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Effect of AMT on Responsive Supply Chain Strategy, Pull System and Responsiveness to Market

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Abstract. This paper presents a model of structural equations in which four variables (advanced manufacturing technology, Pull system, responsiveness to market and, responsive supply chain strategy) are related using six hypotheses. The objective of the research is to measure the effect that occurs between these variables and identify the most important activities that have the greatest effect on the others. The model is statistically validated with information of 254 responses to a questionnaire applied in the manufacturing industry and the partial least squares technique is used. The results indicate that advanced manufacturing technologies indirectly help companies to be able to respond to changes in demand and allow them to offer a rapid response in the changing market through the implementation of a pull system.

Keywords: AMT, pull system, supply chain, responsiveness supply chain.

1 Introduction

With complex and globalized production systems, supply chains (SC) perform essential functions in coordination with various commercial entities and in connecting offer with demand. [1]. In addition, with the growing proliferation of products and shorter technology life cycles, time to market is critical to avoid obsolete inventories [2] and therefore, manufacturing companies must continually update their product offerings, while remaining competitive [3] in that sense, managers must adapt the characteristics of the SC [3].

To achieve the above and maintain or improve the competitive position of their companies, managers must continue to improve their operations [4] and resort to the implementation of advanced manufacturing technology (AMT) in their SC, which must be aligned with Product development decisions that must be designed at low cost and delivered in specific time and quality [3]. Thus, AMT facilitates the development of a successful long-term strategy of the SC with the client [5].

This strategy of the SC and AMT should be integrated into the production system and therefore, companies use pull systems, which support the administration of component inventories and their applications are varied. Fortunately, there are works in which these variables have been related; for example, Koufteros [6] has linked through a SEM the Pull system with preventive maintenance, where he analyzes the improvement of the setup as an independent variable and the reliability of delivery as a dependent variable. Also in Díaz-Reza, García-Alcaraz [7], AMTs have been related to the benefits that are obtained from their correct implementation within the production systems. The main problem is that these two tools have not been analyzed together and, in addition, have not been related to the strategy and speed of response of the supply chain. That is why, the aim of this research is to quantify, using a structural equation model, the effect of AMT on a pull system on the responsiveness of companies and their strategy in the supply chain within the industry of manufacturing. The rest of the article addresses the definitions for each of the variables, the methodology, the results and the conclusions.

2 Literature Review and Hypotheses

2.1 Advanced Manufacturing Technology (AMT)

Advanced manufacturing is understood as the use of modern technologies to deliver existing products and new products to the market, and also focuses on the improvement of design and manufacturing processes in all areas, along with the integration of information technology systems throughout the SC [8]. In manufacturing, technology is incorporated into products, in the physical processes by which they are manufactured and, increasingly, in the management systems that control all operations, which are traditionally known as AMT [9]. The benefits of AMT is that it helps improve cost, quality, flexibility and delivery times. [9]. AMT has operational, technical superiority and other intangible benefits, compared to traditional systems [10-12], such as: increased competitiveness, lower production cost, higher value for money, employment of fewer people, minimum inventories, product quality, flexibility, among others. In this investigation, AMT is evaluated by the following items, which are associated with the handling of materials and support the SC:

> *Automated parts loading/unloading, Automated guided vehicles, AGV´s and, Automated storage-retrieval systems, AS/RS.*

2.2 Responsive Supply Chain Strategy (RSCS)

The effective strategy SC refers to the process configuration of a supply network so that operation directly support corporate strategy. [13]. However, it is likely that the introduction of new products and services or the entry into new markets will be more successful if it is accompanied by innovative CS designs, innovative practices and technology enablement [14]. In this investigation, the supply chain strategy is evaluated with the following items:

Wider product range, Offer new products more frequently and, Offer more innovative products.

To achieve this, AMTs allow customers to absorb the options to create a new design and transform it into tangible products [15]. Therefore, the capabilities to achieve flexibility of products and processes contribute greatly to maintaining the competitive advantage among the companies that implement these technologies [16]. In that sense, the following hypothesis is established:

H_1: AMT has a direct and positive effect on responsive supply chain strategy.

