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## Chapter

# Conceptualization, Definition and Assessment of Internal Logistics through Different Approaches Using Artificial Intelligence

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## Abstract

The aim of this chapter is to develop a new concept of internal logistics, its components parts and how to evaluate it. To quantify the level of performance of the internal logistics of a company is an important issue to gain competitiveness. There are few papers now at days that analyze how to quantify this issue. In recent years, it has been developed numerous applications of Fuzzy logic and Neural Networks to solve diverse problems of Engineering. Fuzzy logic is a mathematical tool that emulates the method used for humans for managing and processing information and Neural Networks are computing systems inspired by the biological neural networks that constitute human brains. Such systems “learn” to perform tasks by considering examples, generally without being programmed with task-specific rules. This chapter offers a new definition of internal logistics and shows the procedure to evaluate its level in a company. This procedure for assessing the internal logistics was developed through an Excel tab, a fuzzy inference system and a neural network. To validate this procedure, it was applied to 93 companies in the Industrial Pole of Manaus. Results obtained by different approaches are very similar, demonstrating the validity of the procedure developed.

**Keywords:** internal logistics, measurement, neural networks, fuzzy logic, performance, industrial companies

## 1. Introduction

The advent of globalization promotes organizations with the persistent pursuit of competitiveness, forcing businesses moving competitive advantages. Still, organizations that are in the forefront of their sectors and considered successful are

those that actually trying to develop its core competencies to offer a standard of excellence in goods and services and are concerned with its strategy and with the workforce. The market organizations have demanded a set of features that include efficiency, effectiveness, dynamism, creativity, agility, flexibility and having holistic vision, to be competitive and having defined their strategies, seeking business sustainability.

In [1] are highlighted the indicators that assess the efficiency of internal activities and processes, and logistics performance indicators are suggested. They are classified into the following categories: stock management, cost, productivity, quality and customer service. However, it is necessary to develop a performance evaluation form for the supply chain, using external and internal indicators together to evaluate the performance of the entire chain, not only internal indicators of logistics, so that, working together, companies manage to achieve the best return business of supply chain.

In [2], it is considered the designation of logistics as “logistics management.” Also it is cited that this concept can be included into customer service, traffic and transportation means, storage, selection of local to manufacture and store, inventory control, order processing, acquiring, transportation of materials, distribution, supply of parts, packaging, returning goods and order volume forecast and that an organization must provide products and services to customers according to their needs and requirements as efficiently as possible.

Sometimes logistics is related to the marketing, as the strategic process to managing the acquisition, transfer, storage, parts, and finished products, together with the flow of information and its marketing channels to maximize profit with cost-cutting. There is no single definition for conceptualizing logistics, which be accepted by all researchers in the field. The important thing is that companies know that it is present in the business world and that professionals must understand their target that “is to make available products and services where they are needed, when they are desired” [3].

The traditional logistics refers to activities such as packaging, transportation, loading, unloading and storage, etc. The modern logistics reaffirms the concept of integrated logistics management and its implementation. It is important to outstanding that modern logistics must be understood as the medium during the acquisition, production, and operation of the whole process to delivery to the final consumer [4].

In contemporary organizational environment, logistics appears as a strategic concept, because of not only materials management and physical distribution, but also for providing values of time and place for customers, for becoming an element that stands for organizations, with agility, flexibility and integration of internal and external channels. Several authors describe that the concept of logistics can be separated into three basic items: food (suppliers), plants (internal) and distribution (customers). This represents a group that is often defined as highly empirical, resulting in negative effects that directly influence the outcome of the final performance of organizations [5, 6].

Despite the importance of internal logistics, it has not been fully understood, particularly in manufacturing industry [7–9]. However, it constitutes a large part of the total cost for businesses [10]; average logistics costs represent between 10% and 30% of total sales volume in a typical production company [11]. This chapter is composed by eight parts: An introduction, a Literature Review, a section of materials and methods where it is explained all the procedure developed, a section of results analysis and finally the conclusions, the acknowledgments, the conflict of interest and the references.

## 2. Literature review

### 2.1 Internal logistics concepts

Several authors state that an internal logistics system well designed and correctly used increases the efficiency of an organization [12, 13].

