ICT Validation Methodologies for Logistics Management

Jose Alejandro Cano[#1], Fernando Salazar[#2], Rodrigo Andrés Gómez-Montoya[#3]

[#1]*Universidad de Medellín, Medellín – Colombia*
[#2] *Pontificia Universidad Javeriana, Bogotá – Colombia*
[#3] *ESACS – Escuela Superior en Administración de Cadena de Suministro, Colombia. Politécnico Colombiano Jaime Isaza Cadavid, Medellín – Colombia*
Corresponding author: E-mail: jacano@udem.edu.co.
[2]salazar.fernando@javeriana.edu.co
[3]ragomez@elpoli.edu.co

Abstract- **This article aims to characterize the main methodologies for validating the implementation of ICT in logistics processes to support the decision-making process to select the ICT that best suits to logistics processes in a firm. For this, the characterization of models such as TAM, UTAUT, DART, DMAIC, AMEF, and QDF is presented. The study concludes that the implementation and appropriation of ICT in logistics processes requires adequate selection and validation, for which reference frameworks must be used to structure and design robust technological solutions according to the real problems faced by each firm, and that in turn, support decision-making on the selection of the most appropriate technologies generating the greatest benefit and low risks to logistics processes.**

Keywords; *Technologies, Logistics, Logistics 4.0, Supply chain management, ICT.*

1. Introduction

The supply chain has become a key element to increase the productivity and competitiveness of companies, offering benefits to suppliers and customers [10], because it represents the set of functional activities associated with the flow of products, services, information, finances, and transformation of goods from primary suppliers to the end-user, where raw materials are transformed into finished products by adding value [4].

Among the logistics processes in the supply chain, those related to purchasing processes, inbound transportation, quality control, demand planning, material handling, inventory control, production planning, scheduling, warehousing, distribution, and customer service can be mentioned; and all these activities must be performed sustainably and supported by information and communication technologies (ICT) to guarantee efficiency in the supply chain [17, 38].

To achieve the challenges faced by logistics in supply chains (increase competitiveness, optimize processes and resources), it is essential to implement a strategy based on the use of ICT [16]. The use of ICT in the supply chain has performed a significant role in improving the economic performance and integration of companies [25], especially through increasing the operations agility and the ease of sharing resources and information between and within the members of the supply chain [16]. Likewise, ICT can promote sustainable and ecological transportation of goods [15], and support reducing delays and tardiness in the logistics system [29].

According to [15], [12], [6], [28], [18], [17], and [41], there is a great diversity of ICT (more than 80 ICT), which can be applied to the different logistics processes of a single organization, representing a wide offer for a logistics managers who decide to implement these technologies to access the benefits they offer and that have been abovementioned.

This situation complicates the selection of technologies to be implemented in logistics processes and the prioritization of logistics processes for the implementation of ICT. In this sense, [13] emphasize the need to develop models to justify the investment and implementation of ICT in logistics processes to support the decision-making process.

2. Characterization of methods for the selection and validation of ICT

Selecting the ICT that best suits the logistics strategy of an organization continues representing a challenge and a complex problem for decision-makers because multiple variables are involved, and these decisions are critical for the future performance of the organization [27]. This is more relevant nowadays in the context of Logistics 4.0 that involves disruptive technologies such as IoT, Big Data Analytics, sensor networks, wearable technologies, among others, that must be integrated with conventional technologies existing in each company and generates a new paradigm that allows real-time information exchange and maximum visibility of the supply chain networks [19].

Accordingly, there are models such as the Technology Acceptance Model (TAM), the Unified Theory of Acceptance and Use of Technology (UTAUT), Dialogue-Access-Risk Assessment-Transparency (DART), Define-

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Measure-Analyze-Improve-Control (DMAIC), Failure Modes and Effects Analysis (FMEA), and Quality Function Deployment (QDF), which can identify the relevance of an ICT for a specific business process to define the needs of the process, the acceptance of the technology, and the future benefits obtained with its implementation. Consequently, as shown in Table 1, Table 2, Table 3, Table 4, Table 5, and Table 6, this study conducted a search process mainly in high impact databases such as Scopus, Web of Science, and Science Direct to characterize the TAM, UTAUT, DART, DMAIC, AMEF, and QDF, specifying for each method elements such as their definition and justification, variables and criteria, benefits and drawbacks.

