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Key factors of international trade logistics chain of the Mexican Port: Analysis through artificial neural networks

Factores clave de la cadena logística del comercio exterior de un puerto mexicano: análisis a través de redes neuronales artificiales

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Abstract

Currently, international trade evolves showing different trends, such as the expansion of global value chains that have been reinforced to be more efficient achieving integrated into the world economy with lower costs; thanks to technological advances and improved organizational processes increasing product competitiveness in world markets. The objective of this study is to identify the main elements of five key factors in the logistics chain foreign trade port of Lazaro Cardenas and calculate the predicted value for each factor identifying areas of opportunity and propose improvements and adjustments. The methodological tool used are artificial neural networks (ANN) through the Multilayer Perceptron processing. The results show that the five variables are highly significant stressing that the office had the lowest weighting thus showing the need for improvement of customs processes in the port, to make it more efficient.

JEL Codes: C00, F13, F23, H11.

Keywords: Artificial Neural Network (ANN); Supply chain; International trade; Customs; Cost; Time; Storage and transportation.

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Resumen

Actualmente, el comercio internacional evoluciona, mostrando una mayor expansión de las cadenas de valor mundiales, que se han reforzado logrando ser más eficientes integrándose a la economía mundial con costos más bajos; gracias a los avances tecnológicos y la mejora de los procesos organizacionales, se ha aumentado la competitividad de los productos en los mercados mundiales. El objetivo de este trabajo es identificar los principales elementos de cinco factores clave de la cadena logística del comercio exterior del puerto de Lázaro Cárdenas y calcular el valor pronosticado para cada factor, identificando las áreas de oportunidad y proponer mejoras y adecuaciones. Para lo cual se utiliza la metodología de redes neuronales artificiales (RNA) a través del procesamiento perceptrón multicapa. Los resultados muestran la existencia de cinco variables, las cuales son altamente significativas, destacando de entre ellas la aduana que, obtuvo la ponderación más baja, lo que indica la necesidad de mejora de los procesos aduanales en el puerto, para hacerlo más eficiente.

Códigos JEL: C00, F13, F23, H1.
Palabras clave: Redes neuronales artificiales (RNA); Cadena logística; Comercio internacional; Aduanas; Costos; Tiempo; Almacenaje y transporte.

Introduction

Some of the characteristics of the global economy are constituted by technological advances, as well as by the existence of consumers with an ever-increasing offer of products at their disposal. This means that modern supply chains face great challenges in order to achieve sustained growth and maintain their competitive advantage positions. Due to the above, there is constant pressure in the markets to reduce costs and improve the quality of services provided, hence the growing importance of continuous improvement in the logistics chain as a key factor for the competitiveness of companies.

The concept of a logistics chain in international trade implies the incorporation of the different parts or links that comprise the marketing process, within which the following are identified, among the most important: infrastructure, transport services, warehousing, information technologies used, the different logistics processes inherent to cargo movements, as well as the official procedures required. All these links operate between the nodes of origin and destination of the chain, propitiating the connectivity of foreign trade, which includes intermediate points in the logistic corridor.

Thus, the importance of analyzing the main elements that comprise the logistics chain of international trade in order to see the variables that are the most important within the logistics system. For this reason, the objective of this research is to identify the main factors: customs, costs, time, warehousing, and transport, inherent to the logistics chain of foreign trade of the port of Lázaro Cárdenas, as well as determine the predicted value for each of these factors, in order to demarcate the areas of opportunity in each case and propose improvements and adjustments for greater future efficiency.

It should be noted that the port of Lázaro Cárdenas was selected as an object of study because of the great importance it has for Mexico in foreign trade, along with the port of Manzanillo, Colima. Indeed, the port registers a strong public and private investment, which currently places it as a port with avant-garde infrastructure in constant expansion. In addition, it should be noted

that the Mexican ports that connect with Asia will become more important given their strategic position in relation to the ports of greatest productivity in the world (WTO, 2017).

This research is divided into six sections. The first corresponds to the introduction; the second presents the antecedents of the port of Lázaro Cárdenas and its logistics chain; the third section deals with the methodology with which the analysis will be carried out in order to achieve the objective of the investigation; the fourth section presents the results derived from the application of the methodological tool; the fifth section presents the forecasts by variable; and the final section consists of the conclusions of the investigation.

Background: the port of Lázaro Cárdenas and its logistics chain

Currently, most international trade is carried out through maritime transport (WTO, 2015; 2017), so that ports nowadays are the main nodes in world trade. Although in previous years it was a means of transport that lost its strength in trade, in the last 20 years it has been recovering ground, largely due to the great technological advances present in the ports as well as in the new generation of ships and, in general, the entire logistics system involved (CNUCYD, 2017).

