and practitioners to better comprehend the synergies and the advantages of implementing Industry 4.0 technologies in manufacturing environments where continuous improvement is highly based on EI practices. Furthermore, the understanding of the relationship between these approaches helps to anticipate occasional difficulties and sets the proper expectations along the era of the fourth industrial revolution, providing improvement guidelines that might reinforce employees' engagement towards higher operational performance levels. Moreover, the empirical verification of the mediating effect of EI practices on the relationship between Industry 4.0 and operational performance improvement allows demystifying certain traditional taboos raised by the incorporation of high-technology into shop floor environments.

The rest of this paper is structured as follows. Section 2 presents the theoretical background and hypotheses developed to answer our research question. Section 3 describes the proposed method, with results of its application presented in section 4. Section 5 closes the paper presenting conclusions and future research opportunities.

2. Literature and hypothesis

2.1. Industry 4.0

Originally coined in the Hannover Fair in 2011 as part of the recent high-tech manufacturing strategy of the German government, Industry 4.0 entails an increased interconnectivity of people, objects and systems through real time data exchange (Brettel et al., 2014). More specifically, Cyber-Physical Systems (CPS) allow production systems to be modular and changeable, which is demanded to massively produce highly customized products (Kagermann et al., 2013; Liao et al., 2017). CPS provide an increased level of automation and changeability by focusing on information exchange with other entities, control production processes and integrate themselves into their environment (Lee, 2008; Shariatzadeh et al., 2016).

Industry 4.0 contributes to decentralized and simple structures over large and complex systems; while aim for small and easily integrated modules with lower levels of complexity (Züehlke, 2010). However, the understanding of the association between its technologies and the improvement level of operational performance still finds contradictory evidence in literature (Erol et al., 2016; Schumacher et al., 2016; Sanders et al., 2016), which motivates further studies about the subject. In this sense, Industry 4.0 creates many new opportunities for organizations, but at the same time several challenges arising from the ongoing automation, digitization and interconnectivity (Hecklau et al., 2016).

First, in terms of technical and economic challenges, increasingly customers expectations regarding customization and flexibility have transformed businesses models while entailed more volatile and heterogeneous markets (Gjeldum et al., 2016; Landscheidt and Kans, 2016). Such facts have reinforced the establishment of collaboration and strategic alliances throughout the value chains, increasing management complexity (Erol et al., 2016). Further, the required level of capital expenditure to implement Industry 4.0 is relatively intensive, reducing its attractiveness to manufacturers located in emerging countries (Anderl, 2014; Sanders et al., 2016). With regards to political and legal challenges, governments must determine legal parameters for the usage of big data, especially the ones related to privacy protection. Another concern is the growing work flexibility, which demands the revision of work regulations for work times and safety of employees (Brazilian National Confederation of Industry, 2016; Forbes India, 2016). Overall, although research initiatives and practical experimentations are already observed, these are mostly applications of single aspects which narrow the perspective about the benefits and barriers related to Industry 4.0 adoption, especially for manufacturers within emerging economies' context.

2.2. Employees' involvement

An organization's performance and competitiveness levels greatly depend on how its employees are managed and engaged into the daily activities (Hecklau et al., 2016). Several studies (e.g. Lawler III, 1986; Welikala and Sohal, 2008; Mendes, 2012; Kyndt and Baert, 2013; 20) have highlighted the importance of EI to keep up with the rapidly growing and continuous changing organizations. Traditional EI aimed at creating a sense of belonging towards the organization through a high degree of commitment. Further, it was supposed to empower employees to make changes in their working environment by giving and implementing suggestions for improving performance. In this sense, the more organizations reinforce EI practices, the more positive results they will achieve, such as employee satisfaction, quality of work life, operational performance outcomes, profitability and competitiveness (Mann, 2009).