To summarize, several aspects of logistics performance are very important for a company, and among others refer to delivery, quality, robustness, information, and cost and customer service. However, it is also important to consider which is the combination of high efficiency, performance, and effectiveness [14]. For [15] the performance efficient logistics activities alone are not enough. To create competitiveness for the company, it is essential that the right kind of logistics activities to be prioritized and through the right performance variables. However, as discussed by [16], there is a lack of standardized ways of dealing with the internal logistics requirements influencing the overall logistics performance. In general, logistics managers are trying to use measurements to help design and manage more effective and efficient logistic systems for the client. Identifying the value of internal logistics and its critical performance criteria can be a way to help this development [17].

Design and improve the internal logistics system involves decision making at different levels, such as strategic, tactical and operational issues. As such, it involves long-term planning (strategic) and aspects of planning and control (management) of short and medium term [18]. An internal logistics system that works well requires involvement and understanding of the system at all levels. Logistics professionals should be empowered with the necessary experience in essential and critical functions for their own company and fully understand how they affect the entire value chain [19].

Internal Logistics handles all the management of the internal supply process, storage, transportation and distribution of goods within the organization, that is, to meet its domestic demands as support for manufacturing [20]. According to [6], the cycle of support to manufacturing activities is directly related to internal logistics, i.e., planning and production control. Thus, the logistical support to the production aims mainly to establish and maintain an economic and orderly flow of materials and stocks in process in order to meet the schedules of the production sector. The logistics support production has the operational responsibility for the following activities: handling and storage of products, materials, components and semi-finished parts. With the changes in the business environment, logistics service concepts have evolved and various issues were added in operational logistics tasks such as packaging, outsourced inventory management, bar code, and information systems. These operational logistics tasks were considered, and called as “internal logistics,” and these activities should “interact with other functional areas” [21]. Internal logistics thus involves logistics activities within the walls of an organization, e.g. internal transport, materials handling, storage and packaging [15].

Other more recent studies indicate that the internal logistics has been the attempt to organize and optimize the internal activities with the cost reduction objective for organizations in different segments. However, organizational issues such as the lack of a strategic vision that become in difficulties need to be addressed. The transfer of knowledge and technology used in the manufacturing industry could be of great benefit concluded by [22].

According to [23], the end consumer determines the success or failure of supply chains. Thus, an important part of logistics performance is linked to customer service and to be able to respond to their needs and requirements. When it comes to internal logistics as a system, both the client and the service provider are the same at



the organization itself. So to see the internal logistics as a system, both the service provider and the customer are the same company. As such, the customer's needs and requirements can be translated for internal purposes. Therefore, the performance of internal logistics is under the control of the company, and can provide a more direct indication of the effects of the relationship involving structure and logistics [16].

Given this approach to internal logistics, was noticed a gap both in theory and in practice referred to this issue. Many discussions in the general theoretical field of logistics has been developed. Companies need support with tools and models or methods that make it possible to identify, organize and help to define and shape to analyze them; it is evident in the daily graded citations mentioned above about the lack of studies in this area. Therefore, this chapter suggests a way to define and evaluate the internal logistics.

Based on the readings of selected articles and the development of a pattern was possible to define a more comprehensive concept of internal logistics:

Internal logistics is planning, execution and control of the physical flow and internal information of the company, seeking to optimize the resources, processes and services with the highest possible profit.

According to the standpoint of logistics as a picture or an approach that consists of several parts and aspects, it is often described as a system, which is the perspective used in this work to analyze the internal logistics as part of the system. According to [24], the logistics system is always open and in a state of exchange with its environment. However, the limits of the system and subsystems and components included vary depending on different perspectives.

The system studied in this chapter is the internal logistics system, where the system boundaries are the physical limits of the company under study. Then internal logistics comprises logistics activities within the walls of an organization, such as internal transport, materials handling, storage and packaging [15].

There are three different angles from which, logistics operations can be seen: processes, resources and organization. All these aspects can be seen as parts of the logistics system, as the flow of goods and information to be made through a series of stages called activities and processes [25]. In addition, resources refer to all means, equipment and personnel needed to run the process. Finally, the organization includes all planning and control procedures necessary to implement and manage the system.

