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A systematic review/survey for JIT implementation: Mexican *maquiladoras* as case study

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A B S T R A C T

Mexico has a free trade agreement with the United States of America (USA) and Canada which was signed in 1988. This agreement created the conditions for establishing many foreign companies in several Mexican cities along the border zone between Mexico and USA. This strategy takes advantage of the geographic proximity with one of the biggest markets in the world, qualified manpower, and low production cost. With the arrival of those companies, frequently called *Maquiladoras*, a lot of production approaches have been introduced, and one of those widely applied is the just-in-time (JIT) production strategy. Despite the benefits of JIT, the interrelationship among several industrial factors and their impact on results derived from the implementation of JIT are unknown in Mexico. This is the underlying reason of this article, which aims at illustrating the results of a survey applied to foreign companies established in the Mexican–USA border. On the one hand, the activities developed by these companies during the implementation process of JIT are investigated and grouped as latent independent variables. These variables include organizational commitment, communication channels in organization, empowerment granted to employees, education provided in different organizational levels, and the capacity to solve problems, among others. On the other hand, the obtained benefits investigated are grouped as latent dependent variables. These dependent variables involve inventory management, quality, and cost, among others. Those aspects in the activities and benefits of the companies were evaluated using the structural equations model (SEM), which is useful to identify and analyze causal relationships. Result obtained from SEM indicates that management commitment and education are the main critical success factors in the JIT implementation, and that success can be measured through inventory, quality, and cost performance indicators.

1. Introduction

JIT is a manufacturing approach initially used in Japan that is emphasized on excellence through continuous improvement in productivity and quality indexes in all the phases of the production cycle [1]. Some JIT's definitions and concepts have been proposed. These concepts range from the strict sense of just-in-time production applied to material flow to the concept of a management philosophy focused on increasing customer satisfaction and obtaining competitive advantage in the market [2]. Hence it can be stated that the initial concept related to material flow has now been transformed into another concept which considers JIT as a tool which impels the competitive advantages of companies.

Thus, over time, the JIT concept has evolved. Initially, Ohno [3] and Matsui [4] defined JIT as the ability to get the appropriate quantity of material in the right time, but JIT is not only focused on material flow. When JIT is applied to manufacturing system, it is based on a philosophy of waste elimination [5,6] that logically includes materials flow, but it also takes into account resources such as time for machining and workers capacities [7], and in this case, it is aimed to minimize raw materials in stocks, work in process, finished goods inventory and help expose other serious deficiencies in the production cycle [8]. Vokurka and Davis [9] and

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Profeta [10] reported an evolved concept of JIT as: a methodology [11], a concept [12], a goal [13], a creed or trust [14], a philosophy [15,16], a strategy [17], a program [18], a process [19], a state of mind [20], an approach [21] and finally, a system [20,22].

Thus, according to Singh and Garg [6] a JIT production system covers all aspects of the production process, which includes the management of the organization, planning, flexible working, inventory, transportation, quality, supplier relations, among others. It also covers every stage of the process which involves product design, physical distribution, production, processing, and final sales, to mention but a few. Therefore, this means that JIT can be implemented from the product design stage until the final sale [23], but as Shi et al. [24] have established, it must be adequately oriented to customer satisfaction, whom pay for products and services.

From Ohno [3] to nowadays, more than 30 years after, JIT is still considered as a technique able to be applied in different industrial sectors that consents an important list of benefits after a good implementation.

1.1. Benefits of JIT

Numerous papers have reported benefits obtained from JIT application in different industrial sectors and companies. From Priestman [25] to Teeravaragrup et al. [26], Table 1 shows a list of 35 authors that have reported 22 main benefits in a period of 26 years of JIT practices. The list is hierarchically classified according to the number of times that they are cited by other authors. According to Table 1, the benefit *increase in productivity* was cited by 15 of 35 authors. This increase in productivity can result from other benefits, and this has been reported from Ajit [27] to Cai-Feng [23].

The second benefit frequently reported by authors is the *reduction of total production cost*, with 12 of 35 times mentioned. This benefit is a natural consequence of improving the flow of raw materials, WIP (Work in Process), and finished product and its distribution. This benefit is described in different works from Priestman [25] to Teeravaragrup et al. [26].

Therefore, it can be stated that the *increase in productivity* and the *reduction of total production cost* factors are benefits that can be observed that improvement the *quality process*, which is the third benefit of JIT application. This benefit was reported by 11 of 35 authors. Therefore a better production process can be measured by observing the *reduction in waste and reworks*, which results in an increase in *production quality* (both are cited in 10 of 35 authors).

There are other benefits which, despite the fact of being less frequently mentioned by authors, are still important for the success of any company in a global market. Among the most important are: (a) the reduction of administrative processes, (b) fewer suppliers, (c) reliable supplier, certified and accredited in quality systems, (d) an increase in internal rates of efficiency and (e) the responsiveness to customers, since they are who gets better quality products thanks to the fact that the manufacturing activities are integrated and have a shorter production cycle time.

Certainly, the list of JIT benefits shown in Table 1 would seem very attractive to any chief executive officer (CEO). Moreover, according to Machuca [28] and Danese et al. [29], JIT generates a competitive advantage for companies in today's global marketplace. For instance, the elements that have contributed to JIT success in the Toyota production system in the 1980s are still valid today. JIT is also a competitiveness key factor, and competitiveness is the basis for the company's survival. Consequently, JIT can be even more important and effective than in past decades, when it was highly popular. More specifically, within the industrial sector of *maquiladoras* in Mexico, JIT is one of the latest techniques used, since many of the materials and parts used by *maquiladora* industries come from other countries, and the flow of materials deserves much attention. That is due most *maquiladora* companies established in Mexico have very efficient logistic departments.

Taking this into account several managers in different companies may be now asking themselves: What should we do to obtain the JIT benefits reported in literature? What measures should be taken to obtain the JIT maximum benefits? What is the right procedure for a successful JIT implementation in the *maquiladora* industry in Mexico? Which are the key activities, if they exist, to ensure the success of JIT in Mexico's manufacturing industry?

