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Information Sharing with ICT in Production Systems and Operational Performance

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Abstract: In globalized times the integration of information and communication technologies in companies and their supply chains is required, but there is uncertainty regarding the true impact that these have on efficiency indices or benefits gained in the productive system. This article reports a structural equation model that contains ten hypotheses with five latent variables associated with the integration of information and communication technology in production systems such as information exchange, operations management, production control, distribution activities, and operational benefits obtained. The paper aims to quantify the relationships among those variables, facilitating managers to make decisions in information and communication technologies (ICT) implementation. The model is validated with information from 80 responses to a questionnaire applied to manufacturing companies, and partial least-squares technique is used to statistically validate the hypotheses; the results indicate that the implementation of information technologies facilitates the exchange of information, operations management and production control. This means that ICT integration can create visibility for a supply chain in a material's flow among partners, facilitate operations management in production lines and distribution activities, and these benefits are ultimately transformed into operational benefits that managers measure as flexibility, low cost and short cycles times with customers.

Keywords: ICT; operational performance; production control; ICT in distribution

1. Introduction

Companies seek to add value to their products through the processes of the supply chain (SC), which is defined as the conformation by all those partners involved directly or indirectly in the satisfaction of a customer's request, including procurement, production and distribution, where innovation has been presented as an essential link. In this context, Cerchione and Esposito [1] and Boiko et al. [2] indicate that SC is considered a system of multiple objectives (economic, productive, strategic, environmental, social, among others), which passes through a wide range of flows (financial, material, information, technology, among others). To help achieve that goal, information and communication technologies (ICT) have been implemented in the SC reconfiguring the global landscape and facilitating the decision-making process [3,4].

In the SC, the *Information Exchange* with suppliers facilitates the flow of materials and economic resources [5], where networks of companies, services, and production processes are formed that execute operations where the application of ICT is required, which is defined as a set of elements and techniques that allow users to manipulate information, convert it, store it, manage it, transmit it, and find it through the use of computers, software, and computer networks [6], which allow users to process and disseminate it simultaneously and in real time with partners.

The ICT application to SC has allowed companies to reduce transaction costs, including those related to transportation, communication, processes, and inventory and that is why companies from different sectors and sizes are currently using ICT to transform their ways of doing business, integrating processes, and improving productivity and relations among partners. Therefore, the competition will no longer be among production processes but in the SC [7,8], given that global commerce is interconnected and ICT is required to adequately address the competitive dynamism [9].

This information flow using ICT allows decision-making in almost real time. In this context, Jorgenson and Vu [10] point out that ICT has become a means of business development and a source of competitive advantage, however, it requires high economic investments that frequently put the company at risk of bankruptcy and involve multiple activities during its implementation; in addition, Cragg and McNamara [8] mention that the company requires ICT implementation as a strategy that allows decisions to be made quickly in the dynamic environment, especially in its SC.

ICT implementation is a complex process and Pérez-López et al. [11] discuss three stages: planning, execution, and control, and in each of them a series of activities are carried out. During the planning stage, a technological tracking for ICT is carried out based on the economic company's capabilities, possible alternatives and benefits, which must be carried out by specialized personnel, generating an investment plan. In the execution stage the plans and programs developed in the first stage are carried out, the purchases are made and the ICTs are installed throughout the SC, and this is where most of the problems occur due to incompatibility in communication protocols with previously installed systems, lack of clear instructions, and translation issues; in the control stage, the aim is to monitor the efficiency indices expected from these ICT.

Despite the problems that may exist in the implementation process, ICT offers benefits because it allows collecting, storing, accessing, sharing, and analyzing effective information and this gives SC visibility and allows the data analysis and decisions made to maximize profitability [12]. Levi et al. [13] and Chung [14] mention that companies investing in ICT are waiting: a) for information availability and visibility; b) to have the data available from a single access point; c) to facilitate decision making in a holistic manner, and d) to allow collaboration between partners.

Additionally, Levary [15], Jorgenson and Vu [10] affirm that ICT provides advantages to the SC such as cycle time reduction, low inventories, minimization of the whip effect, and improvements in channels distribution. However, ICTs must have a high level of integration, which is the degree to which the information systems are related and shared [16], including the already established systems. ICT integration in SC helps to redesign internal processes, improve efficiency, practicality, precision, and allow a rapid response management. It also helps to visualize work instructions, quality, and productivity graphs, and flow diagrams, among other things [17]. In addition, ICT allows the increasing of the volume of complexity of the information that needs to be communicated among partners, such as the level of inventory, delivery status, planning and production scheduling, which translates into a better SC control, which also facilitates coordination between clients and suppliers [18]. However, investments in ICT can fail if the information that is really needed is not shared due to lack of coordination and integration that facilitates strategic decision making.

Finally, Monostori [19] and Allaoui et al. [20] declare that the ICT adopted in the SC decrease the complexity and streamline the information flows, improve the coordination in production process and partners because of the increase in profitability and efficiency, and this in turn facilitates operation planning and control. Based on the above, it can be concluded that by integrating ICT into a productive process and SC into a company, tangible *Operational Benefits* are guaranteed that facilitate greater workforce capacity [17].