Table 1. TAM

TAM	
Definition	**Variables**
Designed to explain the use of technologies and information systems in diverse environments, modeling how users accept and use a technological tool. It focuses on the behavior of individuals and the analysis of the beliefs and attitudes of the subjects, as well as their opportunities and resources. The TAM proposes two components of the behavioral intention based on perceived usefulness and perceived ease of use, which lead to the acceptance of technology and become the essence of the model.	Four variables determine the effective use of technology in the TAM: • Perceived usefulness: Degree in which a person estimates that the use of a particular system would improve his/her performance at work. • Perceived ease of use: Degree to which a person believes the use of a system is effortless. • Attitude towards use: Positive or negative feeling regarding performing a behavior (for example, using an information system). • Behavioral intention: Degree to which a person has formulated conscious plans to perform (or not) any future behavior.
Benefits	**Drawbacks**
• Effective and highly tested model for predicting the use of information and communications technologies. • Effective alternative to analyze the reasons that lead individual to adopt new technologies. • Simplicity, adaptability and theoretical strength. • Robust and influential model applied in numerous fields.	• Model dependent on external factors that can be diverse like cultural factors. • Lack of relationship among psychological, social, and contextual variables such as material access conditions or digital user skills.
Authors	
[5, 8, 9, 34, 40]	

Table 2. UTAUT

UTAUT	
Definition	**Variables**
It is a technology acceptance theory that explains why some people are more or less likely to adopt and use information technologies. It comes from the TAM and other related models to integrate the theory of reasoned action, the TAM, the motivation model, the planned behavior theory (PBT), the combination of TAM and PBT, the model of PC utilization, innovation diffusion theory and social cognitive theory.	• Performance expectancy: The degree to which an individual believes the use of the system will help him/her to obtain a benefit in work performance. It can be moderated by the age and gender of people. • Effort expectancy: The degree of ease of use associated with the system. It can be moderated by the age, gender, and experience of people. • Social influence: The degree to which an individual perceives that others will value the use of the system. It can be moderated by the age, gender, experience, and willingness of people to use. • Facilitating conditions: The degree to which an individual considers that an organizational and technical structure helps him to adopt the system.
Benefits	**Drawbacks**
• An effective tool to evaluate the success probability of the introduction of new technologies. • It helps to understand the acceptance factors during the proactive design of technologies, aimed at users less likely	• The limited application for some business areas, such as the health care. • Most of the studies performed by UTAUT have been within the same country, which leaves out culture as a technology acceptance criterion.

to adopt and use new systems. • It can be applied to a broad variety of technologies and information systems in various fields.	
Authors	
[20, 21, 23, 33, 40]	

technological service experience to adapt to their context and achieve sustainable performance in the market.	supply chain. • Discussing options openly gives customers a degree of control over the risks to assume but not necessarily over the responsibilities.
Authors	
[1, 23, 24, 31, 35, 37]	

Table 3. DART

DART	
Definition	**Variables**
Scheme for the co-creation of the customer with the technology supplier based on four interactions: dialogue, access, risk assessment, and transparency. These interactions simplify the experiences and values of such co-creation. Companies and customers exchange information about new products and services, and supplier companies must allow access to technological tools and communicate the benefits and potential risks of their proposals, increasing trust and active collaboration between them.	• Dialogue: Interactivity, communication and commitment between customers and suppliers, implies shared learning. • Access: Offer the customer adequate information and tools to participate in the processes of the technology supplier. • Risk assessment: Probability of harm to the consumer. The supplier must inform the customer about the risks they are facing. • Transparency: Renounce the asymmetry of information between the customer and the supplier.
Benefits	**Drawbacks**
• It allows technology providers to better involve customers as collaborators, facilitates dialogue with consumers, constant experimentation, and risk assessment on both sides. • It provides the developer with consumer expectations and experiences to improve trust. • The customer becomes part of the value creation process. • It allows the client to co-create a personalized	• The centrality in technology is underestimated in the model since it was created for generic products or services. • The deep dialogue with customers represents a time-consuming task and it is necessary to guarantee an intense interaction with each consumer. • It must be established correctly how much access should be allowed to customers upstream and downstream of the

Table 4. DMAIC

DMAIC	
Definition	**Variables**
A Six Sigma method focused on reducing variation and solving operational and design problems in manufacturing and services systems. It uses statistical tools and devices to observe the process variables and their relationships. It is employed to improve an existing business process through an iterative method that follows a structured and disciplined format based on the approach of a hypothesis, the performance of experiments, and its subsequent evaluation to confirm or reject the hypothesis previously raised.	• Define goals to improve the process, which are consistent with customer demands and the company strategy. • Measure the key aspects of the current process and obtain relevant data. • Analyze the data to verify cause and effect relationships. • Improve the process based on data analysis, using design-of-experiments techniques. • Check to ensure that any deviation from the target will be corrected before defects occur.
Benefits	**Drawbacks**
• Powerful statistical techniques for hypothesis verification. • It provides procedures for the effective integration of tools within a systematic framework.	• The generality of the method. • The identification of the causes of potential problems has no strategic orientation. • It does not use simulation and optimization tools to model complexity.
Authors	
[11, 26, 30]	