Numerous studies confirm the importance of connectivity and logistics performance as decisive factors in the competitiveness of foreign trade, by helping reduce the costs of international trade (Fugazza and Hoffman, 2017; Wilmsmeier *et al*., 2017; and Hoffmann et al., 2017). In the case of ships, it should be noted that they have been adapting to market demands in addition to their great advantages, such as the low cost and large capacity of cargo ships. Thus, it has proved to be a fairly efficient means of transport that can connect very distant points at low costs with respect to their cargo capacity, both in volume and tonnage. Currently there are different types of cargo vessels ranging from specialized ships to large container ships with virtually all types of goods.

For their part, ports have also been playing a very important role in foreign trade and, thanks to the use of cutting-edge technology and infrastructure in port facilities, it is now possible to have greater connectivity between the maritime and land environment, which allows an increasing flow in intermodal transport (SCT, 2013). For logistical purposes, ports can be divided into three types, depending on the area in which they are located: the maritime or access area, the land for maneuvers, and the link with land means (road and rail).

The maritime zone, as its name indicates, allows the entrance of the different vessels that arrive at the port, through a main access channel, the back-water turn[1] dock[2], and the secondary channels to their various docking positions. Its capacity is limited, on the one hand, to the width of the channels and the diameter of the dock, as well as to the minimum depth of its waters, which is known as the draft. This being one of the competitive advantages of the port of Lázaro Cárdenas—since its navigation areas of up to 18 ml (59 ft) for vessels of great draught and displacement capacity of 170,000 t—, gives it great advantage over other ports. (SCT, 2017).

The land area consists mainly of the quays located in the different terminals of each commercial port, based on the vocation of the different types of goods (bulk, liquid, vehicles, general cargo, refrigerated, and containers, among others) and the equipment available to carry out the loading and unloading maneuvers of the vessels.

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[1] It is the maneuver that aims to make a boat rotate or turn around in the smallest possible space.

[2] It is the artificially protected part, in navigable waters, for the emergence or for the comfortable loading and unloading of boats.

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Currently, the land area of the port of Lázaro Cárdenas consists of a Phytosanitary inspection point and twelve terminals: grain terminal, two terminals for bulk minerals and steel products, three multipurpose terminals, two container terminals, metal and mineral terminal, oil fluids terminal, coal terminal, fertilizer terminal, and ship dismantling and fluid handling terminal (APM, 2018).

As far as the link zone is concerned, there are the areas and facilities that allow access, circulation, parking, and operation of the modes of land cargo transport, as well as those intended for the storage and transfer of goods operated, both import and export, such as customs recognition circuits, bonded warehouses, and the offices of the various authorities, services, and private actors operating within the port area.

In turn, ports are divided into two categories according to the type of traffic they receive: high-altitude ports, which receive international flows, and cabotage ports, which only receive national flows. Mexico has 11,500 km of coastline, around 117 port facilities of different types and vocations (see Figure 1), among which are ports for shelter, commercial, industrial, oil, fishing, tourism, and for military and national security purposes (SCT, 2013).

Figure 1. National Port System
Source: SCT, 2012.

Currently, in terms of commercial port facilities, the most relevant in the country are the ports of Manzanillo and Lazaro Cardenas on the Pacific coast, and those of Veracruz and Altamira on the coast of the Gulf of Mexico.

The port of Lázaro Cárdenas is 18.00 meters deep in its access channel and 16.50 meters deep in the main back-water turn dock. Additionally, it is protected to receive boats of up to 165 thousand tons of displacement. This makes it, as mentioned above, a unique port in its class for its large capacity to receive deep draught vessels.

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Another feature that allows to talk about connectivity and competitiveness in logistics services is the time factor, so it is important to highlight the distance from the port of Lázaro Cárdenas both within the Mexican Republic and the different international ports with which it communicates. As can be seen in Table 1, the port of Lázaro Cárdenas is a strategic point between different points of the republic, where the connection with Mexico City, Monterrey, San Luis Potosí, and Altamira stands out.

Table 1.
Distance from the Port of Lázaro Cárdenas to the interior of Mexico.