All the above benefits are attractive for managers, especially in SC, where the adoption of ICT plays an important role. However, companies that have not invested in ICT have reduced ongoing production due to the lack of timely and reliable information, which leads to uncertain decision making [21]. Due to the above, models have been studied to measure the integration of ICT in the SC [22] where it is mentioned that access to ICT is hindered due to lack of training in its use, ignorance of the usefulness of the exchange of information, and managerial commitment.

Currently there are many studies that indicate what should be measured to determine the ICT integration level in CS [23], such as the level of *Information Exchange* between the different partners of the SC, the ease with which the operations in the productive system and the outside of it are managed, the control they have over the operations in real time and the ease of handling of the variables, distribution of the goods produced, and the visibility of the products and services in the SC [24]. However, these studies are descriptive and only analyze parts of the ICT implementation process without integrating the effect they have on the *Operational Benefits* that are required in the production lines and the SC. Therefore, a manager knows that ICT will bring *Operational Benefits*, but does not know how much and does not know if it is worth making the investment.

To contribute to this research area, the objective of this article is to quantify the ICT integration level in the SC, for which four latent variables are measured that allow knowing that level: *Information Exchange*, *Operations Management*, *Production Control*, and *Distribution Activities*, which are related to the *Operational Benefits* obtained through a Structural Equation Model (SEM) and ten hypotheses that lets dependence values among them be obtained. The results in the SEM will allow managers to identify the ICT integration level they have implemented and how it impact the benefits obtained, in addition to identifying those activities that are essential and differentiating them from the trivial ones, focusing on those that are important for the company.

The rest of the manuscript is structured as follows: After this introduction section, Section 2 reports a literature review based on the five latent variables integrated in the SEM, Section 3 reports the methodology and materials used, Section 4 reports the results, Section 5 reports a discussion of findings and Section 6 reports the conclusions and practical implications.

2. Literature Review

According to the proposed objective, the SEM integrates five latent variables; four are used to identify the ICT integration level in SC, and the other refers to the *Operational Benefits* obtained, so these variables are defined below and the hypotheses that relate them are established.

2.1. Information Exchange

Information Exchange refers to the extent to which a company shares relevant, accurate, complete, and confidential information in a timely manner with its partners in the SC [25,26]. To measure this latent variable, five items are used [5,27,28]: relationship with suppliers, logistic process, compliance with customer requirements, improvement in customer service, and inventory management with suppliers and customers.

The willingness of suppliers to share information is analyzed, which implies the existence of trust and commitment to design, implement, and manage initiatives that create added value [29]. The *Information Exchange* significantly affects the reduction of costs and represents a competitive advantage, given that it allows decision making in a shared and agile way between manufacturer and supplier [25,30,31].

This information sharing keeps business structures together and makes it possible to respond to the competitive challenges in the logistics process [24], where ICTs are seen as a nervous system for SC management and play an essential role in linking the needs from market with the capabilities in suppliers [7,25]. Therefore Ryu et al. [32] conclude that the *Information Exchange* could help reduce the problems of excess inventory due to the uncertainty in market, suppliers, and customers [25,33,34].

2.2. Operations Management

ICTs should facilitate the operations management in SC, which helps to simultaneously improve the efficiency and effectiveness of the execution of activities in production processes. *The Operations and Supply Administration* (OSA) is understood as the design, operation, and improvement of the systems that create and deliver the primary products and services of a company, where the "operations" refers to the processes that are used to transform resources into products and services that customers want, and "supply" refers to the way of supplying the materials and services that enter and leave the company's processes [35].

To measure the efficiency of ICT in *Operations Management*, its effect is measured in the following five items [36–38]: production processes, maintenance management, strategic management of the production process, production planning, and improving decision making in production.

Then, to improve the SC coordination and quality product, companies often demand that their partners as subcontractors and suppliers carry out the ICT integration in common processes that often require the *Information Exchange* [30,39,40]. Therefore, ICT allows transmitting instantaneously and at a low cost the information needed in *Operations Management* for the productive processes, as demand forecast [41,42]. For example, suppliers of machinery provide real-time information about performing maintenance, or which parts to acquire [43,44], which facilitates decision making and is part of a sharing economy [45], then the following hypothesis is proposed:

Hypothesis 1 (H1). *The Information Exchange in the SC with the support of ICT has a direct and positive effect on the Operations Administration of the company.*

2.3. Production Control

Another application of ICT in a SC is to support to *Production Control* and facilitates the globalized and collaborative economy for the companies [46]. Petrick et al. [47] indicates that ICT improves the production process, which directly affects the profits of the company in the short and long term. Llach and Alonso-Almeida [17] declare that the adoption and use of ICT help to redesign internal processes, and this means that they improve the efficiency of the *Information Exchange* in *Production Control*, causing activities to be fast, easy to handle, and more precise. To measure the impact of ICT in *Production Control*, the following five items are measured [17,47,48]: maintenance planning, performing tasks in the work area, delays in the process, introducing new products and services, and responding to market changes.