Several authors argue that an internal logistics well designed and properly used increases the efficiency of an organization [26]. The project of internal logistics system is therefore an aspect that strongly influences the competitiveness of the system and is therefore related to the objective of this chapter.

Projecting and improve internal logistics system comprises decision making at different levels, such as strategic, tactical and operational levels. As such, it includes long-term planning (strategic) and aspects of planning and control (management) of short and medium term [18]. Internal logistics system that works well requires participation and understanding of the system at all levels. Logistics professionals must be equipped with the necessary expertise in critical and essential functions for their own company and fully understand how they affect the entire value chain. Supply chains are often faced with the situation where they have to accept some degree of uncertainty, however, must develop a strategy that allows them to adjust supply to demand [27]. In general, it can be affirmed that a strategy is about how to make the planning, which is very different from doing [18]. To conduct portfolio analysis were consolidated by central themes articles and one can see some evidence as to the possible parts of internal logistics. For a better demonstration of sets of items was prepared to **Table 1** resulting in a preliminary view of the parts.

Articles key points	IT	LT	PCP	PCM	ST	IM	SP	RC	WP	LA	HL	IM	PP
Supply networks	X	X					X						
Decision making	X	X		X	X	X							X
Delivery		X	X					X					
Health care logistics	X	X		X			X				X		
Logistics performance	X	X	X			X	X					X	
Inbound logistics	X	X			X	X					X	X	X
Cross-docking		X			X						X		X
Automated material handling systems	X		X		X						X	X	
Identifying business value using the RFID e-Valuation framework	X	X											
Cost-cutting	X	X	X		X	X	X			X	X		X
Customer and supplier logistics	X	X	X									X	
Inventory and transportation decisions	X	X			X	X							
Intralogistics operations	X	X								X			
EDI in logistics	X	X				X		X				X	
Integration between logistics and Assembly lines	X	X	X		X	X				X			X
Optimization transport		X	X								X	X	X
Routing and inventory	X	X	X		X	X	X				X	X	X
Smart logistics	X	X	X				X		X				
Manufacturing strategy	X	X	X						X				
Consolidation loads	X	X					X					X	

IT = information technology; LT = logistics techniques; PCP = planning and control production; PCM = planning and control manufacturing; ST = storage; IM = inventory management; SP = supply; RC = receipt; WP = working-in-progress; LA = layout; HL = handling; IM = internal transport; PP = picking and packing.  
 Source: Prepared by authors (2020).

**Table 1.**  
 Key points to compose the concept and components parts.

A well-formulated strategy helps to use all the resources of an organization and create value based on its internal competition and shortcomings in relation to the external environment. However, it is of great importance that the logistic function and logistics strategy are integrated and aligned with other functions and strategies of the organization, to create competitiveness [15].

Companies that emphasize logistics periodically reorganize its logistics functions in their attempt to find and keep the best design in the business environment which is rapidly changing [28]. The overall response capacity could be achieved through a greater sharing of information between partner organizations and a careful selection of suppliers by the purchaser. **Table 2** provides a summary of the components used in different studies applied to internal logistics.

The novelty of this chapter is related to a new definition of internal logistics which implies a description of its component parts according to this new definition, and the procedure for evaluating its level in anyone company or factory.

Internal logistics components	Source
<b>Physical flow</b>	
Receipt	[29–33]
Warehouse	[25, 34–39]
Supply	[40–42].
Movement	[32, 34, 43–47]
Working in process	[19, 48–53]
Internal transport	[39, 54–58]
Picking/packing	[32,59–65]
<b>Information flow</b>	
Information technology	[40, 55, 66–71]
Planning and material control	[54, 68, 72–75]
Planning and production control	[74, 76–79]
Customer service	[40, 80–84]
Order processing	[48, 68, 73, 85–87]
Inventory management	[32, 34, 41, 66, 68, 88–91]

Source: Prepared by authors (2020).