Additionally, involved employees actively participate in problem-solving and their cross functional character. Particularly, Treville and Antonakis (2006), Angelis et al. (2011) and Bortolotti et al. (2015) have emphasized the importance of involving and committing employees during continuous improvement initiatives, so changes become sustainable in the long run and a cultural change is addressed. Consequently, some factors may favor to an enhanced EI, such as: establishment of interpersonal trust and communication, organizational openness and reputation, proper level of social and technical skills, career opportunities, brand alignment, recognition, work life balance and leadership (Thomas et al., 2009; Bedarkar and Pandita, 2014; Hecklau et al., 2016).

The role of EI for an improved performance has been extensively examined in previous research, but under different associations. Alfalla-Luque et al. (2015), for instance, investigated its relationship with supply chain integration dimensions to explain several performance measures, such as flexibility, delivery, quality, inventory and customer satisfaction. Alt et al. (2015) verified the link between EI and environmental performance through companies' proactive environmental strategies, and that this link is contingent on shared vision. More specifically, Hanaysha (2016) tested the effects of EI, organizational learning, and work environment on organizational commitment in higher education sector. Overall, studies suggest the adoption of EI practices usually has a positive impact on the aimed performance, and its association with other organizational aspects may lead to an improved result.

2.3. Employees' involvement and Industry 4.0

The human dimension of Industry 4.0 is considered a point of attention by some researchers, since contradictory indications are evidenced in literature. On one hand, a few studies that focused on the anthropocentric aspects of Industry 4.0 claim that its implementation should not occur at the expense of the human factor (David et al., 2016). In fact, Züehlke (2010) affirms that the upcoming use of various wireless technologies will bring mobility to workers, allowing self-organization and changing the traditional sense of hierarchy. Further, the advent of Industry 4.0 provides means to more precise data collection and analysis, entailing a larger amount and better qualified information (Kagermann et al., 2013). According to Thomas et al. (2009), the availability and access to an enhanced information reinforces employees' trust, which in turn shapes perceptions of general openness in the organization and direct influences EI supporting performance improvement. At the same time, the dissemination of Industry 4.0 technologies is argued to provide chances to promote a work-based learning environment (Schuh et al., 2015; Mrugalska and Wyrwicka, 2017), contributing to EI.

On the other hand, coping with knowledge and skills related to Industry 4.0 technologies demands new strategic approaches for a holistic human resource management (Hecklau et al., 2016; Benešová and Tupa, 2017). As the level of process automation increases, the operating complexity is also likely to increase, entailing the need of higher educational level of employees and the integration of new training programs to provide that (Schuh et al., 2015). Further, misinterpretations of its benefits or improper adaptation of its technologies may lead to negative effects on employees' behaviors and managerial routines, as observed in the era of Computer-Integrated Manufacturing (CIM) (Tamás et al., 2016; Buer et al., 2018). Pirvu et al. (2015) focused on an anthropocentric approach describing the application of CPS-based solutions on employees' contexts, emphasizing current needs for adapting communication interfaces properly to different roles and languages within an organization. In this sense, there is a lack of organizational instruments and approaches that integrate such technologies into new socio-technical systems resultant from the fourth industrial revolution (Hermann et al., 2015). Such fact may jeopardize a successful implementation causing employees aversion to Industry 4.0 technologies.

Thus, while EI is widely deemed as essential for creating a continuous improvement culture within an organization, the effect of the introduction of Industry 4.0 technologies on employees still needs further investigation. To examine such association, we formulated the following hypothesis:

H: The implementation of Involved Employees positively mediates the effect of Industry 4.0 technologies on operational performance improvement.

In sum, Figure 1 illustrated the hypothesis model under investigation in this study and the proposed mediating effect of EI on the relationship between Industry 4.0 and operational performance improvement.

Figure 1 – Models' schematic illustration on the examined hypothesis

3. Method

3.1. Sample selection and characteristics

As our study focused on Brazilian manufacturers, we limited our sample only to leaders from companies that have a minimum initiative level on Industry 4.0 implementation and have already established a formal continuous improvement program. Due to these criteria, our sample included companies from different industrial sectors because of the limited number of companies in this country adopting both approaches. Such criteria lead to a non-random choice of companies for surveys, which is a commonly used strategy in other exploratory studies (Shah and Ward, 2003; Shah and Ward 2007; Tortorella et al., 2016).