City	Intermodal and Multimodal Point	Distance (km)	Approx. time (hours.)	Train	Possibility to clear customs
Mexico City	Terminal Intermodal Pantaco (Ferrovalle)	863	42	KSC	YES
Cuautitlán, State of Mexico	Terminal Contrimodal, S.A. de C.V.	863	42	KSC	YES
Monterrey	Terminal Intermodal KSC de México	1292	64	KSC	YES
Guadalajara	Terminal de carga intermodal de Guadalajara (TCIG)	896	66	KSC-Ferromex	YES
Querétaro	Servicios Integrales y Desarrollo GMG (SID)	617	40	KSC	YES
Veracruz	Internacional de Contenedores Asociados de Veracruz. S.A.	1303	64	KSC	YES
San Luis Potosí	Terminal Intermodal de carga KSC de México	792	44	KSC	YES
Altamira	Altamira Terminal Intermodal, S.A. de C.V.	1266	64	KSC-Ferromex	YES
Toluca	Terminal Maclovio Herrera (KSC de México)	897	48	KSC	NO
Laredo	Terminal de KSC de México, Laredo	1558	94	KSC	YES

Source: SCT, 2016.

Concerning connectivity with other countries, it should be noted that within the port there are several shipping lines, among them Maersk Line, APL, HAPAG-LLOYD, which connect the port with North America, Central America, South America, and Asia.

Methodology

Artificial neural networks (ANNs) are a mathematical representation, inspired by the human brain, based on the information processing system, as well as the systemic structure that follows the flow of information. It can be affirmed, from a mathematical point of view, that it is a non-linear tool for the optimization of information. According to Freman and Skapura (1993), it is a system of parallel processors connected to each other in the form of a directed graph. Schematically, each processing element (neurons) of the network is represented as a node. The development of the ANN technique makes it possible to learn, recognize, and apply relationships between objects and frames of real-world objects (Sotolongo and Guzmán, 2001).

The simple ANN technique consists of adding the values of the inputs it receives from other units connected to it, the values are compared with the threshold value and, if it equals

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or surpasses it, it sends an activation or output to the units to which it is connected. Both the inputs that the unit receives and the outputs it sends depend in turn on the weight or force of the connections through which these operations are carried out. Therefore, the technique also allows seeing the weight, connection force, or degree of importance between the variables analyzed and the dependent variable (Figueredo and Ballesteros, 2016).

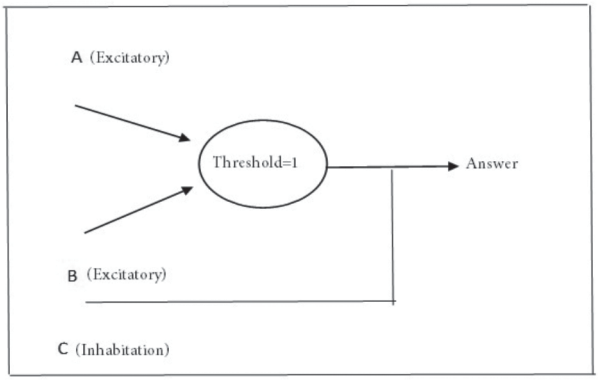

Figure 2. McCulloch-Pitts neuron.
Source: Montaño (2012).

The difference between neural networks and other traditional statistical methods, such as linear regression, is that while linear regression starts from a rigid model data structure and a set of assumptions that must be imposed before data modeling, ANNs form relationships between variables during data processing in such a way that, if the dependent variable relationship and independent variable(s) is adequate, ANNs will show a result according to the linear regression, but if it is not so, ANNs will show the "correct" model association or structure.

Some advantages of ANN application include: the ability to learn to perform tasks based on initial experience and training; easy insertion into existing technology; the ability to perform operations in parallel; and self-organization of the network through learning processes.

Another important characteristic of this technique is that it does not presuppose a pre-programming of the system, hence the behavior of the system is free so that the variables interact according to their own connections; likewise, the technique does not follow a sequential processing, since the processing is carried out in parallel (Montaño, 2002).

Structure of an ANN

Artificial neural networks are formed by a large number of neurons, these are not usually called artificial neurons but nodes or output units. A node or neuron has a variable number of inputs that come from outside (X1, X2, ..., Xm). At the same time, it has only one output (Xj) which will transmit the information to the outside or to other neurons. Each Xj or output signal has a magnitude associated with it called weight. This will be calculated as a function of the inputs, so that each of them is affected by a certain weight (Wjo...Wjq+m). The process followed by the model consists of finding the weight of each of the variables and the interrelations that are generated and that codify the knowledge. By connecting several neurons in a certain way,

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a network is obtained. There are variations of topology, which are classified according to three criteria (Sotolongo and Suárez, 2000):

1) Number of levels or layers.
2) Number of neurons per level.
3) Forms of connection.