1.2. Key success factors of JIT

Fortunately, a great amount of researchers have been interested in answering the previous questions and defining the most important group of activities for the successful JIT implementation that are commonly called Critical Success Factors (CSFs), and several of them are reported in this literature.

Mehra and Inman [30] were the pioneers to present a procedure for JIT implementation, and they defined four strategies aimed to guarantee its success: JIT vendor strategy, JIT production strategy, management commitment to JIT, and JIT education strategy. These strategies are related to three aspects. In the one hand, these strategies are related to the aspect of raw materials, which involves material supply and purchases from vendors. Also, these strategies are related to the production process within the company. Finally, the strategies are related to human factors which are: the management commitment and education for every human resources (including managers and supervisors).

Only one year later, Sakakibara et al. [31] proposed grouping JIT management in only three strategies that they called dimensions that are related to: supplier management, physical flow simplification, and management of people and schedules. The latter includes the JIT education strategy proposed by Mehra and Inman [30].

Six years later, Gelinas [32] divided JIT CSF in only two main factors that were subdivided in others categories. These main factors are organizational and operational. The operational subcategories include: purchasing management, inventory management, production management, distribution management, design location management, and management of facilities. The organizational factor is composed by three subcategories: (1) JIT implementation management, (2) human resource management, and (3) financial resources management. These nine categories (operational and organizational) are more specific and financial resource had a special category by first time.

Meanwhile, Profeta [10] proposed the classification of CSF for JIT implementation according to the field they address, i.e. factors related to management commitment, factors related to education and training, factors related to the provider, factors linked to production and factors related to organizational aspects.

Also, Ahmad et al. [33] emphasized on the need to separate the infrastructure practices required for JIT implementation (as resources) from those exclusively focused in JIT (as methodology). Authors divided the infrastructure practices into the following categories: quality management, manufacturing strategy, product technology, system integration, and policies related to human resource management.

Matsui [4] divided CSF's for JIT in two categories: the first one is related to the function of JIT manufacturing systems in production companies (JIT practices), and the second one consists of the scales of measurement in several areas of the organization (JIT management): human resources management, quality management, information production systems technology development, and manufacturing strategy.

Table 1
Benefits obtained from JIT.

Benefit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	Total
Increase in productivity	*		*			*	*		*			*		*	*				*			*		*	*	*		*						*		15
Reduction of total production cost	*			*	*	*			*	*	*											*					*				*		*	*		12
Increase in quality process	*													*					*					*	*	*			*	*			*	*	*	11
Reduction of number of pieces										*											*	*			*	*		*	*		*			*	*	10
Reduction in waste and rework						*		*	*		*		*					*	*			*						*						*		10
Increase in production quality	*				*			*					*	*	*				*		*	*	*													10
Increase in innovation													*										*	*	*	*		*		*		*	*	*		10
Improvement in employee motivation		*			*						*		*	*			*				*				*					*						9
Reduction in moving distances and materials	*		*			*			*												*						*							*		7
Reduction in number of activities			*	*		*																	*								*			*	*	7
Reduction of administrative work						*			*		*	*			*					*																6
Increase in flexibility of the process				*	*				*		*												*									*				6
Increase in teamwork		*	*				*				*		*					*																		6
Good relationship with providers				*					*					*					*										*	*						6
Increase the internal communication				*	*				*		*												*													5
Reduction of incidental spends	*										*		*									*										*				5
Reduction in material handling	*				*	*													*																	4
Improvement in resource utilization								*		*	*											*														4
Administrative processess implification						*			*													*														3
Increase of efficiency and responsiveness						*					*											*														3
Integration of manufacturing activities										*						*																				2
Improvement of cycle time																												*					*			2
Total	7	2	4	5	6	9	2	3	9	4	10	2	6	5	3	1	1	2	6	1	4	9	5	3	5	4	2	5	3	4	3	3	4	8	3	

1: Ajit [27]; 2: Balakrishnan et al. [70]; 3: Bonito [71]; 4: Chong and Rundus [72]; 5: Dutton [73]; 6: Ebrahimpour and Schonberger [74]; 7: Fiedler et al. [75]; 8: Flynn et al. [76]; 9: Garg et al. [77]; 10: Garg [7]; 11: Garg and Deshmukh [78]; 12: Garg et al. [79]; 13: Hall [13]; 14: Padukone and Subba [80]; 15: Priestman [25]; 16: Roy and Guin [81]; 17: Singh and Bhandarkar [82]; 18: Singhvi [83]; 19: Vrat et al. [84]; 20: Vuppalipati et al. [85]; 21: Voss [86]; 22: Kumar and Garg [87]; 23: Kumar et al. [88]. 24: Lawrence and Hottenstein [89]; 25: Dean and Snell [90]; 26: McKone et al. [91]; 27: Petersen [92]; 28: Shah and Ward [93]; 29: Aghazadeh [94]; 30: Yasin et al. [95]; 31: Swink et al. [96]; 32: Avittathur and Swamidass [97]; 32: Matsui [4]; 33: Dal Pont et al. [98]; 34: Cai-Feng [23]; and 35: Teeravaragrup et al. [26].

Table 2
JIT CFS's.

	A	B	C	D	E	F	Total
Production strategy	*		*	*	*	*	5
Management commitment	*		*	*	*		4
Personnel management		*			*	*	3
Suppliers relationship	*	*		*			3
Education and training	*			*			2
Organizational aspects				*		*	2
Layout		*					1
Purchasing			*				1
Inventories			*				1
Distribution net			*				1
Design			*				1
Ubication			*				1
Quality management					*		1
IT systems						*	1

Adapted from: A: Mehra and Inman [30]; B: Sakakibara et al. [31]; C: Gelinas [32]; D: Profeta [10]; E: Ahmad et al. [33]; and F: Matsui [4].

Table 2 shows a summary of the main critical success factors for JIT implementation which were identified in a literature review.

Table 2 also shows that the first CSF reported by every author is *production strategy* factor, which is a management responsibility. The second CSF is the *management commitment* to JIT, and it can be measured by the amount of resources assigned to JIT implementation. The third and fourth CSFs mentioned are related to *personnel management* and *suppliers relationships*. As it was the case of *production strategy*, these are also management responsibilities. The *education and training* for workers, supervisor, and CEOs factor is in fifth place within the review, and again, it also depends on management. This enables to conclude that JIT success depends greatly on management commitment.

