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The Role of ICT in the Supply Chain of Ciudad Juarez Industrial Sector

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Abstract. Procurement and inventory represent two of the most important stages that integrate the supply chain (SC), if there is a mistake or problem in one of them, it can lead to total failure of the chain, therefore, generate losses to the companies among other issues. To avoid that kind of problems, multiple companies have decided to invest in information and communication technologies (ICT) to improve and facilitate communication, as well as simplify the management of their inventory. In that sense, the objective of this paper is to identify the importance of ICT related to the procurement and inventory of the Mexican industrial sector, specifically, in the maquiladora industry in Ciudad Juárez, Chihuahua. To gather data, a questionnaire was developed and it was administered to that sector, obtaining 306 valid questionnaires. In addition, to measure the relationship between variables, a structural equation model was developed using partial least squares by the WarpPLS V.5® software, which integrates three hypotheses. Finally, the results indicate that ICT has a direct and positive effect on the procurement process; however, its explanatory power is greater for the inventory.

Keywords: ICT, SEM, supply chain, procurement management, inventory management.

1 Introduction

A supply chain (SC) is defined as a set of organizations that create a network where services / products, information and finance can flow. Its aim is to transform raw material into finished products which are delivered to final consumers with the highest quality, in the right quantities and at the requested time [1]. An efficient management of SC includes the ability to manage the flows of products, information and economic resources [2], thus it requires a connection between the different stages of SC to coordinate and maximize its overall effectiveness.

To achieve it, companies use ICT to improve SC efficiency, since they facilitate access to information about different agents (suppliers, transporters, manufacturers,

distributors, among others), also they have played an important role in creating networks of greater value in all sectors of society [1].

The appropriate use of ICT facilitates several aspects, for example, they can allow to identify the best supplier and send him an order immediately (even automatically) [1], locate raw and finished materials in real time, providing a greater agility and visibility [3], and know inventory levels at all time.[4]. Because of the above mentioned, it is increasingly recognized that ICT are altering communication patterns between companies, customers and suppliers [5].

1.1 Problem Statement and Research Objective

Currently, the relationship between the activities of inventory management, provisioning and the use of ICT in SC is still unknown, so the objective of this work is to quantitatively measure the impact of these variables on the Maquiladora industry of Ciudad Juarez, Mexico.

2 Literature Review and Hypotheses

2.1 ICT in SC

Nowadays, companies have included ICT in their areas in order to facilitate their operations, specifically in industrial companies within dynamic areas, such as in the supply chain management [6], since ICT is believed to improve human resource, financial resource, and asset productivities, vertical integration efficiency in supply chain and customer relationship management, and competitive power in the market [7].

It is demonstrated that the use of ICT improves bilateral relations between companies and offers new opportunities for vertical collaboration, even in mature industries [8], also, the use of the internet and e-mail is common in supply chain management in all industries [9]. In order to know if a company is applying ICT properly, it is advisable to investigate the following aspects: internet use in B2B (Business-to-Business), internet use for business administration, collaboration and customization via internet, shared information and inter-organizational coordination, intra-organizational information systems for SC coordination and integration, and the use of efficient consumer response (ECR).

2.2 Procurement: Supply of Raw Materials

The acquisition of raw materials is a key activity for any company, since it facilitates to increase the creation of value minimizing the cost, this is the reason why it is crucial to have the suitable suppliers to guarantee the supply, in the right quantity at in the right quality at the right place and time. It means that the supplier selection process becomes, therefore, a crucial area of decision making [10]. In this work, in order measure the raw material supply process in a company, the following points are analyzed: cooperation level with suppliers, quantity of suppliers, use of the JIT philosophy in supply process and purchases focused on the best price.

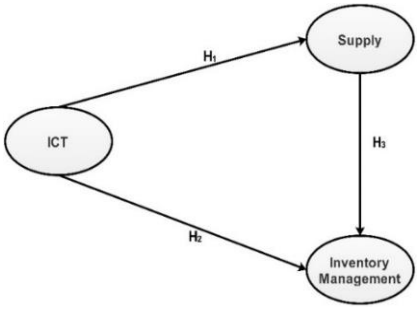

Fig. 1. Proposed model.

However, the successful adoption of ICT enables supply chain management to have a reliable information system, perform an adequate provisioning, more efficient control of inventory and material resources. Therefore, the following hypothesis is proposed

H_1: *ICT* have a direct and positive impact on the *Procurement* process in the supply chain.