2.3 Pull System

In a pull system, work in process (WIP) is extracted through down-demand operation instead of the traditional push approach. The efficiency of the pull system is due to the visible signals and the WIP limit [17]. Pull systems are evaluated by the following items:

Undertaking actions to implement pull production (e.g., reducing batches, setup times, using kanban systems, etc.) and, Planned effort to implement pull production (e.g. reducing batches, setup times, using kanban systems, etc.).

AMT favors the Pull system, since the main motivation to invest in this technology is to improve the competitiveness of the organization, such as responsiveness, quality and flexibility [18]. One of the benefits that AMT brings with it when implementing certain technologies is the flexibility to respond to changes in schedules and the combination of products [9], in that sense, the following hypothesis is posed:

H_2: AMT has a direct and positive effect on Pull system.

In addition, with Pull systems and managing the downstream flow, being closer to the market, it has the final authority over how many units to produce [19]. The general philosophy of pull systems is to produce as much as necessary and adapt to external changes faster than push systems and have less inventory accumulation [20]. In that sense, the following hypothesis can be raised:

H_3: Pull systema has a direct and poditive effect on Responsive SC strategy.

2.4 Responsiveness to Market

Responsiveness corresponds to "the ability to respond and adapt effectively over time based on the ability to" read "and understand the real signals of the market" [21].

It corresponds to the speed with which the tasks are performed in which key metrics are used such as order fulfillment, cycle time, delivery cycle time, among others. [22]. Responsiveness in manufacturing is considered as the main source for building responsiveness in the SC [23] and is valued by the following items:

> *Time to market; Delievery speed; Delievery dependability and, manufacturing lead time.*

Currently, AMTs play a fundamental role for the growth of industry and organization, since mass production can be achieved in customer demand in a short time. [24]. In addition, AMT are able to adapt to changes in the variety of products with a short delivery time, while maintaining efficiency and profitability [24]. Since AMT favors production, helps shorten production times and gives companies flexibility, in that sense, the following hypothesis is proposed:

> *H4: AMT has a direct and positive effect on Responsiveness to market.*

Pull-based manufacturing strives to synchronize production with real-time consumption, which increases on-time delivery performance, reduces shortages and reduces costly last-minute changes in orders [25]. A pull system reduces WIP, releases cash flow and space requirements that allow for expansion, quality and less cycle time [26]. Therefore, the following hypothesis can be raised:

> *H5: Pull system has a direct and positive effect on Responsive to market.*

The SC plays a crucial role during the execution of the efficient launch and subsequent product performance [27]. The impact of the SC on the development of new products and the introduction of products is important in areas such as; Fast product delivery to the market, ensuring sufficient inventory in the launch data and ensuring a flow of parts and components for the manufacture of new products [2]. The SC can improve the process of developing new products, reduces development costs and engineering changes, improves product quality and time to market [28]. In that sense, the following hypothesis can be established:H_6: Responsive supply chain has a direct and positive effect on Responsiveness to market. In Fig. 1 the proposed model, as well as the hypotheses, are presented graphically.

3 Methodology

To carry out this investigation, the following steps were carried out:

Step 1. Survey development. A literature review was made in databases such as sciencedirect, emeraldinsight, linkspringer, among others. The search was performed using the keywords; supply chain, supply chain strategy, advance manufacturing techcnology, supply chain responsiveness. The information collected was classified by latent variables according to their affinity. The preliminary questionnaire was submitted to an evaluation by judges. To answer each of the questions, a five-point Likert scale