Gunasekaran et al. [49] and Llach and Alonso-Almeida [17] claim that ICT adoption in managing the SC has strategic value because it provides competitive benefits in terms of efficiency and effectiveness in the production process, since it facilitates planning machine maintenance, provides solutions to delays, and streamlines the introduction of new processes. In addition, Shishodia et al. [50] indicate that these ICT in production processes minimize human errors thanks to the automation of processes, which is reflected in the achievement of a better performance of the SC. Therefore, the following Hypothesis is proposed:

Hypothesis 2 (H2). *Information Exchange in the SC with the support of ICT has a direct and positive effect on Production Control.*

In addition to the above, companies gain benefit from combining ICT with *Operations Management*, improving human skills and the production system control [17], that is, by integrating ICT into productive operations, there is better control of processes, and product development, procurement, logistics, production scheduling, and customer service are promoted [48]. In other words, the agility to control production quickly and accurately gives companies the ability to respond and recover from business interruptions, thus saving processing costs [48]. Furthermore, this *Information Exchange* in the company accelerates the processes in terms of efficiency and speed, providing accurate data through the use of software where solutions are proposed in real time and accurately [51]. Therefore, the following hypothesis is proposed:

Hypothesis 3 (H3). *The Operations Management in the SC with the support of ICT has a direct and positive effect on the company's Production Control.*

2.4. Distribution Activities

Distribution refers to the activities to be followed to move and store a product in a journey from one point to another in the different stages along the SC, through the supplier until delivery to the client [52]. In essence, distribution is a key guideline of the total profitability of the company, because it directly affects the costs in SC, and consequently, the organization and the added value to a product [53,54]. As mentioned, the ICT integration in product distribution activities is important because it is responsible for planning, executing and controlling the movement processes to the final customers. In this research, the following three items are evaluated to assess these variable [36–38]: production management, planning management of material requirements, and coordination of suppliers with production lines.

To achieve those activities specific to distribution, *Information Exchange* is required to help manage relationships with the logistics management processes such as storage and collection, optimizing transportation resources [55]. In addition, the fluidity of information between manufacturer and customer in a SC allows rapid decision making [52,56], so the following hypothesis is proposed:

Hypothesis 4 (H4). *Information Exchange on SC with support from ICT has a direct and positive effect on Distribution Activities.*

In addition, if the operations are properly managed with the support from ICT to transform the inputs for the manufacture of the product, then the delivery and distribution processes will be done without delay [54]. In the same way, if the planning process for materials required is done in a timely manner with ICT support and partners' integration in the production process, then customers get the expected product [57]. Therefore, the following hypothesis is proposed:

Hypothesis 5 (H5). *Operations Management of the SC with the support of ICT has a direct and positive effect on Distribution Activities of the company.*

Controlling the activities in the production system guarantees an adequate distribution; otherwise, there will be delays and production systems failures appear with lack of materials, and lack of maintenance in machines and equipment, among others, which affects the SC and the material flow [58]. However, these problems are solved with support from ICT, given that quality problems and maintenance requirements are detected in real time from the machines [59]. Considering that there is a relationship between *Production Control* and *Distribution Activities*, the following Hypothesis is proposed:

Hypothesis 6 (H6). *The timely information of Production Control in SC with support from ICT has a direct and positive effect on the Distribution Activities of the company.*

2.5. Operating Benefits

The ICT implementation is a competitive advantage for different departments in a company since decision making integrates information from all those areas [60]. If companies did not receive benefits from their investments in ICT, they would definitely not do it. The main operational benefits from ICT are measured using five items [25,30,31,47,61–65]: flexibility in systems to meet customer needs, strengthening the relationship with suppliers, cost competitiveness, shorter order cycles and customer response flexibility.

The ICT integration and use in SC activities allows the company to interact and coordinate activities among partners, due mainly to an exchange of information [10]. In other words, the incidence on logistics operators and ICTs play an important role in the function of sharing and transferring information, improving the performance of these operations at low cost and with high flexibility.

In addition, the *Information Exchange* favors the internal communication into the company [49], decreases transaction costs by encouraging interaction with customers and suppliers, reduces transaction costs and increases productivity by stimulating internal communication and the use of techniques and methods [66]. In addition, access to more market information allows appropriate decisions to be made quickly [67]. Therefore, the following hypothesis is proposed:

Hypothesis 7 (H7). *Information Exchange with ICT in the SC has a direct and positive effect on the Operational Benefits obtained by the company.*

Kumar, Singh and Shankar [62] mention that, by integrating ICT in production processes, the company reflects an improved performance of production activities to deliver and receive full information, which gives greater flexibility in shipping orders, integration, and collaboration between departments, and to offer a quality service to customers and suppliers. Therefore, the benefit of integrating ICT into the activities of the company directly affects customers, suppliers, internal collaborators, and, therefore, processes, that is, ICT in productive operations add value to the product or service [8,68], so the following hypothesis is proposed:

Hypothesis 8 (H8). *Operations Management with ICT support has a direct and positive effect on Operational Benefits obtained by the company.*

Chen et al. [69] suggested that the ICT integration to control production can lead to better performance, and Petrick, Maitland and Pogrebnyakov [47] mention that ICT improve production and therefore the benefits of the company are mediated by access to productive capacities such as the planning of work activities, maintenance, and responsiveness towards market needs. In the search for SC integration, the ICT and the information systems based on data play an important role, which allows the supervision and operations control [70], and therefore, the following hypothesis is proposed:

Hypothesis 9 (H9). *Production Control in the SC with the support of ICT has a direct and positive effect on the Operational Benefits obtained by the company.*

Transportation decisions within the company concern the movement of inventory from one point to another, which influences decisions on internal transport and distribution processes between warehouses [65]. Therefore, there is the need for organizations to stay ahead of the competition by adopting the advance of ICT in their daily distribution operations [71]. Efficient and effective management of materials handling can only be achieved when cooperation between departments is efficient and effective within the entire SC [64].