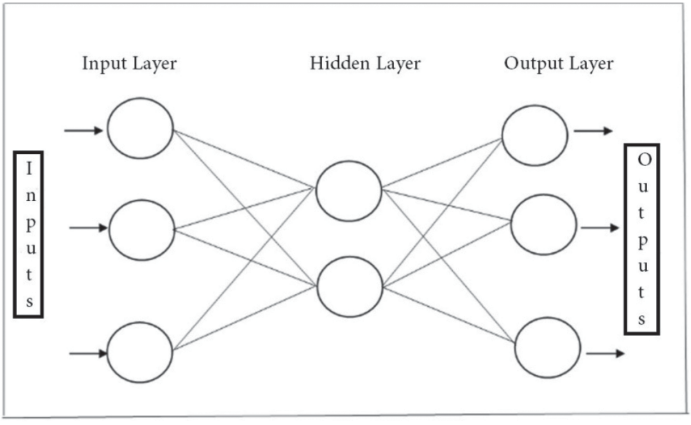

Figure 3. Architecture of a multilayer perceptron.
Source: Montaño (2012).

There are several techniques within ANNs modeling, such as multilayer perceptron and radial basis function. Multilayer perceptron processing (MLP) as well as the radial basis function (RBF) generate a predictive model for one or more dependent or target variables based on the values of the predictive variables. However, MLCs allow more complex relationships with the possible cost of increasing training time and score. The RBF can have lower training times and scores, with the possible cost of reduced predictive power compared to MLC, so the selection between one type of model and another lies largely in the volume of information, as well as on the variables of the model.

Multilayer perceptron processing (MLP) also known as the backpropagation algorithm is an extension of the rule proposed by Widrow and Hoff in 1960 (delta rule), which aims to propagate errors made by output units backwards, since, in a system of this type, the error made by an intermediate unit depends on the error made by the output units to which the intermediate unit is connected (Rodríguez and Turias, 2016). Once the error made by the intermediate units is known, the connections between input units and intermediate units can then be modified. Similar to the delta rule, the mathematical basis of the backpropagation algorithm is the decreasing gradient technique, based on modifying the weights in the opposite direction to the gradient[3], that is, ∂Ep /∂w ij, in the direction that determines the fastest decrease of the error (Montaño, 2002).

[3] Variación de una magnitud en función de la distancia, a partir de la línea en que esta variación es máxima en las magnitudes cuyo valor es distinto en los diversos puntos de una región del espacio.

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Selection of variables

According to the World Bank (2014) and the World Trade Organization (2015) 5 factors can be identified that are critically important for production chains, such factors exist in the planning of all production chains but are relatively more dominant in terms of combinations and extension in a global context. These factors are: warehousing, transport, customs administration, costs, and time. Each of these factors is described below, which in the case of this research will act as variables:

a. *Customs Administration*. Customs are government agencies strategically located at the points of entry and exit of a country. Their main functions are to allow the flow of goods according to the corresponding fiscal regulations, as well as to safeguard national security. Good customs administration ensures that effective controls are in place to ensure revenue collection, compliance with legislation and national security, as well as the smooth movement of goods. The effectiveness and efficiency of customs procedures have a considerable influence on the economic competitiveness of countries, the growth of international trade, and thus on the development of the world market.

b. *Warehousing*. Warehouses or Warehousing are spaces close to customs, which have the function of guarding and the ability to store and handle goods, thereby optimizing the transfer of the same to the points of stowage or transportation.

c. *Times*. Notwithstanding the distances and the uncertainty of some phenomena susceptible to happen in the transfer of the goods from one place to another, nowadays in light of the great competition between products and the increasing demand of the consumers, the time factor plays a fundamental role since the punctual delivery in a determined place and time can make the difference between a product considered internationally competitive and the loss of that competitiveness.

d. *Transport*. This factor refers to the transfer of merchandise from one point to another; the types of transportation according to Mexican customs law are: maritime and fluvial, ferrous, road, air, cables, and ducts. However, in matters of foreign trade, the term multimodal transport is also used, i.e. the use of different types of transport within the logistic system, in order to bring the merchandise to the point agreed to with the client in a more efficient manner, thus reducing time and costs.

e. *Costs*. In any trade system, cost has to be a key factor in the determination of competitiveness; therefore, the additional monetary amounts to the production of the product related to logistics services should not be high, since these will impact on the final price of the product.

Once the five main variables had been explained, information was collected for them. The collection was made from direct sources of information, through interviews and structured questionnaires applied to 68 companies specialized in the area, which, according to the company, type of company, area of development and function, provided the necessary information to have a wide vision regarding the analyzed variables. Table 1 summarizes the basic information collected from the surveys applied to the specialists of these companies. It should be noted that the network entry variables were determined by means of an autoregressive model.