**Table 2.**  
*Theoretical background of the internal logistics components.*

### 3. Materials and methods

#### 3.1 Approach developed for evaluating the components parts of internal logistics

There were identified a few systematic attempts, proposals and techniques that improve the manufacturing system and the internal logistics and their related performance. They have to be able to assess the dynamics of production and the corresponding improvement and taking into account environmental issues. For developing the objective of the chapter there were carried out the following steps:

- To identify the composition of the industrial pole of Manaus according to the different industries that compound it.
- To identify in literature, the component parts and definitions of internal logistics.
- To develop a new definition of internal logistics and its component parts.
- To confront and discuss the new definition and its component parts with industry professionals through surveys and interviews.
- When there were defined the component parts, it was elaborated a survey of then questions for assessing each one of the component part using a Likert scale of five points. This survey and questionnaire was also discussed with engineers and researchers that deal with internal logistics and supply chain.

- The survey was applied to the different industries of the industrial pole of Manaus.
- With all these information, then there were analyzed and decided which tools would be used for assessing the internal logistics according to its new definition and according to its components parts.
- It was established an Internal Logistics Index for evaluating its level in any company or factory
- For this porpoise there were used an Excel tab, the fuzzy logic, and the neural networks.

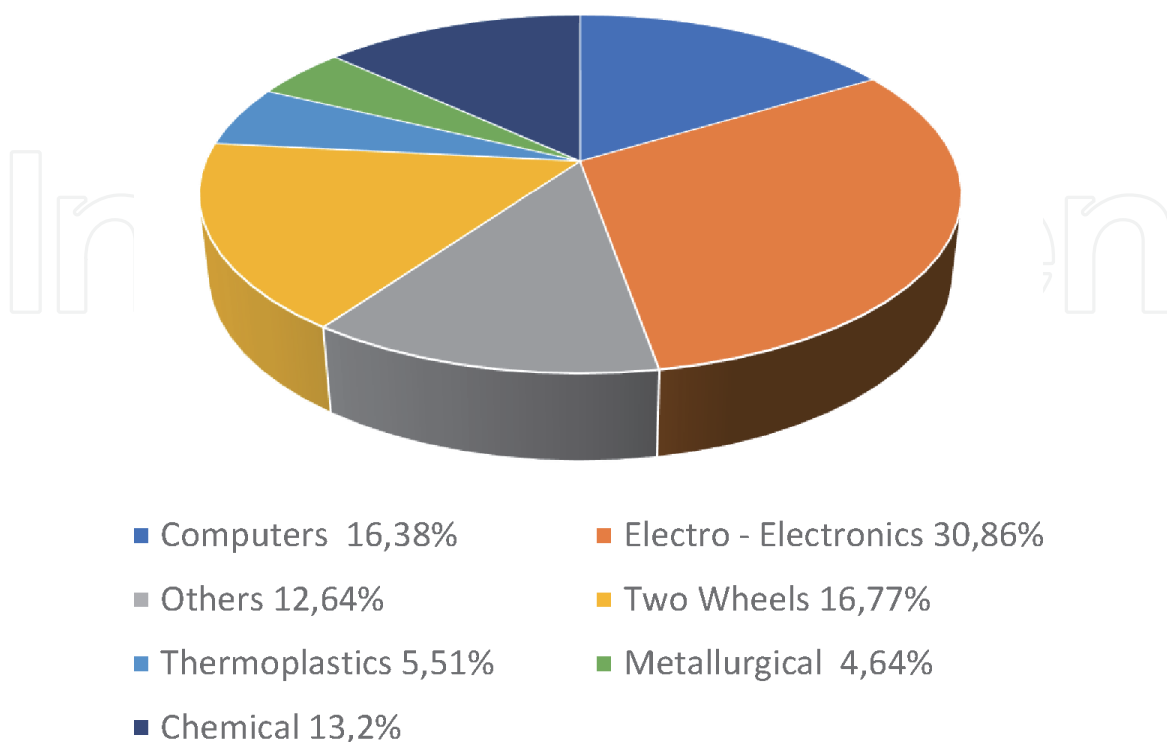
All this procedure is explained in detail below.