Therefore, benefits such as inventory reduction, material management, and *Production Control* increase when the entire network of logistics channels is integrated to organize the distribution route from a central warehouse in the search for the optimization of the SC, and therefore, in the development of a robust and flexible supply [65]. Therefore, the following hypothesis can be defined:

Hypothesis 10 (H10). *Distribution Activities in the SC with the support of ICT have a direct and positive effect on the Operational Benefits obtained.*

Figure 1 graphically represents the hypotheses in which the variables analyzed are related.

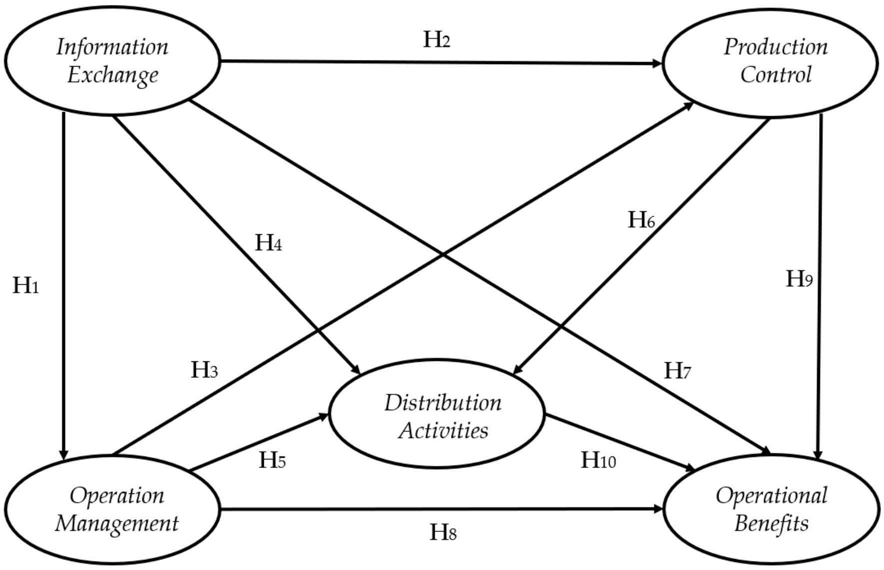

Figure 1. Raised hypotheses.

3. Methodology

To statistically validate the hypotheses in Figure 1 the following methodology was followed, which was divided into five stages.

3.1. Construction of the Questionnaire

A questionnaire was constructed to obtain information from companies and their ICT implementation. A literature review was done for every latent variable in Figure 1 in databases such as Elsevier, Springer, Emerald, and EBSCO host, among others. The key words were Small and Medium Enterprises (SMEs), Information Technology (IT), Technological Integration (TI), Information and Communication Technology (ICT), Supply Chains (SC). 145 articles were identified, and reduced to 55 because they reported industrial applications.

Ninety-one activities and benefits from ICT were identified and integrated into a questionnaire divided into 12 latent variables and this literature review constituted a rational validation [72]. This questionnaire was presented to academics and managers in the industry to understand viability for the industrial and geographical context, because identified variables come from other industrial sectors and countries. The final questionnaire had 86 items since it was suggested that five other items be removed. Although the questionnaire had 12 latent variables, only five are reported in this research, and these appear in Figure 1. The questionnaire had three sections: the first concerns demographic information from company and responder; the second contains latent variables related to activities associated with ICT planning; and the third is about the execution and control, as well as three variables associated with operational, economic and commercial benefits.

3.2. Application and Capture of Information

The questionnaire was applied to manufacturing companies in Baja California (Mexico) and was answered on a Likert scale [73] with values between one and five [74]. The questionnaire was aimed at managers in production lines, CEO departments and supervisors using ICT in SC. Therefore, the sample was stratified and focused on persons using ICT in real production systems; however, sometimes responders recommend others persons according to the job position and relationship with ICT in SC and then the sampling method snowballed. Responders must have had more than two years in their job position and have been belonging to production improvement projects.

The information was captured in a database designed in SPSS 23® software (IBM, New York, NY, USA), which groups and represents the information in an orderly manner; with this it is possible to identify characteristic behavioral aspects of the data treated [75].

3.3. Debugging the Information Base

The database was debugged to identify questionnaires with duplicate answers, missing and extreme values, which affected the median [76]. Additionally, uncommitted respondents were identified and removed from the analysis [77].

3.4. Validation of Latent Variables

Several indices were used to validate the latent variables, such as the following [78]: R^2 and adjusted R^2 to measure parametric predictive validity ($R^2 < 0.2$); Q^2 to measure non-parametric predictive validity ($Q^2 > 0.2$), Cronbach's alpha and composite reliability index to measure the internal validity of the variables (>0.7), average variance extracted (AVE) for convergent validity (AVE > 0.5) and variance inflation factor (VIF) to measure collinearity (VIF < 3.3).