Therefore, it can be observed that the first five CSF for JIT are related to human factors, the communication among different organizational levels, and the management capacity of the company's executives.

1.3. Problem and research objective

Several of the most important CSFs for JIT implementation, such as the abilities to manage available resources and processes, the capabilities to supervise human resources, and the existing communication with suppliers and workers are related to human factors. Therefore, from this perspective, CEOs may be asking themselves which activities related to human resources must be performed within their companies, which person would be the most suitable to perform these activities, and which would be the impact of executing these activities in each CFS, all this with the purpose of achieving and maximizing the benefits offered by JIT.

In order to answer these questions, this paper presents a systematic survey applied to manufacturing companies located in several Mexican cities along the Mexico–USA border. On the one hand, the main objective of this systematic survey is to identify the key successful activities associated to human factors that are involved in the successful JIT implementation. On the other hand, this work also aims to clearly identify the obtained JIT benefits.

Many of the CSF's described in Table 2 depend on senior management (or at least the first five). For instance, the factor of Education for employees, supervisors and CEOs may depend on Management Commitment, and might have a direct or indirect impact on the JIT benefits. These facts are related to the second objective of this research, which is to identify the causality of different CSF over the obtained JIT benefits.

Consequently, the main contribution of this s research is to offer the ability to calculate the level of dependence between CSFs and its benefits in order to generate new knowledge that could explain which factors define the success and help to gain the benefits offered by JIT.

1.4. Hypothesis

According to the objective of this research, some dependence hypotheses are established, but they were based only on some CSF's related to human factors and benefits. On the one hand, the CSF's analyzed were: management commitment (*Manage*), communication (*Communic*), education (*Educati*), empowerment (*Empower*) and problem-solving abilities (*ProSolve*). On the other hand, the benefits obtained were: higher quality and reduced production cost (*QualCto*) and less inventories (*Inventar*). The hypotheses to be tested appear in Fig. 1 and they were established according to the JIT benefits that appeared in Table 1 and the CSF's presented in Table 2.

H1. Management Commitment has a positive and direct impact on Communication among human resources in JIT implementation.

H2. Management Commitment has a positive impact on the Empowerment provided to employees.

H3. Education and Training of Human Resources has a positive impact on Empowerment.

H4. Empowerment has a positive impact on Problem-Solving process.

H5. Management Commitment has a positive impact on Education.

H6. Education of Human Resources has a positive impact on Problem-solving.

H7. Education of Human resources has a positive impact on Communication among them.

H8. Communication among human resources has a positive impact on Problems solving capacities and abilities during JIT implementation.

H9. A problem solving capacities and abilities from human resources has a positive impact on benefits associated with Quality and Cost.

H10. Education in Human Resources has a positive impact on benefits associated with Quality and Cost.

H11. Communication among human resources has a positive impact on Inventory.

H12. Inventory has a positive impact on Quality and Cost.

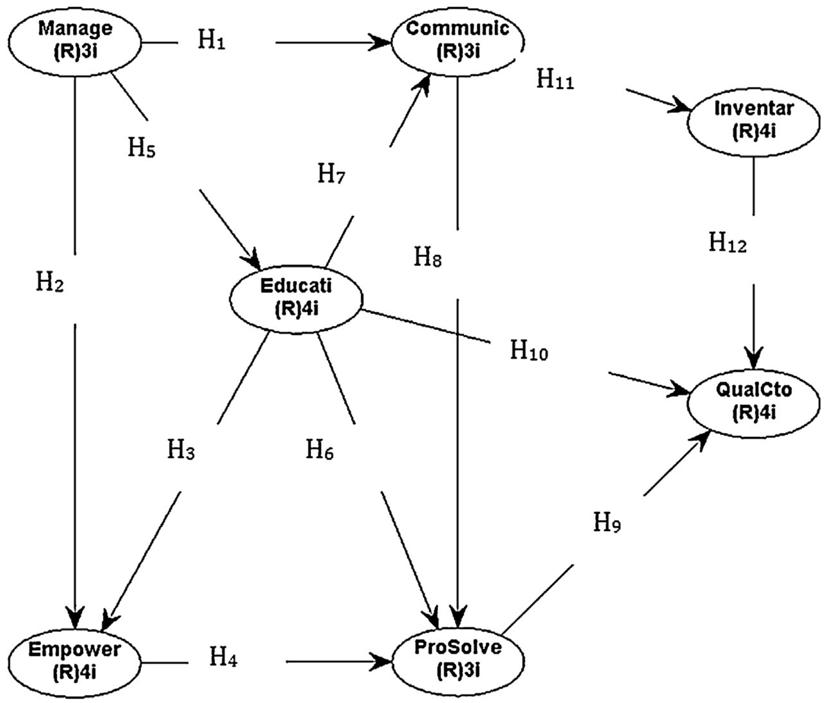

Fig. 1. Initial model with hypotheses.

Table 3
Latent variables for activities and their items.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Management Commitment (Manage)																			
There is support and commitment from CEOs for the implementation of JIT (*Man1*)	*		*	*												*			
The company encourages change (*Man2*)		*	*	*									*			*			
Quality initiatives are customer oriented (*Man3*)			*	*	*														*
Education and Training (Educati)																			
There is an emphasis on improving the skills and knowledge of workers (*Edu1*)			*	*	*	*							*				*		
Employees are trained to perform multiple tasks (*Edu2*)			*	*	*			*	*										
Workers were torn between workstations (*Edu3*)		*	*					*	*				*						
Operators are rewarded for learning new skills (*Edu4*)			*	*		*			*										
Communication (Communic)																			*
Different departments within the company are coordinated and in constant communication (*Com1*)				*						*	*								
Supervisors promote teamwork by motivating operators to cooperate and express their ideas (*Com2*)				*			*				*	*							
Managers, engineers and operators have discussion meetings (*Com3*)				*				*		*	*								
Empowerment (Empower)																			
There is a system that allows the operator inspectionate the machine that he or she operates (*Emp1*)		*	*	*									*					*	
Operators are responsible for maintaining their machines (*Emp2*)		*		*				*					*						
Operators are responsible for inspecting their own work (*Emp3*)		*		*		*				*							*		
The operators have the authority to stop production lines if necessary (*Emp4*)		*		*			*					*							*
Problems solving (ProSolve)																			
Operators are involved in the problems solving process (*PSo1*)										*					*				*
Operators are hired for their ability to solve problems and teamwork (*PSo2*)						*							*			*	*	*	*
There are working groups to solve production problems and encourage employee participation (*PSo3*)														*	*	*	*	*	