Table 2.
Experts in the field of international trade who were interviewed

Compañía	Type of company	Area	Number of respondents	Role
LC Logistics GPS	Audited premise	Commercial	10	Search for potential customers, sales, customer service
LCTPC	Audited premise	Commercial	16	Search for potential customers, sales, customer service
Mitsui Co.	Distribution company of steel sheets	Traffic and logistics	3	Logistics Coordinator
Steel Technologies de México	Manufacture and sale of steel plates	Traffic and logistics	2	Logistics Coordinator
Hanwa Steel Service	Distribution company of steel sheets	Traffic and logistics	2	Logistics Coordinator
Eurotranciatura	Producer of electrical sheets of steel	Traffic and logistics	2	Logistics Coordinator
Nippon Express	Company specialized in Global	Traffic and logistics	2	Logistics Coordinator
V Modal Mexicana	Intermodal Logistics and Rail Transport Services		3	Traffic and Customs
Servilamina Summit Mexicana	Distribution of steel sheets	Logistics and traffic	2	Logistics Coordinator
Polímeros Mexicanos	Polymer Exporter	Head of exports	3	Export logistics, necessary formalities
Nicometal Mexicana	Producer of steel sheets	Traffic and logistics	3	Logistics coordinator
Ulises Anaximandro	Triplay Importer	General management	1	Supervise and approve all processes within the company
Nicometal Hidalgo	Producer of steel sheets	Traffic and logistics	3	Logistics coordinator
Oñate Willy y Cía.	Customs Agency	Head of traffic	2	Ensure that all dispatches leave in a timely manner
Visa Logística	Customs Agency	Dispatch	1	Comply with the necessary formalities for the clearance of goods
Agencias Aduanales Padilla	Customs Agency	Traffic Executive	2	Manage all the formalities for the clearance of goods
Agencia Aduanal CONIA	Customs Agency	Traffic Executive	2	Manage all the formalities for the clearance of goods
Muris Salinas Consultores	Customs Agency	Exports executive	3	Manage all formalities for the export of goods
Valdez & Woodward	Customs Agency	Head of operations / Traffic	2	Review and compliance with established rules and processes
Logística Corporativa en Comercio Exterior	Customs Agency	Traffic executive	2	Manage all the formalities for the clearance of goods
Luis Hoyo	Customs Agency	Traffic	2	Manage all the formalities for the clearance of goods

Source: own elaboration based on the interviews and surveys applied to the companies

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Results

The results obtained through the ANN method were divided into two parts in order to have a clearer view of them. In the first part, the satisfaction forecast by variable was analyzed considering five possible answers, said forecast is presented in the ROC curve aided by the area percentages below the obtained curve. In the second part, the importance analysis is presented according to the networks of each of the independent variables regarding the dependent variable analyzed, for which the five phases of the aforementioned logistic system were analyzed; it is worth adding that each one was considered as an independent variable regarding the indicators of the same.

For all variables analyzed, the network architecture was feedforward, in other words, network connections flowed unidirectionally from the input layer to the output layer, without feedback cycles, in a three-layer structure: input, hidden, and output. It should be remembered that the values of the input layer were of the ordinal type, because they are extracted from a questionnaire where the answer values represent five categories for each question. In order to obtain better results, the data were run in two sets of active data corresponding to the training sample and the test sample.

The training sample comprises the data records used to train the neural network, introducing a certain percentage of cases from the data set that must be assigned to the training sample in order to obtain a model. The test sample is an independent set of data records that is used to track errors during training. Both tests can be seen in the annex.

Concerning the hidden layers, each model showed only one layer whose activation function was of the hyperbolic tangent type, $\gamma(c)=\tanh(c)=(e^{c}-e^{-c})/(e^{c}+e^{-c})$, which allows to transform the arguments in ranges that oscillate in numeric values from -1 to +1. Finally, for the output layer the function of identity activation was used, this function has the following form: $\gamma(c)= c$. From these analyses a susceptibility analysis is derived, which calculates the importance of each predictor in the determination of the neural network. The analysis is based on the combined training and testing samples. Thus, a table and graph are created showing the normalized importance of each predictor.

Satisfaction forecasts by variable

The ROC (Receiver Operating Characteristic) curve provides a visual representation of susceptibility and specificity for all possible cuts in a single graph, which is much cleaner and more powerful than a series of tables. The graph is the representation of the true positive ratios (TPR= True Positive Ratio) against the false positive rate (FPR = False Positive Ratio). As well as representing the discrimination threshold (value from which it is decided if a case is positive), thus the graph shows different categories with respect to a 45-degree line, which goes from the upper left corner of the graph to the lower right corner (Fogarty, Baker & Hudson, 2005).