3.5. Descriptive Analysis of the Sample

A descriptive analysis was performed using the SPSS 23® software [75]. Crosstabs were made to detail the years of experience of the respondents, the position they occupied, the years of experience, the industrial sector to which they belonged and the number of employees.

3.6. Descriptive Analysis of Items

The median was obtained as a measure of central tendency because data were expressed in an ordinal scale [79], and as a measure of dispersion, the interquartile range (IR) of each item was estimated.

3.7. Structured Equation Modeling (SEM)

The SEM technique was used because the latent variables can play a double roll as independent and dependent variables [80]. The WarpPLS 6.0® software (ScriptWarp Systems, Laredo, TX, USA) was used to evaluate the SEM, based in partial least-squares regression (PLS) and recommended for small samples and where there is no normality of the data [78]. The following efficiency indices were evaluated: the average path coefficient (APC) as a measure of predictive validity with $p < 0.05$, average R^2 (ARS > 0.2) and adjusted average R-Squared (AARS > 02) with $p < 0.05$ [81]; the average block variance inflation factor index (AVIF < 3.3) and average full VIF collinearity index (AFVIF < 3.3) to measure the collinearity among the variables; and finally, the Tenenhaus Index (GoF > 036) to measure data fit to the model.

3.8. Model Effects

To indicate the relationships that exist between latent variables in Figure 1, the impact between them is measured testing the following hypothesis, where β is a dependence measure in standard deviations.

$$H_0\text{: } \beta_i = 0 \quad (1)$$

$$H_1\text{: } \beta_i \neq 0 \quad (2)$$

The relationship between latent variables is measured in different effects, which are:

- Direct effects are the effects that indicate the impact between the latent variables, regarding the initial hypotheses in Figure 1.
- Indirect effects are the indirect impact that exists between variables through a third mediator variable [82].
- Total effects represent the arithmetic sum of the direct and indirect effects between variables [83].

4. Results

4.1. Descriptive Analysis of the Sample

Ninety-six responses to the questionnaire were received, and after the debugging process, 16 were eliminated and only 80 surveys were analyzed (see Supplement Material). Table 1 illustrated the sector and gender and it was observed that manufacturing companies are the sector that most answered the questionnaire.

Table 1. Sector and sex.

Sector	Manager	Chief Executive Officer Department	Supervisor	Total
Manufacturing industries	8	11	17	36
Food industry	4	1	2	7
Manufacture of clothing	2	5	0	7
Manufacture of computer equipment	1	1	5	7
Manufacture of electronic accessories	2	1	4	7
Plastics industry	1	2	3	6
Manufacture of metallic products	2	0	3	5
Printing and related industries	2	0	1	3
Manufacture of non-metallic mineral products	1	0	0	1
Manufacture of furniture, mattresses, and blinds	1	0	0	1
Total	24	21	35	80

Table 2 shows the years of experience in the job, highlighting those who have between 2 and 3 years in the position with 37%; next, there are those who have between 3 to 5 years' experience, with 33%; and workers with more than 5 years of experience with 24%. In terms of gender, women had less participation with 32% compared to 68% for men.

Table 2. Years on the job.

Gender	Time (Years)				Total
	>2 and <3	≥3 and <5	≥5 and <10	≥10 Years	
Male	18	21	7	8	54
Female	12	6	3	5	26
Total	30	27	10	13	80

4.2. Validation of Variables

Table 3 shows the indices obtained for the latent variables' validation, and based on this, it was concluded that there were parametric and nonparametric predictive validity, internal validity and there were no collinearity problems, and that enough variance had been extracted.

Table 3. Validation of latent variables.

Indices	Latent Variables				
	Information Exchange	*Operation Management*	*Production*	*Distribution*	*Benefits*
R-Squared		0.458	0.558	0.406	0.662
Adjusted R-Squared		0.451	0.546	0.382	0.644
Reliability Index	0.914	0.897	0.891	0.921	0.954
Cronbach's Alpha	0.882	0.855	0.847	0.872	0.939
Extracted Variance Average	0.681	0.638	0.622	0.796	0.806
Variance Inflation Index	2.579	2.48	2.373	1.98	2.829
Q-Squared		0.462	0.563	0.415	0.662

4.3. Descriptive Analysis of Items

Table 4 illustrates the median and interquartile range for each item in each latent variable. In the column corresponding to the median, there are eight items with values greater than 4, which means that according to the perception from responders, these activities are important and are frequently executed in the company. It is observed that the activities associated with *Production Control* and *Distribution Activities* have all medians less than 4; this indicates that they are areas of opportunity to improve. Likewise, it is observed that only one of the five benefits do not have a median greater than four, that is, ICT certainly offer the planned benefits.

Table 4. Descriptive analysis of the data.