Adapted from: A: Mehra and Inman [30]; B: Ramarapu et al. [99]; C: Yasin and Wafa [100]; D: Zhu and Meredith [101]; E: Ajit [27]; F, G and K: Garg et al. [79]; Garg et al. [77]; Garg et al. [102] H: Singhvi [83]; I: Vrat et al. [84]; J: Ansari and Modarress [103]; L: Mazany [104]; M: Boer and Krabbendam [105]; N: Golhar and Deshpande [106]; O: Hankock and Zayko [107]; P: Inman and Brandon [108]; Q: Crawford and Cox [109]; R: Sohal and Naylor [110]; S: Walleigh [111]; and T: Willis and Suter [112].

Table 4
Latent variables for benefits and their items.

Inventory (Inventar)	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
The levels of the raw material inventory are reduced (*BInv1*)	*	*	*	*	*	*	*	*		*	*	*	*	*	*	*
The levels of the working inventory process are lower (*BInv2*)	*	*	*	*	*	*	*	*		*	*	*	*	*	*	*
There is a decrease in finished goods inventory (*BInv3*)	*	*		*	*	*		*	*	*	*		*	*	*	*
Increases inventory turnover (*BInv4*)		*	*			*			*	*	*	*	*	*		
Quality and Cost (QualCto)																
There is a decrease in the amount of waste (*BCal1*)	*	*	*		*	*		*	*	*	*		*	*	*	*
Improves product quality (*BCal2*)		*	*		*	*	*	*	*	*	*		*	*	*	*
Improves support and customer service (*BCal3*)	*	*	*	*		*		*	*		*			*		*
There is a low production cost (*BCal4*)			*	*		*	*		*		*		*		*	

Adapted from: A: Aggarwal [113]; B: Malley and Ray [114]; C: Manoochehri [115]; D: Inman and Mehra [116]; E: Crawford and Cox [109]; F: Inman and Mehra [117]; G: Lummus and Duclos-Wilson [118]; H: Inman and Brandon [108]; I: Payne [119]; J: Hendricks [120]; K: Norris et al. [121]; L: Epps [124]; M: Hum and Yong-Tjoon [122]; N: Karlsson and Ahlstrom [123]; O: Yasin and Wafa [100]; and P: Garg et al. [102].

2. Methodology

The methodology used in this research involves the design of the instrument to collect data, the identification of main activities in each factor, and finally, the identification of the most relevant benefits. Hence, the methodology is composed of four stages. Next paragraphs thoroughly describe each stage:

2.1. Stage 1: development of the survey

This stage is focused on the design of a survey, based in activities and benefits previously identified in others research. Five CSF's related to human factors activities were identified and extracted from Table 2 and especially from Profeta [10] and they appear in Table 3 as constructs with a variable name and the criteria items that are used to measure them. As far as the benefits gained from JIT implementation are concerned, two latent variables or factors were identified from Table 1 and Profeta [10] and are exposed in Table 4. This literature review represents a rational validation for the survey [34].

So, the survey contained three main sections. The first section was designed to identify activities related to the human factors deployed during JIT implementation and those factors and activities included: management commitment, communication, education, empowerment, and problem solving abilities. The second section offered a brief catalog of the benefits produced by a successful JIT implementation. Finally, the third section included demographic data.

With this initial questionnaire, a response validation was made to ensure a good understanding of the items in Mexican maquiladora industry. Hence, preliminary test was applied to 41 managers, supervisors, technicians and academics, focused to have a judge validation [34,35]. The questionnaire was answered by using a Likert scale based on subjective assessments, which included a (1–5) scale [36,37], where in the lower value (1) indicates that such activity was not performed during JIT implementation, or that particular benefits were not obtained after JIT implementation. The highest value (5) demonstrates that the activity was always executed during JIT implementation or that some particular benefit was obtained as a result of JIT implementation. This scale was selected because is easy to understand and recently was used by Inman et al. [38], Furlan et al. [39] and Tamayo et al. [40] in their surveys related supply chain.

The survey was used as a strategy to get empirical data from persons that have direct knowledge from JIT implementation process and its benefits, and according to Melnyk et al. [41], whom analyzed 464 surveys related to supply chain; they conclude that surveys are the best way to get reliable information, because managers and engineers have a daily experience with the problems related to supply chain. Similar conclusions and recommendation were given by others authors that are studying supply chain; for example, Chadha and Gagandeep [42] in Indian health sector, Zailani et al. [43] in Malaysian sustainable supply chain of manufacturing sector and Tarofder et al. [44] in web technologies applications in supply chain environments.

2.2. Stage 2: survey application

The sample for the survey application was stratified since it was focused on industries having some degree of JIT implementation, since the research is aimed to identify and confirm activities and benefits gained, therefore JIT must have some maturity degree in the companies, and basically, some results from its implementation. The survey was aimed to personnel working in supply chain, including purchasing and procurement managers, materials supervisors and engineers, and suppliers relation officers, because according to Foster et al. [45] they are the persons that have a better and reliable information related to supply chain.

Three strategies were used to apply the survey to the board managers, engineers and supervisors in several companies established in Mexican cities along the Mexico–USA borderline. The first strategy was a personal interview applied to some companies established in Ciudad Juarez. The second and third strategies were deployed in companies located in others Mexican states along the borderline with USA. The second strategy involved electronic surveys emailed to some directors. Thus, responders had a deadline of two weeks to answer the survey; after this deadline, a reminder was send. After three unsuccessful attempts or reminders, the interview was simply ignored. The third strategy employed a website that offered a special platform for surveys.