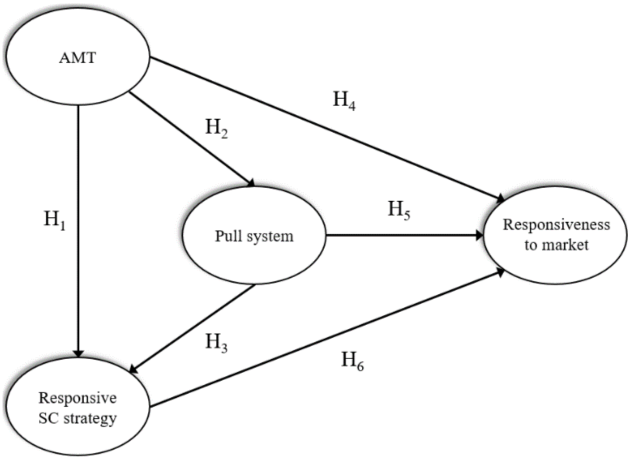

Fig. 1. Proposed model.

Table 1. Industrial sector vs position.

	Industrial sector							
Position	A	B	C	D	E	F	G	Total
Manager	3	0	0	0	0	0	2	5
Engineer	39	2	11	6	4	0	15	77
Supervisor	17	0	8	2	1	0	6	34
Technician	57	2	7	5	1	3	3	78
Operator	27	1	1	1	0	0	1	31
Total	143	5	27	14	6	3	27	225

A Automotive; B Aeronautics; C electric; D Electronics E logistics; F Machining; G Medical

was added where 1 means that the activity is never done and the 5 that the activity is always done.

Step 2. Administration of the questionnaire. The questionnaire is administered in the different sectors of the Mexican maquiladora industry; this was done through a stratified sample to identify the people involved in the activities of interest.

Step 3. Data screening. With the information collected in a database in the SPSS 21® software, a debug is performed to eliminate lost, extreme and unencumbered respondents.

Step 4. Validation of the questionnaire. latent variables are validated through the use of indices such as R^2, Adjusted R^2, composite reliability, Cronbach's alpha, average variance extracted, the inflation index of the variance and Q^2, these indices are proposed by Kock [29].

Step 5. Structural equation model (SEM). SEM is used to validate the hypotheses proposed in Figure 1 and the partial least squares technique integrated in WarpPLS 6.0® software is used, extensively to test relationships with ordinal data, without normality and small samples. The efficiency of the model is evaluated using the Average path coefficient (APC), Average R-squared (ARS), Average adjusted R-squared (AARS), Average block VIF (AVIF), Average full collinearity VIF (AFVIF) and Tenenhaus GoF indices (GoF).

Three effects between latent variables are estimated: direct effects that occur between an independent latent variable and a dependent latent variable and that in Fig. 1 are represented by arrows, the indirect effects that occur between an independent latent variable and a dependent variable a Through a mediating variable and (3) total effects, these are the sum of the previous two. The calculations are made with 95% confidence level and the null hypothesis H_0: $\beta = 0$ is tested vs the alternative hypothesis H_1: $\beta \neq 0$.

4 Results

4.1 Sample Description

254 valid questionnaires were analyzed. Table 1 illustrates that the sector that participated the most was the automotive industry with 143 and the most respondents had the position of technician with 78 participants, followed by engineers with 77. Note that of the 254 questionnaires analyzed, only 225 people gave demographic information.

4.2 Questionaire Validation

Table 2 shows the values of the indices to validate the latent variables and it can be concluded that the questionnaire has enough predictive validity from a parametric point of view since it has R-squared and adj R-squared values are high. Also, the latent variables have content validity, and the Cronbach composite reliability and alpha index are greater than 0.7. Also, the AVE is greater than 0.5 and it is concluded that there is sufficient convergent validity; in addition, there are no multicollinearity problems since the VIF values are less than 3.3 and finally, Q-squared is similar to R^2 and it is concluded that there is non-parametric predictive validity.

4.3 Structural Equation Modeling

Table 3 shows the quality and efficiency indices of the model presented in Fig. 1, it is observed that all the indices have acceptable values. According to the p values associated with the APC, ARS and AARS indices, it is concluded that the model has sufficient predictive validity, there are no collinearity problems and it fits the data, so it is analyzed.

Table 2. Latent variables coefficients.