Table 5. AMEF

AMEF	
Definition	**Variables**
A risk analysis method for the reliability evaluation and the identification of effects of failures in systems, products or services. It determines the possible failure modes of technologies, assessing their causes, effects, frequency, and severity (impacts). AMEF assigns a risk-weighted number to the possible implementation of technology.	• Failure mode: How a component, subsystem or system could potentially stop performing the desired function. • Cause of failure: Weakness that can result in failure. • Failure effect: Result of a failure mode in the system function perceived by the user. • Hierarchy the system to be evaluated in system, subsystem, component, and failure mode.
Benefits	**Drawbacks**
• It provides additional data for the identification and prevention of failure modes in ICT projects. • It eliminates potential failure modes to generate savings in repair costs, repeated tests, and shutdowns. • Increases product quality perception and customer satisfaction. • Its application is common in processes requiring new technologies and maintenance prevention because AMEF usually has a design, manufacturing, installation, testing, and start-up component.	• Usually, the risk is quantified but not the actors contributing to it, so the risk priority can be misleading.
Authors	
[14, 22, 36]	

Table 6. QDF

AMEF	
Definition	**Variables**
A systematic procedure to define customer needs and translate them into product and process characteristics to obtain the best product development solutions.	Its deployment is based on the "House of Quality" (HOQ) that takes into account: • Customer needs • Customer priority level • Evaluation of competing products • Technical requirements of customers • Relationship matrix • Correlation matrix • Target value matrix
Benefits	**Drawbacks**
• It can transform the customer's needs into technical solutions to improve the performance of a process, covering all the development stages of a technology. • It can be utilized for the evaluation of technology suppliers in the supply chain.	• Information about individual judgments can be generated in multiple formats that may be alien to the knowledge of the individual. • The preferences generated can be difficult to assess consistently.
Authors	
[2, 3, 32, 42]	

According to the information from Table 1-6, there is a wide variety of methodologies used for ICT selection and validation for logistics management. From these methodologies, the TAM is very useful for understanding if the ICT is suitable or not for a logistics process, avoiding obstacles such as resistance to change, high acquisition and installation costs of technologies, and inadequate business process structuring in the implementation stage. Likewise, the TAM can be modified, adapted, and strengthened with additional elements to the perceived usefulness and ease of use through TAM2 and TAM3 models [39, 40]. Even, the TAM can evolve to the UTAUT, based on performance expectation variables, effort expectation, social influence and conditions facilitating the use of ICT, and moderating variables of gender, age, experience, and willingness to use ICT to unify a technology acceptance and use theory in business processes [20].

The DART allows co-creating technologies for logistics processes considering the needs, benefits, and risks expected by users, and in this process, variables analyzed directly in the TAM and UTAUT can be integrated to provide feedback on the ICT design, ensuring its success after a future implementation. On the other hand, the DMAIC methodology is usually utilized to support and verify the ICT appropriation and guarantees a successful ICT implementation in logistics processes, being a complement to selection and validation methodologies such as TAM, UTAUT, and DART, which allows taking these logistic processes to world-class levels.

As a proactive method, the AMEF allows identifying failure effects of the technologies to be implemented in

logistics processes, which becomes a significant input for the decision making of selecting logistics ICT and selecting suppliers to obtain these technologies to minimize the risk associated with the technological change. Likewise, the AMEF is usually complemented with other methods such as the QDF, responsible for supporting the creation of logistics process requirements, the evaluation of criteria, and even the selection of technologies; after using the QDF, the AMEF can analyze the risk associated with technology selection. The QDF shares with the DART the consideration of customers' needs to turn them into solutions through the functionalities and characteristics of the technologies to be developed, and both methodologies assess external factors affecting the future performance of logistics processes.
Therefore, to ensure a coherent implementation of ICT within logistics processes, especially under the framework of Logistics 4.0 that requires a vertiginous technological change in all industries, a support methodology must be available to structure and design high-quality and robust technological solutions. These solutions must be consistent with the real problems faced by each logistics process in each company. Thus, it is expected that the validation of ICTs to implement in each logistics process correspond to the usefulness, benefits, and ease of use perceived by the users, as well as to the minimization of the risk associated with the change in procedures, acquisition costs, infrastructure requirements, hardware, personnel training, among others, being clear that these analyzes must adjust to the logistical problems to be overcome in each firm [13, 7].

3. Conclusions

Based on the requirements for interaction and information management within the supply chains and Logistics 4.0 processes, it is found that ICTs have become a means to streamline, allow greater flexibility, and improve the exchange of information in the supply chain management. However, the success of the implementation and appropriation of ICT in logistics processes requires proper selection and validation. Consequently, this study presented methodologies like TAM, UTAUT, DART, DMAIC, AMEF, and QDF, which consider multiple variables and allow to adapt technologies to users' requirements, predict the success of the technology implementation according to user perceptions, predict the associated risks and modify the current processes to ensure ICTs become facilitators of value creation in logistics management.

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