The Industrial Pole of Manaus has more than 565 companies of small, medium and large size, involving seven subsectors of different branches of activities, which can be seen in **Figure 1**. The emphasis of the companies to be researched will focus in the two-wheel sector that is the 16.77% of the PIM billing. The research will be developed in companies of medium, large and small size.

To assess the internal logistics, a survey was conducted to different companies of the Industrial Pole of Manaus. For data had statistical significance, it was analyzed what size the sample should have.

The “right” sample magnitude for a specific application depends on many factors, such as costs, administrative aspects, level of precision, level of reliability, variability within the population or subpopulation of interest and specimen method.

These factors interact in multifaceted ways. Although a consideration of all the variations is beyond the scope of this chapter, the remainder of this epigraph covers a situation that commonly occurs with simple random samples: How to find the minimum sample magnitude that offers the desired precision.



**Figure 1.**

Share of activities of sub-sectors in sales of the industrial pole of Manaus in the period from January to February 2015 (calculated based on sells in dollars). Source: Suframa – Industrial indicators (2015).



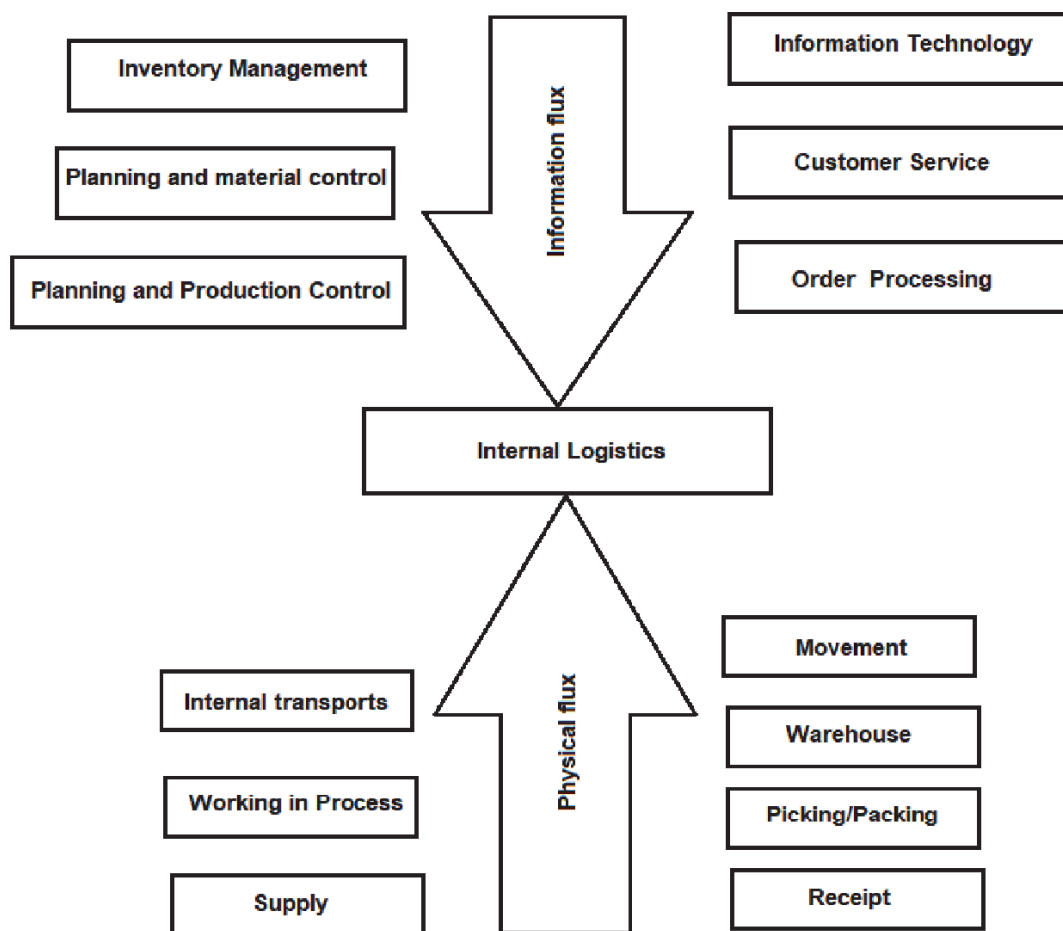
For demonstrating that a process has been improved, it is necessary to measure the process competence before and after improvements are implemented. This permits to measure the process improvement (e.g., defect reduction or productivity growth) and translate the effects into a projected financial result – something that corporate leaders can understand and appreciate. Determining sample dimension is a vital topic because samples that are too large may waste time, resources and money, while samples that are too small may lead to inaccurate results.