The questionnaire was structured in four main parts (see Appendix). The first part aimed to collect demographic information of the respondents and their companies. Particularly, according to previous studies, we added two contextual characteristics as control variables. First, company size has been extensively indicated as influential to the proper development of a continuous improvement culture, as suggested by Shah and Ward (2003) and Tortorella et al. (2015). We considered two categories for this variable: large-sized companies (≥500 employees) and small- and medium-sized companies (<500 employees) (SEBRAE, 2010). Second, company's technological intensity, which is related to the type of industrial sector the company belongs to, has been claimed as an important factor for enabling higher adoption levels of Industry 4.0 technologies (Tortorella and Fettermann, 2017). Hence, we adopted two categories for this variable, based on the indications from Brazilian National Confederation of Industry (2016): high and medium-high intensity (e.g. chemical, information technology and automotive sectors), and low and medium-low intensity (e.g. food, textile and footwear sectors).

The second part of the questionnaire assessed the adoption level of four internally-related EI practices that aim to address continuous improvement in manufacturing organizations, as suggested by Shah and Ward (2007). Each practice is described in a statement that was evaluated according to a Likert scale that ranged from 1 (fully disagree) to 5 (fully agree). The third part of the questionnaire aimed at measuring the degree of adoption of the Industry 4.0 technologies within the studied companies. For that, 10 questions were formulated according to different technologies recommended by Brazilian National Confederation of Industry (2016), who has carried out a cross-sector survey with 2,225 Brazilian manufacturers. In this sense, these technologies have been consolidated and indicated as the most likely ones for adoption in Brazilian industrial scenario. Further, these technologies have already been used as basis for other empirical studies on Industry 4.0, such as Tortorella and Fettermann (2017). Such from a wide Similarly, the degree of adoption was measured in a 5-point Likert scale ranging from 1 (not used) to 5 (fully adopted). Finally, the fourth part assessed the observed operational performance improvement during the last three years, according to four indicators: (*i*) productivity, (*ii*) delivery service level, (*iii*) inventory level, and (*iv*) quality (scrap and rework). A five-point scale ranging from 1 (worsened significantly) to 5 (improved significantly) was used in the questionnaire.

We sent the survey to the leaders of Brazilian manufacturers who were former students of four different executive education courses on lean offered by a large Brazilian University, which were held in February, April, July and September 2017. All the 147 respondents were from companies of different sectors (see Table 1). Most respondents were from large-sized companies (55.1%) and were categorized as companies with high or medium-high technological intensity (53.7%). Further, all respondents claimed to have already established a formal continuous improvement program within their companies.

Table 1 – Sample composition (n = 147)

3.2. Sample and method bias

We analyzed each of the four surveyed classes for non-response bias through Levene's test for equality of variances and a t-test for the equality of means (Armstrong and Overton, 1977). No significant differences in means and variation were found in the four groups (p<0.05), which indicates that our sample did not differ significantly from the rest of the population. Additionally, we addressed some countermeasures to curb the effects of common method and source bias, as suggested by Podsakoff and Organ (1986) and Podsakoff et al. (2003). With respect to the questionnaire design, we separated the dependent variable items from the independent variable items that were placed at the very end of the survey. We also provided a clear statement to assure that respondents would be treated anonymously and that there was no right or wrong answer. As respondents were key leaders in their companies and actively involved in the operational management, we assumed that they were appropriate informants. Finally, Harman's single-factor test with an exploratory factor analysis was used to verify the existence of common method bias (Malhotra et al., 2006), which resulted in a first factor that included only 23.5% of the variance. Therefore, we argued that common method variance was not a problem in our dataset.