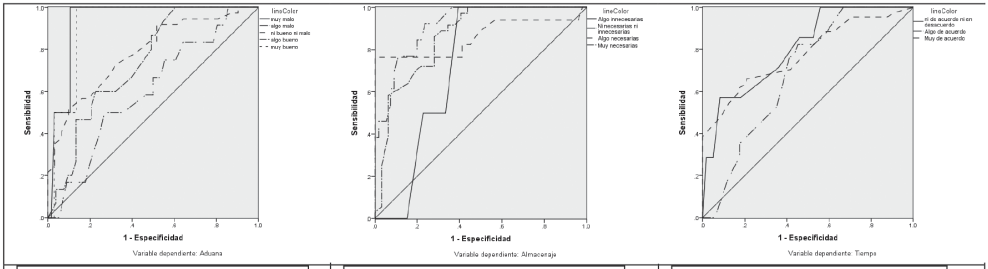
It should be noted that the graph is based on the combined test and training samples. On the other hand, the area under the curve is a numerical summary of the ROC curve, and the values in the table represent, for each category, the probability that the predicted pseudo-probability of being in that category is greater for a randomly chosen case in that category than for a randomly chosen case that does not belong to that category.

As can be observed, the predicted values for the variables of customs, warehousing, and time are presented in Figure 4. The categories for the forecast are five for all cases; however,

some categories did not have a value above zero, so they are not represented in the graph, which means that their predicted value of it happening is zero.

In the case of the customs variable, it is observed that the predicted probability regarding the quality of service according to the ROC curve and the area under the curve varies from "very bad" (0.936) to "neither good nor bad" (0.784), which allows glimpsing a low degree of satisfaction of the service provided by customs.

On the other hand, the storage service is considered as something mostly necessary, since the highest ranges found in the forecast according to the area under the curve range from "very necessary" (0.862) to "neither necessary nor unnecessary" (0.915). In the case of the time variable, according to the model, it is perceived as a fundamental since the predicted value for "somewhat in disagreement" and "not at all in agreement" is zero, in addition to the fact that the highest values are within the options "somewhat in agreement" (0.887) and "very much in agreement" (0.777) (see Figure 4).



Area under the curve

		Area
Customs	Very bad	.936
	Slightly bad	.603
	Neither good nor bad	.784
	Slightly good	.438
	Very good	.417

Area under the curve

		Area
Warehousing	Slightly unnecessary	.623
	Neither necessary nor unnecessary	.915
	Slightly necessary	.860
	Very necessary	.862

Area under the curve

		Area
Time	Neither agree nor disagree	.604
	Slightly agree	.887
	Strongly agree	.777

Figure 4. Forecast of satisfaction by variable for the variables: Customs, Warehousing and Time, ROC curve. Source: own elaboration based on neural networks, multilayer perceptron.

The results with respect to the satisfaction of the transport variable reflect an average to higher satisfaction with the service, since the area under the curve goes from "neither agree nor disagree" (0.665) to "strongly agree" (0.502). Finally, the predicted value for the cost of logistics services is somewhat variable, as almost all options range from (0.604 to 0.799) except for the "very cheap" option (see Figure 5).

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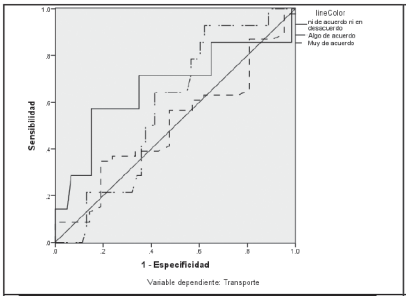

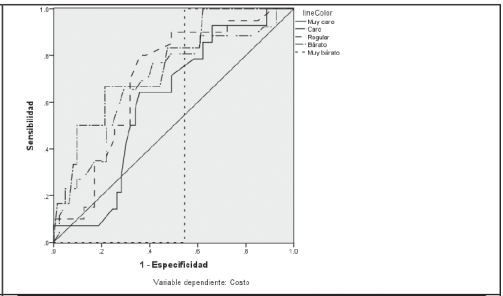

Area under the curve

		Area
Transport	Neither agree nor disagree	.665
	Slightly agree	.580
	Strongly agree	.502

Area under the curve

		Area
Cost	Very expensive	.604
	Expensive	.689
	Regular	.799
	Cheap	.655
	Very cheap	.455

Figure 5. Satisfaction forecast by variable for the variables: Transport and Cost, ROC curve.
Source: own elaboration based on neural networks, multilayer perceptron.

Importance of the independent variables

Once the dependent variables have been analyzed from the perspective of their importance and predicted degree of satisfaction, the results are presented for each of the variables (warehousing, transportation, customs administration, costs, and time) with respect to their independent variables. This is done with the purpose of determining which independent variables are more important regarding the dependent variable analyzed.

The independent variables, for each dependent variable analyzed and that passed Pearson's correlation test, are the variables presented in Table 2. Although it is known that there is a correlation between the parts, the degree of importance of the same is not known, so Table 2 shows the degree of importance of each variable after a process of normalization of the data to improve the understanding and analysis of the results.