2.3. Stage 3: information input and validation

In this stage the information was captured and analyzed by SPSS 21® software. Internal consistency or reliability of the questionnaire for each latent variable (activities and benefits) was made by using the Cronbach coefficient and composite reliability index [46,47], considering a cutoff values of 0.7 ([48,49]; [50,51]). Additionally, some tests were also performed at this stage to improve the quality of the questionnaire, since the analyzed elimination of an item or variable contained in there often increases the reliability of the survey in question [50,52] and was used by Zailani et al. [43], Ramanathan and Gunasekaran [53] and Blome et al. [54] in supply chain surveys.

In the data screening phase, some test were executed in order to detect missing values, which were then replaced by the median, because data were obtained by using an ordinal scale (Likert scale), although it was always kept on mind that there should be 10% maximum of missing values for every observed variable [55,56]. Also, the values in the database were analyzed for outliers or extreme values. This was achieved by standardizing every

Table 5
Sectors and quantity of employees.

Number of employees	Industrial sector						Total
	Textile	Automotive	Electric/electronic	Plastics	Medical	Other	
Less than 500	0	5	5	5	1	7	23
Between 500 and 1000	1	20	8	1	5	9	44
Greater than 1000	0	41	14	7	4	26	92
Total	1	66	27	13	10	42	159

variable, considering a standardized value as outlier if its absolute value is bigger than 4 [56–60].

The average variance extracted (AVE) was used as an indicator of discriminant validity and convergent validity assessment and was used by Berghman et al. [61] in a supply chain survey. On the one hand, for convergent validity assessment, AVE's were employed and the correlations among the latent variables were considered to assess the instrument of measure. However, for convergent validity assessment, the threshold recommended acceptable value is 0.5 [49,62,63].

As a collinearity measure among latent variables, the full collinearity VIFs (variance inflation factor) value was used and the rule of thumb was 3.3 [64,65]. But some authors suggest more relaxed values, i.e. bigger than 10 [55,56,66].

Due to the fact that the survey was answered in an ordinal scale, the *Q*-squared coefficient was used since it is a nonparametric measure traditionally calculated via blindfolding. *Q*-squared coefficient was also used for the assessment of the predictive validity (or relevance) associated to each latent variable block in the model. Acceptable predictive validity in connection with an endogenous latent variable is suggested by a *Q*-squared coefficient greater than zero [62] and preferably, must be very similar to *R*-squared values.

The cross-loadings values were used to evaluate convergent validity of the survey. This was done by considering the *P* values associated to the loadings as values lower than 0.05; then the loadings as equal to or greater than 0.5 [55,56,62].

2.4. Stage 4: structural equation model

For test the hypothesis in Fig. 1, the model was evaluated using the Structural Equation Modeling (SEM) technique, due its wide and recent use in causal relations validations and specifically in supply chain. For example, Green et al. [63] have studied the impact of JIT in supply chain performance; Merschmann and Thonemann [67] have evaluated the chain flexibility, uncertainty and firm performance in supply chain, and Yang et al. [68] have analyzed the effect of green supply chain management on green performance and firm competitiveness, Green et al. [63] has studied the impact of JIT competence and organizational performance, among others.

The SEM model was executed in WarpPls 3.0® software because its main algorithms are based in Partial Least Squared (PLS), widely recommended for low sample size [62]. The model here presented is executed by using specifically the WarpPls3 PLS algorithm, with a bootstrapping resampling method for a better coefficients values convergence and diminish the effect of possible outliers.

Three model fit indices were analyzed: average path coefficient (APC), average *R*-squared (ARS), and average variance inflation factor (AVIF), that are proposed by Kock [62] and used by Ketkar et al. [69] in supply chain environment. For the APC and ARS, the *P* values were analyzed for determining the model efficiency, establishing as cutoff a value minor to 0.05, testing the null hypothesis that APC and ARS are equal to zero, versus the alternative hypothesis that APC and ARS are different to zero. For AVIF, values lows to five are desirable.

Three different effects were measured in the model: (1) direct effect (that appears in Fig. 1 as arrows from a latent variable to another), (2) indirect effect (given for paths with two or more segments), and (3) total effects (the sum of direct and indirect effects). With the aim to determine their significance, the *P* values were analyzed, considering the null hypothesis: $\beta_i = 0$, versus the alternative: hypothesis $\beta_i \neq 0$.

3. Results

Results obtained were divided in sections. The following paragraphs thoroughly explain each section.

3.1. Sample description

A total of 159 valid questionnaires were analyzed, all of them coming from companies located in Mexican cities in Mexico–USA border. Table 5 illustrates the sectors and number of employees of these companies. In regard to the number of workers per company, it was also demonstrated that the vast majority of the surveyed companies had over 500 employees; however only 31 companies had fewer than 500 employees.

In regard to the company's job position among survey respondents, Table 6 shows the results of the research. Both the engineering and supervision departments are the first two most investigated departments. Also, in relation with seniority in these positions, it is shown that the highest class represents people with over 10 years of experience in their position, with 65 respondents, followed by the people in a range of 5 up to 10 years, with 58 persons. According to information in Table 6, it is observed that the respondents are people with extensive experience occupying high job positions in the organizational structure.

3.2. Survey validation

The two sections that contain human factor activities for JIT implementation and benefits obtained were validated by using the Cronbach's alpha. Table 7 illustrates the indices for each factor o latent variable.

All values for Cronbach's alpha and Composite reliability are over the limit of 0.7. This condition reveals that the questionnaire could be qualified as a good data collector instrument. Also, the values for AVE are bigger than 0.5. Therefore, the survey has discriminant and convergent validity.

Table 6
Job position of the respondent and seniority.

Respondent roll	Years of experience				Total
	Less than 2	Between 2 and 5	Between 5 and 10	Over 10	
Technique	1	0	1	2	4
Supervisor	3	11	10	16	40
Engineer	16	18	31	32	97
Manager	1	4	5	8	18
Total	21	33	47	58	159

Table 7
Validation for latent variables.