In the case of the industrial pole of Manaus, it is composed for 565 companies, and using the formulation expressed in [92], the number of companies to be considered for a good statistical representation has to be more than 60 companies.

Analyzing the sectors of the Industrial Pole of Manaus, it was possible to identify the components to assess the internal logistics. They were redesigned through interactions with business professionals from different companies in order to obtain the greatest possible standardization of component parts of internal logistics. **Figure 2** shows these parts. From this picture can be observed that there are component parts that have to do with the physical flow and other with the information flow.

Each component part of the figure above was evaluated by 10 properties or pertinent questions reflecting the respective training component behavior for performance, supported by Likert scale of 1 to 5, with 1 indicating little or no adhesion and 5 full adhesions between the question versus practice where each part can reach a maximum of 50 points is that the resulting properties of 10 x 5 points, and a total of 130 questions as a result of the 13 component parts of 10 questions each.

The questionnaire applied in enterprises, medium and large, the following segments: electronics, appliances, components and two wheels. In March 2015, 539



**Figure 2.**  
Component parts of the internal logistics. Source: Authors (2020).

invitations were sent to participate in the study. A total of 327 responses received, being considered only 140 (25.97%) fit and consistent for research. The sample characteristics are shown in **Table 3**.

### **3.2 Assessment of the weight of the component parts of internal logistics by companies**

To evaluate the weight of each component part of the Internal Logistics were sent a survey to 93 companies to analyze them and to attribute a weight of importance in a Likert scale of 1–5 where 1 was minor and five very important according to the particularity and priority that represents the component parts for the aforementioned companies. In **Table 4** there are offered the results of three of the companies investigated.

It was found that depending on the company and its respective sector, the priorities and the degree of importance may be subject to change and therefore affect the performance of internal logistics index.

The maximum score that each company can get is 65 points, which is the result of the multiplication of the 13 items by the maximum value of each item according to the Likert scale. It is noted for example that the company 1 attributed a very low note for the items: Storage, WIP and internal transport, while companies 2 and 3 attributed notes 5, 5 and 4 respectively for these same items, therefore, it follows which depending on the sector and type of production, whether continuous or discrete, the degree of importance may change. An arithmetic mean of the 3 companies was also developed in this tabulation and it was appreciated that from the maximum possible score of 65 points, company 1 scored 35 points, followed by 61 points by the company 2 and finally the company 3 with 59 points, and the arithmetic mean was 51.67 points.

### **3.3 Evaluation of the internal logistics index by companies using excel solver**

Based on the literature investigated was developed the structure of diagnostic model of the component parts of the internal logistics, its filling, testing and subsequent validation. They were developed 10 questions to assess each property and was conducted a survey in different companies. These questions were developed based on the literature review, the survey results according to the criteria of specialists of logistics management, and consulting and business managers. It was developed an Excel tab to evaluate the performance of each of the component parts of the internal logistics as well as the Internal Logistics Index of a company.

<b>Industrial sector</b>	<b>%</b>	<b>Size dcounter</b>
Domestic appliances	15	100–250
Electronics	35	100–250
Components	40	250–500
Towels	9	500–1000
Others	1	100–250