Items	Median	IR
Information Exchange		
Meet the customer's requirement	4.213	1.492
Improve customer service	4.143	1.616
Inventory management with suppliers and customers	4.07	1.518
The logistic process	3.873	1.447
Relationship with suppliers	3.792	1.501
Operations Management		
Production planning	4.05	1.397
Improve decision making in production	3.957	1.565
Production processes	3.769	1.54
The strategic management of the production process	3.755	1.511
Maintenance management	3.407	1.652
Production Control		
Respond to market changes	3.936	1.58
Introduce new products and services	3.824	1.561
Performing tasks in the work area	3.7	1.68
Delays in the process	3.679	1.514
Maintenance planning	3.455	1.67
Distribution Activities		
Control management of production material	3.98	1.51
The planning management of need for material	3.83	1.649
The coordination of the suppliers with the production lines	3.681	1.786
Operating benefits		
Customer response flexibility	4.123	1.609
Flexibility of the systems to meet customer needs	4.091	1.63
Cost competitiveness	4.038	1.745
Strengthen the relationship with customers	4	1.629
Shorter order cycles	3.878	1.82

4.4. Model Efficiency Index

After evaluating the model in Figure 1, the results were obtained, as illustrated in Figure 2. Each segment that relates two latent variables is associated with a β value with its respective p-value for the test of statistical significance, and the dependent latent variables are associated with a R^2 value as a measure of variance explained by the independent latent variables.

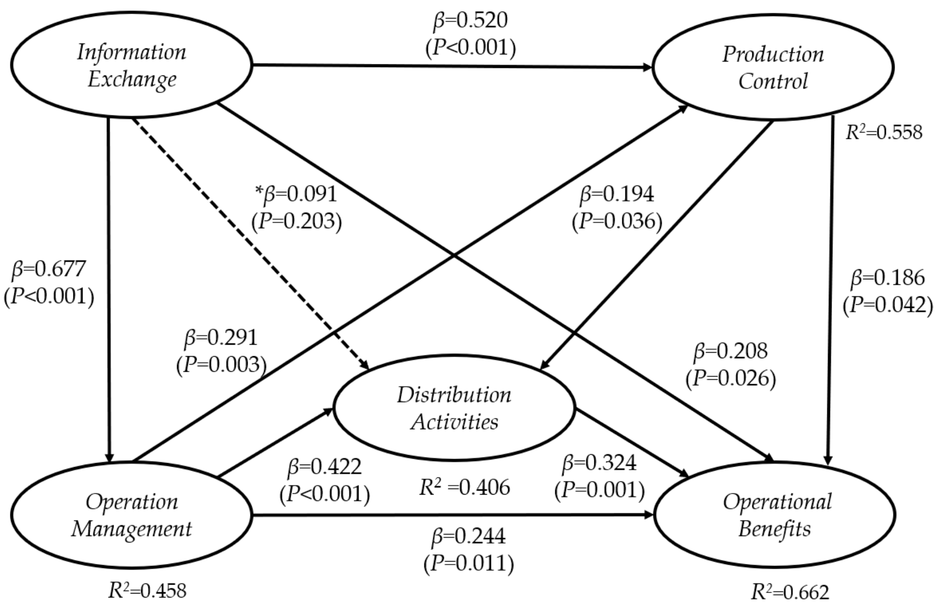

Figure 2. Structural equation model.

Table 5 illustrates the efficiency indices for the evaluated model in Figure 2; it is observed that the predictive validity requirements are met, since ARS, AARS, and APC are associated with low p-values. Similarly, the AVIF and AFVIF index indicate no collinearity problems because their values are lower than 3.3. Finally, the Tenenhaus index (GoF) indicates that the data fit the model properly given that the value is greater than 0.36.

Table 5. Model efficiency indices.

Indices	Results	Criterion
Average Path Coefficient (APC)	APC = 0.316, $P < 0.01$	$p \leq 0.05$
Average R-Squared (ARS)	ARS = 0.521, $P < 0.01$	$p \leq 0.05$
Average Adjusted R-Squared (AARS)	AARS = 0.506, $P < 0.01$	$p \leq 0.05$
Average block VIF (AVIF)	AVIF = 2.123	Ideally ≤ 3.3
Average Full Collinearity VIF (AFVIF)	AFVIF = 2.448	Ideally ≤ 3.3
Tenenhaus GoF (GoF)	GoF = 0.607	Medium ≥ 0.25, Large ≥ 0.36

4.5. Direct Effects

The β and p-values for every relationship among latent variables allow us to conclude the following:

- H1: There is enough statistical evidence to declare that the *Information Exchange* in the SC with ICT support has a direct and positive effect on the *Operations Management* of the company given that when the first variable increases its standard deviation by one unit, the second goes up by 0.677 units.
- H2: There is enough statistical evidence to declare that the availability of *Information Exchange* in the SC with ICT support has a direct and positive effect on the *Production Control* since when the first variable increases its standard deviation by one unit, the second goes up by 0.52 units.
- H3: There is enough statistical evidence to declare that the *Operations Management* in the SC with ICT support of ICT has a direct and positive effect on *Production Control* in a company, given that when the first variable increases its standard deviation by one unit, the second goes up in 0.291 units.