2.3 Inventory Management

Inventory management is one of the factors that affect cost, which is the main reason for the focus on SC management, where coordination and collaboration between activities at all stages of the business system are considered key in the management of modern enterprises, specifically inventories consisting of raw materials, components and finished good [11]. The availability of the product at the time, in quantity, in quality and at the desired price not only provides immediate benefits, but ensures the long-term customer loyalty and brand leadership [11]. Thus, appropriate inventory management allows to develop marketing, sales, and logistics strategies, from the supplier to the final customer.

In general, in order to know whether exists an adequate inventory management in any type of company, it is necessary to identify if there is coordination and inventory management, if the automation in the warehouse is presented, if the JIT (Just in Time) is applied in delivery, if the company is focused on the low inventory costs, and if there are distribution centers nearby. In this regard, these topics are included in this research.

In that sense, ICT are a great help since they allow identifying, monitoring and transmitting information on tagged items throughout the SC, then facilitating its visibility and efficiency [2], as they increase their capacity to respond to a large quantity and variety of demanded products and meet short delivery times [2]. Therefore, the following hypothesis can be stated:

H_2: *ICT* have a direct and positive effect on the Inventory Management in the supply chain.

An important process in SC is the accurate inventory data update that adjusts and changes as goods are transferred from manufacturers to distributors [12]. However, an inaccurate inventory data update could lead to shortages and losses, so it should be avoided to maximize profit. Therefore, the following hypothesis can be constructed:

H_3: *Procurement* has a direct and positive impact on the *Inventory Management* in the supply chain.

The three hypotheses proposed for this study can be graphically represented as shown in Figure. 1, which integrates the three latent variables studied.

3 Methodology

This section describes the methodology followed to collect information and validate the three hypotheses discussed, it is integrated by distinct stages that are described below.

3.1 Stage 1: Literature Review

Multiple electronic databases, such as Springer, Emerald, Taylor & Francis, etc., are consulted and by using keywords as ICT Integration, Inventory Management and Purchasing Management essential information is identified to carry out the next stage.

3.2 Stage 2: Evaluation Instrument Design and Application

Based on information collected, a questionnaire is developed which uses a Likert scale to answer each question (1 to 5). Where 1 indicates that activity is not important or never performed, while 5 indicates that activity is always performed or extremely important [13]. The result is a questionnaire with five sections: the first includes general information of the respondent (seniority, sector, etc.). The second, seven items related to ICT; The third, four items in relation to procurement, and the last has six items in relation to the inventory.

Once the questionnaire has been developed and checked by experts, it is administered to people whose area of work is related to supply chain and it should be noted that its application is carried out by face to face interviews.

3.3 Stage 3: Analysis and Information Debugging

The information is captured in a database developed by a statistical software called SPSS 21®, where each row represents a case and the columns represent the questions. Analyzes are performed to identify missing values and if a case has more than 15% of these, it is eliminated, thus, is not considered for further analysis. If there is a smaller percentage, the missing data can be replaced by the median. Also, the extreme values are identified, so that all variables are standardized, considering as outliers to standardized values greater than the absolute value of 4. [14].

3.4 Stage 4: Questionnaire Validation

Cronbach's alpha index and the composite reliability index are used for the validation of the instrument and to measure the internal reliability by constructs [15]. Cronbach's alpha index measures the degree of correlation between items [16], accepted values are

those higher than 0.7, but this value can be increased by eliminating correlated items, that probably might be explained with others [14].

Likewise, convergent and discriminant validation are performed. The first, explains the amount in which a construct converges in its indicators explaining the variance of the items [17]. On the other hand, discriminant validity indicates how different a construct is from others [17], since both concepts are very similar, the Average Variance Extracted (AVE) is used, whose acceptable values are superior to 0.5[18].

The variance inflation factor (VIF) is used to know the collinearity levels between the variables, high levels indicate that some items may be redundant[15] values below 3.3 are accepted [18]. In addition, the predictive validity is analyzed by R^2, Adjusted-R^2 and Q^2, where Q^2 is a non-parametric measure [18].