	Manage	Educati	Empower	Communic	ProSolve	Inventar	QualCto
R-squared		0.497	0.385	0.627	0.642	0.280	0.722
Composite Reliability	0.857	0.862	0.809	0.884	0.825	0.940	0.915
Cronbach's alpha	0.747	0.786	0.783	0.803	0.781	0.914	0.876
AVE	0.770	0.811	0.720	0.767	0.814	0.796	0.729
Full collinearity VIF	3.194	3.126	1.719	2.775	2.742	3.254	3.023
Q-squared		0.495	0.383	0.628	0.643	0.280	0.721

Table 8
Combined loading and cross loading for convergent validity.

	Manage	Educati	Empower	Communic	ProSolve	Inventar	QualCto	SE	*P* value
Man1	**0.879**	−0.029	0.148	0.217	−0.068	−0.128	0.073	0.069	<0.001
Man2	**0.877**	−0.042	−0.024	−0.091	0.123	0.018	−0.024	0.058	<0.001
Man3	**0.684**	0.091	−0.159	−0.162	−0.071	0.141	−0.062	0.097	<0.001
Edu1	0.591	**0.801**	0.205	−0.043	−0.095	−0.097	−0.042	0.07	<0.001
Edu2	−0.084	**0.851**	−0.064	0.016	−0.419	0.079	−0.07	0.062	<0.001
Edu3	−0.432	**0.774**	−0.09	0.111	−0.163	0.197	−0.185	0.067	<0.001
Edu4	−0.098	**0.692**	−0.057	−0.094	0.807	−0.206	0.342	0.094	<0.001
Emp1	0.366	−0.31	**0.795**	0.067	−0.155	−0.23	0.251	0.08	<0.001
Emp2	−0.247	0.193	**0.752**	0.057	−0.147	0.166	−0.132	0.09	<0.001
Emp3	−0.167	−0.013	**0.782**	−0.016	0.416	0.013	−0.105	0.086	<0.001
Emp4	0.05	0.214	**0.522**	−0.16	−0.176	0.092	−0.035	0.118	<0.001
Com1	0.204	0.169	−0.198	**0.841**	−0.044	−0.11	0.123	0.066	<0.001
Com2	−0.197	0.124	−0.07	**0.865**	0.172	0.301	−0.283	0.064	<0.001
Com3	−0.002	−0.299	0.273	**0.834**	−0.134	−0.201	0.17	0.062	<0.001
PSo1	0.154	−0.417	0.457	−0.195	**0.67**	0.044	0.123	0.084	<0.001
PSo2	−0.253	0.212	−0.338	0.165	**0.821**	0.351	−0.465	0.076	<0.001
PSo3	0.122	0.125	−0.034	−0.006	**0.849**	−0.373	0.352	0.064	<0.001
BInn1	0.278	−0.156	−0.09	−0.209	0.181	**0.864**	0.143	0.047	<0.001
Binv2	−0.12	0.109	−0.021	−0.016	−0.049	**0.923**	0.031	0.057	<0.001
BInv3	−0.175	0.056	0.044	0.139	−0.043	**0.906**	−0.106	0.063	<0.001
BInv4	0.033	−0.02	0.066	0.079	−0.083	**0.875**	−0.065	0.051	<0.001
BCal1	−0.106	−0.092	0.036	0.103	0.135	0.152	**0.864**	0.057	<0.001
BCal2	−0.048	−0.11	0.066	0.063	−0.094	−0.09	**0.847**	0.056	<0.001
BCal3	0.072	0.154	−0.148	−0.07	−0.015	−0.216	**0.87**	0.058	<0.001
BCal4	0.083	0.047	0.05	−0.098	−0.03	0.158	**0.834**	0.058	<0.001

The latent variable Manage is integrated by three items: Man1, Man2 and Man3. The latent variable Educati is integrated Edu1, Edu2, Edu3 and Edu4. So, the bold values indicate that those items are integrating that latent variable.

Table 7 also illustrates the R^2 for every dependent latent variable. It may be inferred that independent variables are really explaining the dependent variable and it is easy to see the similarity between R^2 and *Q*-squared, the non-parametric validation, and that means that the survey has predictive validity.

Also, Table 8 shows the combined loading and cross loading in order to confirm the convergent validity. As it was expected, the factors are high in the loadings but low in the cross-loadings. It was also noted that the *P*-values for the significance test are less than 0.01.

Although there is no general agreement stating the maximum limit that the full collinearity VIF can have, all values are less than 3.3 for latent variables, and this means that there is not collinearity problems among them. Also, the *Q*-squared for every dependent latent variable is bigger than zero, thus the nonparametric predictive validation is qualified as good.

3.3. Structural equation models

The final model appears in Fig. 2 and the model fit indices are APC = 0.382 with a $P < 0.001$, ARS = 0.525 with a $P < 0.001$ and AVIF = 1.959 qualified as good only if the value is less than 5. With those values, the conclusion is that the model is efficient and predictive.

3.3.1. Direct effects

The results of the category of direct effects are shown in Fig. 2. The values on the arrows indicate the value for beta values and their *P* values for a linear regression model, and according to the model, it is possible to state that all the effects are significant at a 95% of confidence. It is important to underline that the relationship between *ProSolve* and *QualCto* indicates that $P = 0.05$ (no significant); nevertheless, this is due to a round process, since the real value for this relationship is 0.047, and then the relation between those variables is significant.