For ANN methodology, the importance of an independent variable is a measure that indicates how much the predicted value changes (by the network model) for different values of the independent variable. Whereas, normalized importance is the result of importance values divided by major importance values expressed as percentages.

There are three independent variables concerning the customs dependent variable: government support, regulations, and customs clearance time. Where the most important, according to the methodology used are: government support, with 100 percent importance; followed by customs clearance time, with 89.7 percent importance; and the number of foreign trade regulations, with 46.3 percent importance.

It is clear that, from the perspective of specialists and theoreticians in international economics, the government plays a fundamental role in foreign trade. The reduction of tariffs and of other commercial instruments that has been occurring in recent years, as well as the facilitation of procedures in the customs administration, directly affects the efficient perception of the work of customs. On the other hand, the time factor in the customs clearance process—particularly when the random system that is part of the customs clearance requires an inspection—is vital

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for the efficiency of the logistics system of any product that seeks to compete in foreign trade; hence, different countries, including Mexico, have oriented their customs to electronic systems, seeking to streamline and digitize procedures.

Regarding the variable of regulations, despite it being an important variable, its importance was minor in the model; this can be explained by the increasing consumer demand that forces companies to improve their quality standards, complying beforehand with many of the regulations revised in the passage through customs.

In the case of the dependent variable warehousing, the most important variable is the handling of the goods—with 100 percent importance—which is consistent because a good handling of the goods ensures the arrival of the same in the best possible conditions. It is important to point out that the handling of merchandise in the warehouse includes activities such as: transfers within the warehouse, loading and unloading, an inventory control system, pest control, and adequate environmental conditions, among other activities.

The independent variable that follows in importance is the equipment, with 56.7 percent; this means that the warehouse must have the necessary equipment to carry out foreign trade transactions, such as distribution equipment to move goods and deliver products, packaging equipment, among others. The location variable received 34.4 percent of importance, showing that it is something to consider but not as significant as the aspects mentioned above, which implies that a warehouse that has excellent management and the necessary equipment, despite being far away, will be preferred when selecting the logistics service to hire.

Finally, the specialization variable of the warehouses received 28.5 percent of importance, which implies that a large part of the users does not need specialized services for very specific or particularly technological products. This can be explained by the fact that the port of Lázaro Cárdenas receives very varied merchandise, unlike some customs offices with specialized foreign trade.

Concerning the time variable, two independent variables are considered: duration of the transfer and compliance with the established deadlines. Indeed, the duration of the transfer can be a variable of great significance depending on the type of product or merchandise being transported. A clear example of this can be the urgency of moving perishable products before the process of decomposition of these begins. However, the perceived degree of importance was 27.2 percent according to the results obtained. This result is largely explained by the specificity of the products in question as already mentioned. Meanwhile, the variable compliance with established deadlines obtained a degree of importance of 100 percent, thus reflecting that it is a key factor in the competitiveness of logistics services in order to comply with previously agreed service times.

The independent variables considered regarding the transport variable were: number of units, fiscal routes, consolidation of shipments, knowledge regarding the selected transport, and types of transport available.

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Table 3.
Importance of the independent variable

Dependent variable Customs		Dependent variable Warehousing		Dependent variable Time		Dependent variable Transport		Dependent variable Cost	
Independent variables	Standardized Importance	Independent variables	Standardized Importance	Independent variables	Standardized Importance	Independent variables	Standardized Importance	Independent variables	Standardized Importance
Dispatch time	89.70%	Handling	100.00%	Duration	27.20%	Units	50.00%	Type of logistics services	100.00%
Regulations	46.30%	Specialization	28.50%	Compliance	100.00%	Routes	100.00%	Cost/volume ratio in import and export	46.20%
Government aid	100.00%	Location	34.40%			Consolidation of shipments	44.70%	Quality of the services	36.30%
		Equipment	56.70%			Bill of lading	44.60%	Prices	83.40%
						Type of transport	41.30%		

Source: own elaboration based on neural networks, multilayer perceptron.

Except for the variable of fiscal routes, which showed 100 percent importance, all selected variables showed a medium level of importance, with values ranging from 50 percent (number of units) to 41.3 percent (types of transport), showing a relatively important but at the same time uniform range. As for the variable of fiscal routes, considered as the most important variable of this item according to the results, it denotes the need for alternatives that connect the port of Lázaro Cárdenas with the rest of the world, not only by sea but also with the intensification of rail routes, road fiscal routes, and air connections.