3.5 Stage 5: Structural Equation Modeling

To test the hypotheses stated in Figure. 1, the structural equation modeling (SEM) technique is used, given its ability to simultaneously examine relationships between a set of variables and including measurement error [17]. The model is evaluated in the WarpPLS software that uses partial least squares algorithms (PLS) and it is recommended for small samples without normality [18].

The quality of the model is assessed using the average path coefficient (APC), average R-squared (ARS) and average block variance inflation factor (AVIF), proposed by Kock [18]. APC and ARS are acceptable when their p-values are less or equal to 0.05, whereas for the AVIF should be less or equal to 5 [18].

The relationships between the variables are analyzed by the effects, in that context, in this model there are three types: direct (direct relations between variables), indirect (relations with two or more variables) and totals (sum of both). For each relation, the p-value is estimated in order to know the statistical significance of the effects, being the null hypothesis $\beta = 0$, against the alternative hypothesis $\beta \neq 0$.

4 Results

4.1 Descriptive Analysis

As a result, 306 valid questionnaires were collected from maquiladora industry of Ciudad Juárez. The sector that showed the highest participation was automotive (31%), followed by electric/electronic (30.7%), other (medical, aeronautical, logistics, etc.) (17%), unspecified (14.7%), plastics (4.9%) and packaging (1.6%). According to the position of respondents, it should be noted that the highest participation was from engineers (35.9%) and technicians (24.2%).

4.2 Questionnaire Validation

As described before, the Cronbach's alpha index was used, for the procurement variable was 0.776, for inventory 0.866 and for ICT 0.915, since all values were higher than 0.7 it was not necessary to eliminate any of the items.

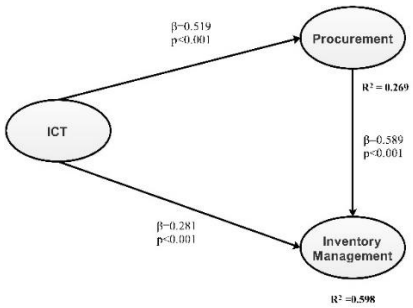

Fig. 2. Evaluated Model.

Table 1. Efficiency indexes.

Index	Criteria	Value
Average path coefficient (APC)	p<0.05	0.463, P<0.001
Average R-squared (ARS)	p<0.05	0.433, P<0.001
Average adjusted R-squared (AARS)	p<0.05	0.431, P<0.001
Average block VIF (AVIF)	Acceptable ≤ 5, Ideally ≤ 3.3	1.372
Average full collinearity VIF (AFVIF)	Acceptable ≤ 5, Ideally ≤ 3.3	2.072
Tenenhaus GoF (GoF)	Small ≥ 0.1, Medium ≥ 0.25, Large ≥ 0.36	0.520

Therefore, it is concluded that the questionnaire fulfills its objective and the information collected is valid and can be used for further analysis.

4.3 Structural Equation Modeling

Figure. 2 shows the generated model and the results obtained for the relations between the variables. The latent dependent variables show a value of R^2 allowing to establish the amount of variance explained by the independent variables. In the same way, their efficiency indices are shown in Table 1.

4.4 Direct Effects

Regarding the direct effects, the following conclusions can be established:

- **H_1**: There is enough statistical evidence to state that *Information and Communication Technologies* have a direct and positive impact on *Procurement*, since when the first variable increases its standard deviation by one unit, the standard deviation of the second latent variable also increases by 0.519 units.
- **H_2**: There is sufficient statistical evidence to point out that *Information and Communication Technologies* used along a supply chain have a direct and positive impact on the *Inventory*. When the first variable increases its standard deviation by one unit, then the standard deviation of the second latent variable increases by 0.281 units.

- **H_3**: There is necessary statistical evidence to declare that *Procurement has a direct and positive effect on the Inventory*, since when the first latent variable increases its standard deviation by one unit, the standard deviation of the second latent variable also rises by 0.589 units.

Table 2. Total effects.

To	From	
	ICT	Procurement
Inventory	0.586 (p<0.001) ES=0.344	0.589 (p<0.001) ES=0.433
Procurement	0.519 (p<0.001) ES=0.269	

4.5 Indirect and Total Effects

Figure 2 shows the unique indirect effect from *ICT* to Inventory through the mediating variable *Procurement.* Its value is 0.305 and the effect size is 0.179. Finally, all the total effects are significant, since their p-values are less than 0.001 as shown in Table 2.