3.3. Construct validity and reliability

First, regarding the EI practices (mediating variables), we performed a Confirmatory Factor Analysis (CFA) using the lavaan package of R programming language (Oberski, 2014) to confirm the convergent validity and unidimensionality of the EI construct suggested by Shah and Ward (2007), as presented in Table 2. In the estimated CFA model all factor loadings were higher than the established threshold value of 0.45 (Tabachnik and Fidell, 2007). Then, we reassessed the CFA model, whose results indicated an adequate fitness of the model using the chi-square test ($\chi 2$/df), Comparative Fit Index (CFI) and Root Mean Square Errors of Approximation (RMSEA). We used CFI values greater than 0.90 combined with RMSEA values greater than 0.10 as thresholds. Resultant values minimize the sum of the type I and II error rates of the CFA model for sample sizes lower than 250 observations, as suggested by Hu and Bentler (1999). In this sense, all items loaded satisfactorily on the construct (factor loading of more than 0.45, $p<0.01$) combined with an acceptable Cronbach alpha level.

Table 2 – Employees' involvement construct and CFA factor loadings

For the 10 Industry 4.0 technologies assessed, an Exploratory Factor Analysis (EFA) was conducted via Principal Components Analysis (PCA) with varimax rotation to extract orthogonal components. Two components were extracted: (*i*) Process- and (*ii*) Product/Service-related technologies (see Table 3). Similar results were obtained using oblique rotation as a check for orthogonality. Moreover, we checked the unidimensionality of each component by applying PCA at the component level, which displayed high reliability with alpha values above 0.80. Process-related construct recalls technologies that aim at supporting and facilitating management of manufacturing processes, such as digital automation and remote monitoring of production control. In turn, the construct denoted as Product/Service concerns technologies that contribute to more flexible and faster product and service development, such as big data and use of cloud services associated with product.

Table 3 – PCA to validate Industry 4.0 technologies bundle-rotated component matrix.

Analogously, with regards to improvement level of operational performance, a PCA with varimax rotation was conducted (see Table 4). The four indicators loaded on one factor (denoted as Operational Performance), with an eigenvalue of 2.871 explaining 71.78% of the variation. The Cronbach alpha of this factor was 0.86.

Table 4 – PCA to validate performance bundle component matrix.

4. Results and discussion

We analyzed the correlation for all variables with their respective Cronbach's alpha and composite reliability, as shown in Table 5. All the independent variables correlated positively with operational performance improvement. Then, a set of OLS (Ordinary Least Square) hierarchical linear regression models were performed to test the theoretical model and the proposed mediation effect (Hair et al., 2006). The results report the unstandardized coefficients, since scales were standardized before the analysis, i.e. unstandardized coefficients will represent a standardized effect (Goldsby et al., 2013). Regression results are shown in Table 6.

Table 5 – Correlation, Cronbach's alpha and composite reliability for variables analyzed

Table 6 – Standardized β coefficients for hierarchical regression analysis

In the hierarchical process, the first model (Model 1) analyses only the effect of the control variables (company size and technological intensity) and independent variables (Process and Product/Service technologies) on 'Involved Employees' construct, which was considered the potential mediating variable. Then, the direct effect of Industry 4.0 technologies (divided into two constructs), on the dependent variable (Operational Performance improvement) was assessed (Model 2). Finally, Model 3 examined the effect of both independent and potential mediating variables on the dependent variables. The variance inflation factors (VIFs) in the regressions models were all <3.0, suggesting that multicollinearity was not a concern.

All three regressions resulted in significant models (p-value<0.01). Results for Model 1 indicated that both 'Process-' and 'Product/Service-related' technologies are positively associated with 'Involved Employees' ($\beta=0.332$; p-value<0.01 and $\beta=0.147$; p-value<0.05). Additionally, for 'Operational Performance Improvement', results show that Model 3 has significantly explained 29.9% of the variation of this dependent variable (F-value$=5.152$). In this model, which comprises control, potential mediating and independent variables 'Involved Employees' ($\beta=0.433$; p-value<0.01) and 'Process-related' technologies ($\beta=0.201$; p-value<0.10) were significantly associated with the improvement level of the dependent variable, respectively.