According to dependence arrows in Fig. 2, the following equations can be expressed:

$$Communic = 0.65 * Manage + 0.19 * Educati + Error \text{ and } R^2 = 0.63 \quad (1)$$

$$Em\,powert = 0.22 * Manage + 0.45 * Educati + Error \text{ and } R^2 = 0.39 \quad (2)$$

$$Educati = 0.71 * Manage + Error \text{ and } R^2 = 0.50 \quad (3)$$

$$ProSolve = 0.12 * Em\,power + 0.64 * Educati + 0.13 * Communic + Error \text{ and } R^2 = 0.64 \quad (4)$$

$$Inventar = 0.53 * Communic + Error \text{ and } R^2 = 0.28 \quad (5)$$

$$QualCto = 0.10 * ProSolve + 0.12 * Educati + 0.74 * Inventar + Error \text{ and } R^2 = 0.72 \quad (6)$$

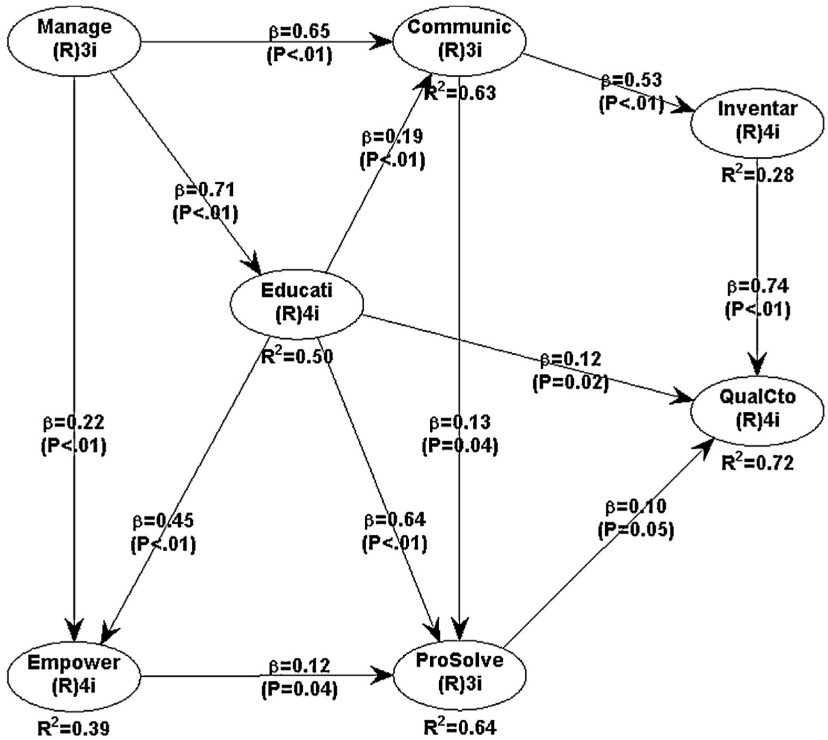

Fig. 2. Final model with parameters values.

Table 9
Indirect effects for paths with two and three segments.

	Indirect effects for paths with:					
	2 Segments				3 Segments	
	Manage	Educati	Empower	Communi	Manage	Educati
Manage						
Educati						
Empower	0.314 ($P < 0.001$)					
Communi	0.132 ($P = 0.008$)					
ProSolv	0.557 ($P < 0.001$)	0.077 ($P = 0.012$)			0.054 ($P = 0.012$)	
Inventa	0.343 ($P < 0.001$)	0.099 ($P = 0.007$)			0.070 ($P = 0.009$)	
QualCto	0.085 ($P = 0.021$)	0.064 ($P = 0.046$)	0.012 ($P = 0.013$)	0.403 ($P < 0.001$)	0.309 ($P < 0.001$)	0.081 ($P = 0.006$)

When interpreting the equations, the explanations are quite straightforward. For instance, Eq. (1) demonstrates that when *Management commitment* is increased in one standard deviation, *Communication is* raised in 0.65 standard deviations, and when *Education and training* is increased in one standard deviation, *Communication is* raised 0.19 standard deviations. The equation also explains that two independent latent variables, *Management Commitment* and *Education and Training*, cannot completely explain the *Education* factor, and this is because an error is displayed. The total variance explained for these independent latent variables is only 63%, as $R^2 = 0.63$. A similar interpretation can be extended for the other dependent latent variables. The model shows that some R^2 have low values, but according to their *P*-values, all of them are significant with a 95% of confidence.

3.3.2. Indirect effects for path with segments and sum of indirect effects

For the model presented in Fig. 2, it can be perceived that there are indirect effects with two, three, and four segments. Therefore, the sum of all of them is the total amount of indirect effects. Table 9 illustrates the indirect effects for path with two and three segments. According to their *P*-values, it is possible to conclude that those indirect effects are significant with 95% confidence. In the present context, there is only one indirect effect for path with four segments, and it is related to *Management commitment* on *Quality and Cost*, with a weight of 0.057 and $P = 0.07$ (significance), and that effect is given through the next path: *Management commitment – Education and training – Communication – Inventories – Quality and Cost.*

Hence, considering the information in Table 9, *Management Commitment* has indirect effect over all the other latent variables (except over education, because this relationship is a direct kind); for example, *Management Commitment* has an indirect effect on *Empowerment* with a weight of 0.314, but that is given trough *Education* and it is obtained by using only two segments. A similar interpretation can be done for other indirect effects of paths with two or three segments.

The sum of indirect effects (for path with different number of segments) is illustrated in Table 10, where the weight and their *P*-value appear and according those values, we conclude that all factors are significant with 95% confidence.

Table 10
Sum of indirect effects.

	Manage	Educati	Empower	Communi
Manage				
Educati				
Empower	0.314 ($P < 0.001$)			
Communi	0.132 ($P = 0.008$)			
ProSolv	0.612 ($P < 0.001$)	0.077 ($P = 0.012$)		
Inventa	0.413 ($P < 0.001$)	0.099 ($P = 0.007$)		
QualCto	0.451 ($P < 0.001$)	0.145 ($P < 0.001$)	0.012 ($P < 0.013$)	0.403 ($P < 0.001$)

Table 11
Total effects among latent variables.

	Manage	Educati	Empower	Communi	ProSolv	Inventa
Manage						
Educati	0.705 ($P < 0.001$)					
Empower	0.538 ($P < 0.001$)	0.445 ($P < 0.001$)				
Communi	0.78 ($P < 0.001$)	0.187 ($P = 0.006$)				
ProSolv	0.612 ($P < 0.001$)	0.713 ($P < 0.001$)	0.12 ($P = 0.001$)	0.126 ($P = 0.037$)		
Inventa	0.413 ($P < 0.001$)	0.099 ($P = 0.007$)		0.529 ($P < 0.001$)		
QualCto	0.451 ($P < 0.001$)	0.264 ($P < 0.001$)	0.012 ($P = 0.013$)	0.403 ($P < 0.001$)	0.1 ($P < 0.047$)	0.738 ($P < 0.001$)

3.3.3. Total effects

The sum of indirect and direct effects gives the total effects obtained among latent variables. These total effects and their *P*-values appear in Table 11, and according to these values, all effects are important with a 95% of confidence.