5 Conclusions

In this work, a model that associates three latent variables: ICT, procurement and inventory management was presented. The relationship between variables sere tested using three hypotheses, which were not rejected since their p-values are less than 0.05, because the inferences are realized at 95% confidence level.

Based on the findings, it can be highlighted that choosing the appropriate procurement methods and strategies is crucial for supply chain management because many factors that can put at risk the proper functioning of the company depends of them such as demand, delivery times, raw material, etc. so directly affecting inventories level in companies. For example, if a supply strategy is not defined and the market needs are not identified, inventory levels would decrease or increase putting in danger the commitment and capital of the company.

According to hypotheses results, it is concluded that:

1. ICT is important for have an adequate raw materials procurement and inventory management.
2. Procurement has the highest effect on inventory management and managers must pay attention to this process.

References

1. Heikkurinen, M., Appleton, O., Urciuoli, L., Hintsa, J.: Federated ICT for global supply chains: It service management in cross-border trade. IFIP/IEEE

International Symposium on Integrated Network Management (IM 2013), pp. 27–31, pp 1268–1275 (2013)
2. Ouadaa, S. E., Bah, S., Berrado, A.: Survey on supply chain ICT requirements. 10th International Conference on Intelligent Systems: Theories and Applications (SITA), pp. 20-21 pp 1–7 (2015)
3. Samdantsoodol, A., Cang, S., Yu, H., Eardley, A.: Buyantsogt, A.: Predicting the relationships between virtual enterprises and agility in supply chains. Expert Systems with Applications, 84, pp. 58–73 (2017)
4. Mensah, P., Merkuryev, Y., Manak, S.: Developing a resilient supply chain strategy by exploiting ICT. Procedia Computer Science, 77, pp. 65–71 (2015)
5. Zhang, X., Liu, Y.: The impact of ICT on supplier-buyer relationship in different types of supply chain, International Conference on Wireless Communications, Networking and Mobile Computing, pp. 21–25, pp. 4694–4697 (2007)
6. Devaraj, S., Krajewski, L., Wei, J. C.: Impact of ebusiness technologies on operational performance: The role of production information integration in the supply chain. Journal of Operations Management, 25, pp. 1199–1216 (2007)
7. Oh, S., Ryu, Y. U., Yang, H.: Supply chain capabilities and information technology characteristics: Interaction effects on firm performance. 49th Hawaii International Conference on System Sciences (HICSS), 5(8), pp. 1417–1425 (2016)
8. Albors-Garrigós, J., Hervas-Oliver, J. L., Márquez, P.: Internet and mature industries. Its role in the creation of value in the supply chain. The case of tile ceramic manufacturers and distributors in spain. International Journal of Information Management 29, pp. 476–482 (2009)
9. Donk, D. P. V.: Challenges in relating supply chain management and information and communication technology: An introduction. International Journal of Operations & Production Management 28, pp. 308–312 (2008)
10. Suryaningrat, I. B.: Raw material procurement on agroindustrial supply chain management: A case survey of fruit processing industries in Indonesia. Agriculture and Agricultural Science Procedia, 9, pp. 253–257 (2016)
11. Candan, G., Yazgan, H. R.: A novel approach for inventory problem in the pharmaceutical supply chain. DARU Journal of Pharmaceutical Sciences, 24(4) (2016)
12. Kocaoglu, M., Oksuz, C., Akan, O. B.: Effect of channel conditions on inventory database update in supply chains, 2013 First International Black Sea Conference on Communications and Networking (BlackSeaCom), pp. 252–256 (2013)
13. Likert, R.: A technique for the measurement of attitudes. publisher not identified (1932)
14. Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E.: Multivariate data analysis: Pearson new international edition. Pearson Education Limited (2013)
15. Peng, D. X., Lai, F.: Using partial least squares in operations management research: A practical guideline and summary of past research. Journal of Operations Management, 30, pp. 467–480 (2012)
16. Cronbach, L. J.: Coefficient alpha and the internal structure of tests. Psychometrika, 16, pp. 297–334 (1951)
17. Sarstedt, M., Ringle, C. M., Smith, D., Reams, R., Hair, J. F.: Partial least squares structural equation modeling (pls-sem): A useful tool for family

business researchers. Journal of Family Business Strategy, 5, pp. 105–115 (2014)
18. Kock, N.: Warppls 5.0 user manual. ScriptWarp Systems (2015)