	AMT	RSCS	Pull System	RtM
R-squared		0.560	0.363	0.718
Adj. R-squared		0.556	0.361	0.715
Comp. Rel	0.908	0.933	0.953	0.942
Conbrach alpha	0.846	0.893	0.901	0.918
AVE	0.768	0.823	0.910	0.802
Full collin VIF	1.730	2.353	3.271	3.224
Q-squared		0.547	0.361	0.705

Table 3. Model fit and quality indexes.

Index	Value	P-value	Index	Value
APC	0.387	< 0.001	AVIF	2.032
ARS	0.547	< 0.001	AFVIF	2.645
AARS	0.544	< 0.001	GoF	0.672

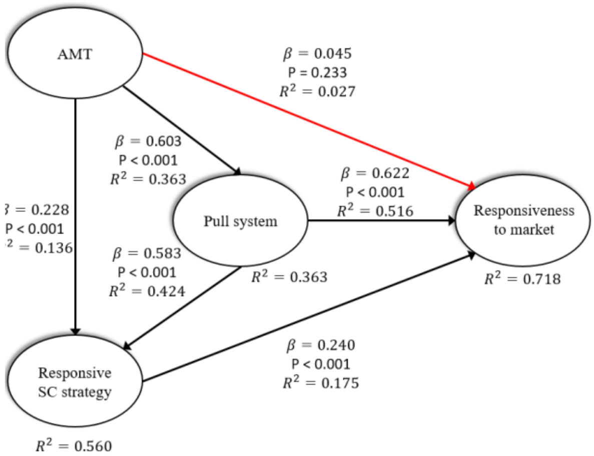

Fig. 2. Evaluated model.

The model evaluated is illustrated in Fig. 2. Based on the p-value associated with β, it is concluded that five hypotheses are statistically significant. For example, for H_1 it is concluded that AMTs have a direct and positive effect on Responsive SC strategy, since when the first variable increases its standard deviation by one unit, the second does so by 0.228 units.

In Fig. 2 a value of R2 is also observed in the dependent variables. For example, 0.718 of Responsive to market is explained in 0.175 by Responsive Supply Chain Strategy (RSCS), in 0.516 of Pull system and in 0.027 by AMT. With these results, it

Table 4. Sum of indirect effects

*ILV	+DLV	Beta	P-value	ES
AMT	RSCS	0.351	< 0.001	0.210
AMT	RtM	0.513	< 0.001	0.302
PS	RtM	0.140	< 0.001	0.116

*Independent latent variable; +Dependent latent variable

Table 5. Total effects

ILV	DLV	Beta	P-value	ES
AMT	RSCS	0.579	< 0.001	0.346
AMT	PS	0.603	< 0.001	0.363
AMT	RtM	0.559	< 0.001	0.329
PS	RSCS	0.583	< 0.001	0.424
PS	RtM	0.761	< 0.001	0.632
RSCS	RtM	0.240	< 0.001	0.175

can be concluded that the Pull system is the most important variable since it explains the 0.516 Responsivenes to market (RtM). Table 4 shows that there are three indirect effects among the variables and that all of them are statistically significant. Table 5 also illustrates the total effects and, all are statistically significant, even though a direct effect was not.

5 Conclusions and Industrial Implications

According to the values obtained in the evaluated model, as well as the variance values of each of the dependent latent variables, the following conclusions can be obtained:

— Regarding the values of the direct effects between the variables, it can be concluded that AMT has a direct effect on the Pull System and on the Responsive SC strategy, not so on Responsiveness to market, but indirectly through the Responsive SC strategy and through the Pull system.

— The results show that having a Pull System within a production system and using tools such as the kanban system, reducing batches and setup times help companies cope with sudden changes in the market, also help reduce manufacturing times and therefore, delivery times, but above all, that there is reliability in delivery. In that sense, managers must ensure that the Pull System runs correctly.

— The results also show that AMTs indirectly help companies to be able to respond effectively to offer a rapid response in the changing market through the implementation of a pull system.

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