According to information in Table 11, *Management Commitment* has total effect over other six latent variables. It also has direct effects on *Education*, *Empowerment*, and *Communication.* On the other hand, Management Commitment has indirect effects on different paths on *Problem solving*, *Inventories*, and *Quality and Cost.* This interpretation of effects demonstrates the great importance of *Management Commitment* in the successful JIT implantation.

Similarly, *Education* has significant effects, both direct and indirect over *Empowerment*, *Communication*, *Problem-Solving*, and *Quality and Cost*. However, it only has indirect effects over *Inventories*. This means that *Education* and *Management Commitment* are the most important CSF for JIT implementation.

4. Conclusions

JIT is a philosophy still applied in competitive and globalized markets today – especially in *maquiladora* industries located in the Mexican border with United States. This is especially due to the fact that these types of companies import and receive raw materials and export finished goods. With a sample of 159 interviews, and after the development of a structural equation models by using partial least squares, the following conclusion validates the hypotheses previously established:

H1. There is enough statistical evidence to state that *Management Commitment* has a direct positive impact on *Communication*, because when the former changes by one standard deviation, the latter consequently directly changes in 0.65 units. Moreover, there is also an indirect impact of 0.312, which makes a total effect change 0.78. In other words, *Management commitment* is required for a good *Communication* among human resources during JIT implementation, but this requires *Education* (indirect effect).

H2. There is enough statistical evidence to declare that *Management Commitment* has a direct impact on the *Empowerment* that is given to employees in a JIT implementation process. In fact, when the first variable changes in one standard deviation, the second also does in 0.22 units. In addition, there is also an indirect impact of 0.314, which makes a total effect of 0.538. This means that *Management Commitment* is required for responsible *Empowerment* in workers, which requires *Education* (indirect effect).

H3. There is enough statistical evidence in order to proof that *Education and training* has a direct impact on *Empowerment* given to employees in a JIT implementation process, because when the first variable changes in one standard deviation, the second does in 0.455. This means that good *Education and training* provided in all organizations leads to *Empowerment*, since it involves workers with skills, experience, and practices in the production process.

H4. There is enough statistical evidence to state that *Empowerment* provided to workers has a direct impact on *Problem-Solving* abilities in a JIT implementation process. When the first variable is increased in one standard deviation, the second also is raised in 0.12. Therefore, a responsible *Empowerment* given to workers improves *Problem-Solving* abilities, and in this case, workers can have authority in some decision making processes in their jobs. Sometimes this is also the product of good *Education*, which also has a direct effect in *Empowerment*.

H5. There is enough statistical evidence to declare that *Management commitment* of CEOs and managers have a direct impact on *Education and training* in a JIT implementation process. When the first variable is increased in one standard deviation, the second equally is raised in 0.71. This means that a good *Management commitment* is required for a good and efficient *Education and training*, because CEOs are the main facilitators for economic resources, time, and materials for education.

H6. There is enough statistical evidence to state that *Education and training* has a direct positive impact on *Problem-Solving*, because when the first variable is increased in one standard deviation, the second also is directly raised in 0.64 units. In addition, there is also an indirect impact of 0.077, which makes a total effect change 0.713. In other words, *Education and training* is required for good *Problem-Solving* abilities from employees, but it also requires some *Empowerment* (indirect effect).

H7. There is enough statistical evidence to declare that *Education and training of* human resources has a direct impact on *Communication* in a JIT implementation process. When he first variable changes in one standard deviation, the second is also modified in 0.19 units. This means that a good *Education and training* is required for a good *Communication* among human resources, since personnel with good training have a better understanding of their jobs and tasks to perform.

H8. There is enough statistical evidence to declare that *Communication* among human resources has a direct impact on *Problem-Solving* abilities in a JIT implementation process, since when the first variable changes in one standard deviation, the second also changes in 0.13. This implies that a good *Communication* is required for a better *Problem solving*, since this facilitates the information flow among parts of the company.

H9. There is enough statistical evidence to declare that *Problem-Solving* has a direct positive impact on *Quality and Cost.* In fact, when the first variable changes by one standard deviation, the second changes directly in 0.10 units directly. This means that a team work with abilities and experience in *Problem-Solving* is required for good standards in *Quality and Cost*.

H10. There is enough statistical evidence to express that *Education and training* has a direct positive impact on *Quality and Cost*, since when the first variable is increased in one standard deviation, the second is also increased as consequence in 0.12 units. In addition, there is also an indirect impact of 0.145 given trough a path with two segments (*Problem-Solving*) and one path with three segments (*Communication–Inventories*), which makes a total effect change of 0.264. In other words, *Education and training* for employees is required to improve *Quality and Costs* standards.

H11. There is enough statistical evidence to declare that *Communication* has a direct positive impact on *Inventories.* When the first variable is increased in one standard deviation, the second consequently does the same in 0.53 units. This implies that a team work to implement JIT requires great *Communication* and information flow to have a higher standard performance in *Inventories*.

H12. There is enough statistical evidence to declare that *Inventories* has a direct positive impact on *Quality and Cost* in a JIT implementation process. When the first variable changes by one standard deviation, the second equally does so in 0.74 units directly. This means that *Inventories* controls are highly required to improve *Quality and Cost* standard in a JIT implementation environment.

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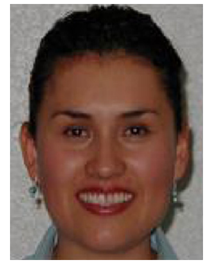

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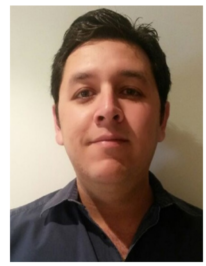

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