It is noteworthy that, although Product/Service technologies are associated with EI practices, this relationship occurs at a lower significance level. This result may be justified by the fact that these technologies are focused on facilitating information flows that usually involve a fewer amount of people and are not directly related to shop floor management, which is a key aspect for manufacturing companies (Ganzarain and Errasti, 2016). This feature is especially true in manufacturers located in emerging economies, whose products and services are often developed at organization's head quarter located in developed countries, such as USA and Germany (Brem and Wolfram, 2014; Hong et al., 2015). Therefore, respondents may understand that there is a positive association between both, but not as strong as the association between Process technologies and EI practices. In fact, results for Process technologies were surprisingly significant, since they also indicate a positive direct effect on 'Operational Performance Improvement' at a lower significance level (p-value<0.10). This finding denotes the intensive efforts that manufacturers have been investing to adopt Process-related technologies on shop floor, and the high expectations on performance impact associated with them.

Furthermore, these outcomes show that practices focused on enhancing EI on continuous improvement initiatives are positively associated with the adoption of Industry 4.0 technologies. In fact, our results suggest that the relationship between Industry 4.0 technologies and operational performance improvement is positively mediated by EI; i.e., the impact of Industry 4.0 technologies on the operational performance level of manufacturers located in emerging countries, such as Brazil, may be enhanced if EI practices are extensively implemented within the company. These results somewhat converge to previous studies from Gorecky et al. (2014) and David et al. (2016), which have indicated that, with proper technological support, it is more likely that employees can achieve their full potential and perform the role of decision-makers and flexible problem-solvers in their work environments. In this sense, the implementation of Industry 4.0 seems to be a promising approach for assisting employees on continuous improvement and reinforcing the need for their participation and engagement, especially in manufacturers from sectors with higher levels of technological intensity (as envisioned by Longo et al., 2017). Furthermore, the positive mediating effect of EI emphasizes that the benefits of Industry 4.0 do not disregard the human aspect for improving operational performance; but these are significantly enhanced if employees are committed and empowered throughout its implementation, as pointed by Qin et al. (2016) and Benešová and Tupa (2017). Overall, our findings provide empirical evidence to support the examined hypothesis, whose outcomes have both theoretical and practical implications.

5. Conclusions

This study carried out a survey with 147 Brazilian manufacturers to investigate the mediating role of EI practices on the relationship between Industry 4.0 and operational performance improvement. The contributions of this research are two-fold.

First, in theoretical terms, our study empirically evidenced that the implementation of a high-tech approach, such as Industry 4.0, does not necessarily conflict with the human aspects of an organization. In fact, we provided arguments to indicate that, when implementing Industry 4.0 technologies, companies that reinforce EI may significantly improve their operational performance. This finding is somewhat surprising since all respondents are from companies located in an emerging economy. Such socio-economic context is assumed to pose additional barriers to Industry 4.0 implementation, especially with respect to employees' education and development level. Our results showed that even in this context EI remains essential and positively influences the impact of Industry 4.0 on operational performance.

Second, regarding practical implications, our research has provided manufacturing managers arguments that emphasize that their current human-centered continuous improvement approaches do not concur with the novel technologies introduced by Industry 4.0 advent. In turn, managers who reinforce EI practices during continuous improvement activities may achieve a higher operational performance level when adopting Industry 4.0 technologies than the ones who neglect the importance of EI. Moreover, we also gave light to a usual management concern related to the apparent paradox between an extensive human-centered system and a high-tech improvement approach. Our findings unfold such polarization between both approaches and suggest that a synergistic effect for continuously improving manufacturers performance.