- H4: There is not enough statistical evidence to declare that the *Information Exchange* in the SC with ICT support has a direct and positive effect on the *Distribution Activities*, given that the associated p-value is equal to 0.203.
- H5: There is enough statistical evidence to declare that the *Operations Management* in a SC with ICT support, has a direct and positive effect on the *Distribution Activities* in a company, given that when the first variable increases its standard deviation in one unit, the second one goes up by 0.422 units.
- H6: There is enough statistical evidence to declare that the timely information of *Production Control* with ICT support has a direct and positive effect on the *Distribution Activities* in a company, given that when the first variable increases its standard deviation in one unit, the second one goes up in 0.194 units.
- H7: There is enough statistical evidence to declare that the *Information Exchange* with ICT in the SC has a direct and positive effect on the *Operational Benefits* obtained by the company, given that when the first variable increases its standard deviation by one unit, the second variable goes up by 0.208 units.
- H8: There is enough statistical evidence to declare that the *Operations Management* with ICT support have a direct and positive effect on *Operational Benefits* obtained by the company, given that when the first variable increases its standard deviation by one unit, the second goes up by 0.244 units.
- H9: There is enough statistical evidence to declare that the *Production Control* in the SC with ICT support has a direct and positive effect on *Operational Benefits* obtained by the company, given that when the first variable increases its standard deviation by one unit, the second goes up by 0.186 units.
- H10: There is sufficient statistical evidence to declare that the *Distribution Activities* in the SC with ICT support have a direct and positive effect on *Operational Benefits* obtained, given that when the first variable increases its standard deviation by one unit, the second variable goes up by 0.324 units.

The R^2 value in Figure 2 indicates the percentage of variance explained by independent latent variables in dependent latent variables. For example, in *Operations Management*, 45.8% of the variance is explained by the *Information Exchange*; for *Production Control* 55.8% of variance is explained by *Information Exchange* (37.2%) and *Operations Management* (18.6%); for *Distribution Activities*, 40.6% of variance is explained by *Information Exchange* (4.7%), *Operations Management* (25.7%), and *Production Control* (10.2%); and finally, the *Operational Benefits* is explained in 66.2%, but come from *Information Exchange* (14.0%), the *Operations Management* (16.6%), the *Production Control (24.5%)*, and the *Distribution Activities* (23.3%). Therefore, all the values of the R-Squared coefficient have a considerable percentage and that indicates that independent latent variables are good predictors for dependent latent variables in the model and a resume is illustrated in Table 6.

Table 6. R^2 contribution.

To	From				R^2
	Information Exchange	***Operations Management***	***Production Control***	***Distribution Activities***	
Operations Management	0.458				0.458
Production Control	0.372	0.186			0.558
Distribution Activities	0.047	0.257	0.102		0.406
Operational Benefits	0.140	0.166	0.245	0.233	0.784

4.6. Sum of Indirect Effects

Table 7 illustrates the sum of indirect effects between the latent variables in Figure 2, where each of them is assigned a *p*-value as a statistical test of significance and an effect size (ES) as a measure of the explained variance. It is observed that two indirect efects are not statistically significant, since they are associated with a *p*-value greater than 0.05. For example, an interpretation of the indirect effects between the *Information Exchange* and *Production Control*, where $\beta = 0.197$ with a $p = 0.005$, concluding that statistically it is significant, and therefore, there is an indirect relationship between those variables.

Table 7. Sum of indirect effects.

To	From		
	Information Exchange	*Operations Management*	*Production Control*
Production Control	$\beta = 0.197$ ($p < 0.05$) ES = 0.141		
Distribution Activities	$\beta = 0.425$ ($p < 0.01$) ES = 0.217	$\beta = 0.056$ ($p = 0.236$) ES = 0.034	
Operational Benefits	$\beta = 0.466$ ($p < 0.01$) ES = 0.318	$\beta = 0.210$ ($p = 0.025$) ES = 0.148	$\beta = 0.063$ ($p = 0.211$) ES = 0.042

4.7. Total Effects

Table 8 illustrates the total effects, the *p*-values and the effect size. It is observed that all *p*-values are lower than 0.05, so it is concluded that all they are statistically significant, even though some direct effects are not. For example, the total effect between *Information Exchange* on *Production Control* is 0.717 and includes the direct and indirect effect. A similar interpretation is made for the total effects among the other variables.

Table 8. Total effects.

To	From			
	Information Exchange	*Operations Management*	*Production Control*	*Distribution Activities*
Operations Management	0.677, $p < 0.01$, ES = 0.458			
Production Control	0.717, $p < 0.01$, ES = 0.513	0.291, $p = 0.003$, ES = 0.186		
Distribution Activities	0.516, $p < 0.01$, ES = 0.263	0.479, $p < 0.01$, ES = 0.291	0.194, $p = 0.036$, ES = 0.102	
Operational Benefits	0.674, $p < 0.01$, ES = 0.459	0.453, $p < 0.01$, ES = 0.320	0.249, $p = 0.010$, ES = 0.167	0.324, $p = 0.001$, ES = 0.223

5. Discussion

ICT integration in SC must be focused on obtaining *Operational Benefits*. Table 6 shows the variance decomposition for every dependent latent variable in order to identify those independent variables that are more important for industrial sustainability. For example, it is observed that the most important variable for the achievement of the activities associated with *Operations Management* is the *Information Exchange* which is the only variable with 0.458. For *Production control* the most important variable is again the *Information Exchange* with 0.372, because is greater than *Operations Management* with 0.186, so managers must therefore pay special attention to the activities associated with *Information Exchange*-based in ICT. In other words, a company requires *Operations Management* and *Information Exchange* for guarantee the *Production Control* and sustainability.