*Source: Authors based on survey (2016).*

**Table 3.**  
*Firms demographics: Industry and size.*

Component part		Assigned weight by each company				
		Company 1	Company 2	Company 3	Arithmetic mean	Company 3 Weight
Component parts of the Internal Logistics	Receipt	3	5	4	4.00	6.8%
	Handling and movement	2	4	3	3.00	5.1%
	Picking/packing	4	4	4	4.00	6.8%
	Storage	1	5	5	3.67	8.5%
	Stocks management	2	5	5	4.00	8.5%
	Supplying	5	5	5	5.00	8.5%
	PMC- planning and material control	2	5	5	4.00	8.5%
	PPC - planning and production control	2	5	5	4.00	8.5%
	WIP- working in process	1	5	5	3.67	8.5%
	Order processing	4	4	5	4.33	8.5%
	Internal transports	1	4	4	3.00	6.8%
	Customer support	5	5	5	5.00	8.5%
	I. T. information technology	3	5	4	4.00	6.8%
Internal Logistic Index	35	61	59	51.67	100%	

Source: Authors.

**Table 4.** Answers from the companies on the degree of importance of the elements of internal logistics.

The Excel Tab developed to calculate the Internal Logistic Index was based on the following equations:

$$ILI = \sum_{i=1}^{13} \left[ \left( \frac{Z_i}{100} \right) \cdot W_i \right] \quad (1)$$

where ILI = General index of the performance of the Internal Logistics;  
 $W_i$  = Weight attributed to each component part  $i$ ;  $i$  = each of the properties analyzed;  $Z_i$  = value reached in % for the property  $i$  based on the sum of all values given to each parameter of the corresponding property of the Likert scale from 1 to 5 and divided by the maximum possible value to reach in% i.e.:

$$Z_i = \sum_{j=1}^{10} \left( \frac{P_j \cdot L_j}{50} \right) \cdot 100 \quad (2)$$

where  $P_j$  = Each of the parameters that assess the  $Z_i$  property (always it going to assume the value 1 in the above expression);  $L_j$  = Value assigned to the parameter  $P_j$  at the Likert scale from 1 a 5.

### 3.4 Assessment of internal logistics through fuzzy logic

#### 3.4.1 The fuzzy logic and internal logistics

Assessing the Internal Logistic Index of a Company is a very complex task due in some case to the lack of information and in other cases to the excess of information for decision-making. This leads to difficulty in defining, measuring and monitoring of objectives and targets to set rates compliance associated with measuring the performance of the Internal Logistics [93]. In response to these challenges of business management there have been emerged theories, approaches and methodologies (flexibility, resilience, etc.) using tools such as fuzzy logic for reliable solutions that adapt easily to changing parameters of imprecision [94].

In addition to the treatment of imprecise environments, another emerging challenge is to achieve that the measurement of organizational performance transcends the traditional financial approach and to be conducted throughout with suitable means to new generations of applications in the management of internal logistics.

#### 3.4.2 Method of fuzzy inference

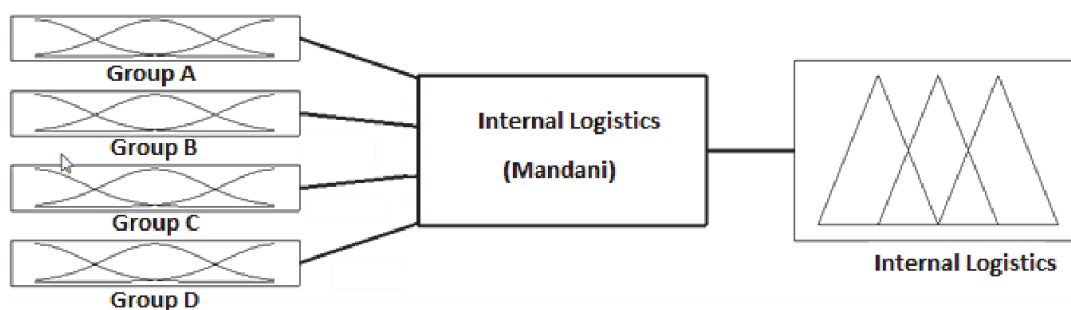
A fuzzy inference method allows deriving conclusions (a fuzzy value) from a set of if-then rules and a set of input values to the system, by applying composition ratios. The two inference methods commonly used are the Mamdani introduced by Mamdani and Assilian [95] and the TSK (Takagi-Sugeno-Kang) proposed by Takagi and Sugeno [96].