Finally, a few limitations of this study are worth to be highlighted. Regarding our sample, the fact that respondents were all from Brazilian manufacturers restricts the generalization to of our findings. At the same time, the outcomes of this study may be extended to manufacturers within similar socio-economic contexts, providing a solid base for comparison. Further, as companies continue to focus on implementing efficient ways of doing business, there will be an increasing appetite for incorporating novel technologies. In this sense, the questionnaire applied here comprises technologies that were previously indicated as the ones most likely to be implemented in Brazilian manufacturers. However, a full implementation of Industry 4.0 may compel the adoption of other technologies that are not included in this study. Therefore, future studies might approach Industry 4.0 from a complementary perspective that enables a more holistic understanding of its relationship with existing organizational initiatives. Finally, as this study was focused on investigating only the mediating effect of EI practices, further research could perform deeper analysis on how Industry 4.0 adoption can influence other dimensions related to labor relationships and work environment. In this sense, additional hypotheses could be formulated to empirically verify the associations between Industry 4.0 technologies and socio-technical aspects such as leadership, team effectiveness and communication.

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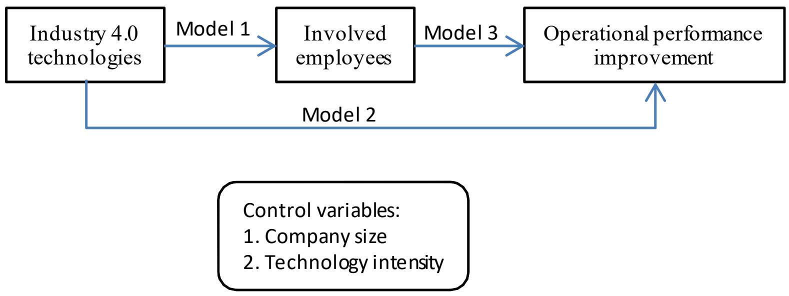

Figure 1 – Models' schematic illustration on the examined hypothesis

Table 1 – Sample composition (n = 147)

Category	Description	Quantity	%
Company size	Large (≥500 employees)	81	55.1
	Small and Medium (<500 employees)	66	44.9
Technologic intensity	High and medium-high	79	53.7
	Low and medium-low	68	45.3
Industry sector	Metal-mechanic	73	49.6
	Chemical	19	12.9
	Food	13	8.8
	Textile	7	4.8
	Others	35	23.8

Table 2 – Employees' involvement construct and CFA factor loadings

Construct	Operational measures	Factor loadings
Involved employees	Shop floor employees are key to problem solving teams	0.792
	Shop floor employees drive suggestion programs	0.869
	Shop floor employees lead product/process improvement efforts	0.884
	Shop floor employees undergo cross functional training	0.641
	χ^2/df = 314.9/6	CFI = 1.000
	RMSEA = 0.000	Cronbach's Alpha = 0.887

Table 3 – PCA to validate Industry 4.0 technologies bundle-rotated component matrix.

Industry 4.0 technologies	Factor loadings		Focus
Digital automation without sensors		0.719	Process
Digital automation with process control sensors		0.806	Process
Remote monitoring and control of production through systems such as MES* and SCADA**		0.782	Process
Digital automation with sensors for product and operating conditions identification, flexible lines		0.769	Process
Integrated engineering systems for product development and product manufacturing		0.573	Process
Additive manufacturing, rapid prototyping or 3D printing	0.631		Product/ Service
Simulations/analysis of virtual models (finite elements, computational fluid dynamics, etc) for design and commissioning	0.749		Product/ Service
Collection, processing and analysis of large quantities of data (big data)	0.765		Product/ Service
Use of cloud services associated with the product	0.803		Product/ Service
Incorporation of digital services into products (Internet of Things or Product Service Systems)	0.629		Product/ Service
Eigenvalues	5.092	1.178	

Initial percent of variance explained	50.92	11.78
Rotation sum of squared loadings (total)	3.172	3.098
Percent of variance explained	31.72	30.98
Cronbach α (sample *n* = 147)	0.855	0.827
Bartlett's test of sphericity	751.63 (df 45. p<0.01)	
Kaiser-Meyer-Olkin measure of sampling adequacy	0.852	

Extraction method: Principal component analysis.
Rotation Method: Varimax with Kaiser normalization.
All empty values indicate factor loadings below 0.3.