However, in order to achieve an adequate *Distribution Activities*, it is necessary first of all to have an adequate *Operations Management* (0.257) since it has a greater explanatory power in comparison with the *Production Control* (0.102) and the *Information Exchange* (0.047), where the direct effect was statistically non-significant, indicating that managers interested in achieving an adequate distribution of their products with ICT support should give preference to the operations that are related to *Production Control*.

Finally, to obtain *Operational Benefits*, companies must focus on achieving, first, adequate *Production Control* (0.245) and *Distribution Activities* (0.233) which have the greatest explanatory power, and then focus on *Operations Management* (0.166), and *Information Exchange* (0.140). The above indicates that the ICT applied to production processes and products distribution guarantee *Operational Benefits* associated with flexibility, cost competitiveness, and shorter order cycles.

From the analysis of direct, indirect, and total effects, it is observed that:

The biggest total effect is between the *Information Exchange* variable and *Production Control* variable with $\beta = 0.717$, which indicates that ICT makes it easier to respond quickly to changes in the market and introduce new products or their variants, minimizing delays in production orders (H2), coupled with the fact that they also favor the *Operations Management* for the manufacturer, since they facilitate the production planning efficiently, the control in maintenance systems, and the decision-making in the production lines (H1).

This *Information Exchange* also generates operating benefits in the production lines given that greater flexibility is achieved in responding to customers, offering alternative products, lower costs, and faster ordering cycles that increase consumer satisfaction (H1). However, this *Information Exchange* does not have a significant direct effect on *Distribution Activities*, but a large indirect effect through mediating variables, which indicates that this information should be useful in the production processes and operations being carried out (H4).

Proper *Operations Management* supported by ICT will promote *Distribution Activities* associated with the supply of raw materials and finished products as well as greater coordination between the manufacturer with suppliers and customers (H5), but also facilitates obtaining *Operational Benefits* given that greater flexibility is achieved in the production process, delays and downtime in operators and machines are reduced, which translates into short cycle times and satisfaction for customers (H8).

The use of ICT in *Production Control* is also reflected in the *Distribution Activities* given that it facilitates the management of raw materials that leave the production process towards the consumer, and this allows having better planning requirements and therefore, a more stable relationship with suppliers (H6). This *Production Control* is complex, but its *Operational Benefits* are reflected in a greater variety of products to the customer or flexible production, affordable costs, and short delivery times (H9).

Finally, the last step in the life of a product is to take it to the consumer, and the application of ICT in *Distribution Activities*, such as satellite tracking and radiofrequency systems, will allow *Operational Benefits* with a SC visible to the client, building trust in that relationship (H10).

To give managers a critical path with activities that guarantee industrial sustainability, and according to the biggest β values, the following sequence must be followed:

Information Exchange → Operation Management → Distribution Activities → Operational Benefits

However, last sequence does not integrate the *Production Control* related to production lines, where sustainability and operational benefits are gained, so the following sequence must be followed:

Information Exchange → Operation Management → Production Control → Distribution Activities → Operational Benefits

Here it is important to mention that the SEM and hypotheses are tested using information from Mexican maquiladora industry, an industrial sector that have specific characteristics, with a lot of raw material importation and finished product exportation, a globalized business and SC, different labour law, culture, among others. Findings here reported have been applied to similar sectors but must be adapted considering the regional context, and that can be somewhat of a limitation.

6. Conclusions

The role of ICT in SC has been widely reported; however, this research has quantified the relationship with *Operational Benefits* and tested this relationship with statistical hypotheses. From the findings of this research, the following conclusions are stated:

(1) In globalized SC, ICT integration is essential for sharing information in real time and joint decision-making processes, due to agility and fast response; in other words, ICT brings benefits to a company.
(2) *Information Exchange* has the highest effects on other variables according to the β value, indicating the importance in *Production Process* facilitating the *Operations Management* for transforming the raw materials into finished products.
(3) ICT support *Operations Management* and facilitate the *Production Control* due to fast information flow from customers to manufacturer, giving SC both more flexibility for finding alternatives for generating a product, and greater agility which in turn creates short delivery times.

(4) ICT integrated in *Production Control* also generates fast and efficient information flow in *Distribution Activities* that generates a better planning management of material requirements, and coordination of suppliers with production lines and better relationships with final customers.
(5) *Distribution Activities* is the last group of tasks for a manufacturer, but maybe the most important because there is contact with the final customer and ICT can be used to track deliveries and product positions, etc.

Finally, is important to mention that this paper reports an SEM analysis with only five latent variables, but the questionnaire applied to Mexican maquiladoras had 12 of them. Therefore, in future research, other SEM will report relationships between latent variables associated with human factors in ICT implementation, the importance for education and training, abilities and skills required and how they impact the finances of a company. Additionally, a second SEM will report an integrated model with second-order variables reduced to human factors, ICT in production and distribution system with benefits (operational and financial).

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