It is important to note that for the variable of costs of logistics services, independent variables were considered. In order of importance: types of logistics services that obtained an importance value of 100 percent, which reiterates that the cost must be intimately related to the services offered; quality of services, with 96.3 percent importance, which implies that service users are willing to pay a higher cost as long as service standards are also high.

On the other hand, the cost-volume relation in import and export showed a degree of importance of 46.2 percent, which indicates that the volume-cost relation is important, but not determinant; it should be noted that, depending on the merchandise to commercialize, the cost can be determined by the weight or even value of the merchandise instead of the volume.

Conclusions

According to the results obtained in the investigation, it can be concluded that the forecast for the analyzed variables, warehousing and time, is very satisfactory, since the results oscillate from the mean upwards, with a strong weighting regarding the set of variables analyzed; while for the variables of transport and cost, the forecast goes from regular to satisfactory. On the other hand, customs is the variable that received the worst qualified forecast, with high values in options such as: "very bad". Said results make it possible to glimpse the strong need to improve the logistics chain in order for the service to be seen as efficient and competitive; however, it is the government who must be the first driver since it could be stated, in terms of the results obtained, that it is customs that shows the lowest rating regarding the logistics services offered in the port.

It is also important to note that Mexican customs is going through a series of changes in both its legislation and operations, which would imply an improvement in the medium and long-term in customs administration if these changes are implemented properly. Therefore, it would be important to carry out these types of studies again in the future.

Each variable was analyzed in turn in order to identify the main elements of each of these five key factors: customs, costs, time, warehousing, and transport, the logistics chain of foreign trade of the port of Lázaro Cárdenas, and the degree of importance of them, with respect to the factor considered as a dependent variable.

In the case of customs or customs administration, according to the results it is necessary to provide more government support in order to encourage foreign trade in Mexico, in addition to implementing measures to streamline procedures to decrease the time spent in customs clearance. These measures can be: greater training, the use of electronic means in an intensive way as long as they work efficiently, and the incorporation of technologies that allow a quick and effective review.

With regard to the storage of goods, it could be thought that the border with customs plays a fundamental role; however, is not as important as the proper handling of goods and equipment

available to those in charge of the warehouse. Therefore, if the goal is to improve this section of the logistics chain, it is of utmost importance to implement technologies, according to storage needs, as well as continuous training of human resources, in order to raise quality levels.

For the time variable, it was found that the time elapsed in the moving process is not as important as the fulfillment of the stipulated terms; however, both are strongly linked to the planning throughout the logistic chain, so the delay or even the anticipated arrival of the products can represent an additional cost (storage) or even the loss of the client, which implies a loss of market and decrease of the competitiveness of the product against the products of its competitors.

Regarding the transport and cost variables, an improvement in the services currently offered is recommended, since the cost is directly related to the service. For their part, the currently established fiscal routes need an improvement in their infrastructure. At the same time, it is necessary to plan for the implementation and improvement of new routes, in order to have better logistics corridors that effectively cover the needs of international markets.

Finally, the importance of linking operators in order to achieve productive chains, optimizing the operation of services globally and locally, is highlighted. Locally, through the improvement of the internal processes of each logistics service provider; and globally, not as the sum of each of the units that comprise the services, but as the whole of the production chain and its various interrelations.

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Annex. Reliability tests, summary of the model

Summary of the model

Training	Cross entropy error	47.420
	Percentage of incorrect forecasts	32.6%
	Stop rule utilized	1 consecutive steps without error reduction[a]
	Preparation time	0:00:00.03
Tests	Cross entropy error	19.747
	Percentage of incorrect forecasts	28.1%

Dependent variable: Customs

a. Error calculations are based on the test sample.

Summary of the model

Training	Cross entropy error	40.987
	Percentage of incorrect forecasts	18.8%
	Stop rule utilized	1 consecutive steps without error reduction[a]
	Preparation time	0:00:00.03
Tests	Cross entropy error	9.371
	Percentage of incorrect forecasts	12.5%

Dependent variable: Warehousing

a. Error calculations are based on the test sample.

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Summary of the model

Training	Cross entropy error	37.154
	Percentage of incorrect forecasts	20.8%
	Stop rule utilized	1 consecutive steps without error reduction[a]
	Preparation time	0:00:00.03
Tests	Cross entropy error	14.872
	Percentage of incorrect forecasts	16.8%

Dependent variable: Time

a. Error calculations are based on the test sample.

Summary of the model

Training	Cross entropy error	36.284
	Percentage of incorrect forecasts	20.0%
	Stop rule utilized	1 consecutive steps without error reduction[a]
	Preparation time	0:00:00.03
Tests	Cross entropy error	17.233
	Percentage of incorrect forecasts	12.5%

Dependent variable: Transport

a. Error calculations are based on the test sample.