Table 4 – PCA to validate performance bundle component matrix.

Performance indicators	Factor loadings
Delivery service level	0.823
Quality	0.882
Productivity	0.875
Inventory level	0.806
Eigenvalues	2.871
Initial percent of variance explained	71.78
Extraction sum of squared loadings (total)	2.871
Percent of variance explained	71.78
Cronbach α (sample *n* = 147)	0.860
Bartlett's test of sphericity	298.86 (df 45. p<0.01)
Kaiser-Meyer-Olkin measure of sampling adequacy	0.797

Extraction Method: Principal component analysis.

Table 5 – Correlation, Cronbach's alpha and composite reliability for variables analyzed

Variables	1	2	3	4	5	6
1. Operational Performance	-					
2. Company size	0.140	-				
3. Technological intensity	0.174	0.095	-			
4. 4.0 Tech – Process	0.440**	0.223**	0.113	-		
5. 4.0 Tech – Product/Service	0.311**	0.191*	0.181	0.634**	-	
6. Involved employees	0.584**	0.047	0.218**	0.438**	0.376**	-
Cronbach's alpha	0.868	-	-	0.855	0.827	0.887
Composite reliability (CR)	0.845	0.731	0.693	0.841	0.852	0.852

* Correlation is significant at the 0.10 level (2-tailed).

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

Table 6 – Standardized β coefficients for hierarchical regression analysis

Variables	Involved Employees	Operational Performance Improvement	
	Model 1	Model 2	Model 3
Company size	-0.143	0.060	0.122
Technologic intensity	0.318 **	0.212	0.075
4.0 Tech – Process	0.332 ***	0.345 ***	0.201 *
4.0 Tech – Product and Service	0.147 **	0.026 *	-0.038

Involved employees			0.433 ***
F-value	11.000 ***	9.501 ***	5.152 ***
R^2	0.237	0.211	0.371
Adj. R^2	0.215	0.189	0.299
Change in R^2			0.110 **

* Significant at 10%; ** Significant at 5%; *** Significant at 1%.

Appendix – Applied questionnaire

1) Please, answer the following information with respect the company you work for:

Company size: ( ) Less than 500 employees

( ) Equal to or more than 500 employees

Company sector: ______________________________

2) Please, indicate the agreement level of the occurrence of the employees' involvement practices below:

** Scale: from 1 (fully disagree) to 5 (fully agree)*

a) Shop floor employees are key to problem solving teams ( )

b) Shop floor employees drive suggestion programs ( )

c) Shop floor employees lead product/process improvement efforts ( )

d) Shop floor employees undergo cross functional training ( )

3) Please, indicate the adoption level in your company of each of the technologies below:

** Scale: from 1 (not used) to 5 (fully adopted)*

a) Digital automation without sensors ( )

b) Digital automation with process control sensors ( )

c) Remote monitoring and control of production through systems such as MES* and SCADA** ( )

d) Digital automation with sensors for product and operating conditions identification, flexible lines ( )

e) Integrated engineering systems for product development and product manufacturing ( )

f) Additive manufacturing, rapid prototyping or 3D printing ( )

g) Simulations/analysis of virtual models (finite elements, computational fluid dynamics, etc) for design and commissioning ( )

h) Collection, processing and analysis of large quantities of data (big data) ( )

i) Use of cloud services associated with the product ( )

j) Incorporation of digital services into products (Internet of Things or Product Service Systems) ( )

4) Please, indicate the improvement level in your company of the following performance indicators during the last three years:

** Scale: from 1 (worsened significantly) to 5 (improved significantly)*

a) Productivity ( )

b) Delivery service level ( )

c) Inventory level ( )

d) Quality (scrap and rework) ( )