The main difference between these methods is the consequent type of the fuzzy rule. The systems Mamdani type use fuzzy sets as consistent rule and TSK used linear functions of the input variables with discrete data outputs. In this research the type Mamdani inference system (**Figure 3**) with outputs continuous values is used.

To facilitate the modeling of the problem in fuzzy logic, it was used the Fuzzy Logic Toolbox™ of MATLAB software. The steps for formulating the model of fuzzy inference of Mamdani type were [97, 98]:

#### 3.4.3 Selection of indicators

Performance measurement of the internal logistics can be based on the selection and definition of indicators used to evaluate the efficiency and effectiveness of its operations. Indicators should have a holistic approach and facilitate the implementation of initiatives for improvement. Indicators selected for the proposed fuzzy model to measure the performance of the Internal Logistics of the company studied are described in **Table 5**. The components were grouped into larger groups as shown therein. A letter from A to B. defines each group.



**Figure 3.** Fuzzy system for asses the internal logistics. Source: Authors (2020).

A	B	C	D
Receipt	WIP- working in process	PPC - planning and production control	Picking/packing
Storage	Handling and movement	PMC- planning and material control	
Stocks management	Supplying	Customer support	
I. T. information technology	Internal transports	Order processing	

Source: Authors.

**Table 5.**  
Component parts of internal logistics.

Component parts/groups	A	B	C	D	LI
1	M	B	M	B	B
2	M	G	G	B	M
3	G	B	M	B	B
4	G	G	G	B	M
5	B	G	G	B	B
6	G	B	G	G	M
7	B	G	B	M	B
8	M	G	B	M	M
9	B	M	M	M	M
10	M	B	M	M	M
11	G	M	M	M	M
12	M	B	G	B	M
13	G	G	M	G	G
14	M	B	G	G	M
15	G	M	B	M	M
16	B	B	M	B	B
17	M	M	G	G	G
18	G	M	B	M	M
19	B	B	M	G	M
20	M	G	B	G	M
21	G	M	B	G	M
22	B	M	B	G	M
23	B	G	B	M	B
24	B	M	G	R	M

Source: Authors (2020).

M = medium, G = good, B = bad.

**Table 6.**  
Fuzzy rules.

Each component part of the previous group is evaluated using 10 pertinent questions that reflect the behavior of the respective part.



### 3.4.4 Development of fuzzy rules

The model has 24 rules, which were created from the experience of official logistics industry specialists and numerical data from surveys and they are offered in **Table 6**.

The model has four inputs that are the four groups described in **Table 5** and an output that is the Internal Logistics Index. The parameters of pertinence functions associated with each variable were also specified. There were adjusted all inference functions and the defuzzification method used. The rules of an inference engine of a fuzzy system has to be made by experts, or learned by the system, in this case using neural networks to strengthen future decision-making. For making the rules in this problem were used criteria of 20 specialists in the field of Internal logistics.

### 3.5 Assessment of internal logistics using neural networks

One problem with the method applied in the previous section is that the user of Excel tab has to assign a weight to each component part of the internal logistics based on in his own experience, which naturally influences the overall index of internal logistics of a company. Attempting to avoid subjectivity in determining this rate, it was looked to the technique of artificial neural networks. To analyze the Internal Logistics of an industrial company was used the Internal Logistics Index (ILI), evaluated between 0 and 100%. This index is calculated based on the values assigned to each of the internal logistics properties between 0 and 50 according to the 10 parameters of evaluation of each property in the Likert scale of 1 to 5.

There were selected the same 10 companies of the Industrial Pole of Manaus for their study and analysis, all of them belonging to the productive sector.

Property	Company number and value of the performance of each property									
	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10
Receipt	30	35	36	50	42	47	32	18	50	22
Handling and movement	20	44	23	50	35	45	34	15	39	19
Picking/packing	50	22	32	48	26	34	45	21	40	23
Storage	40	33	41	43	12	50	23	32	35	34
Stocks management	30	11	25	21	18	16	15	18	18	35
Supplying	24	44	18	50	22	24	18	43	25	23
PMC- planning and material control	33	50	15	39	19	35	22	32	35	41
PP - planning and production control	28	33	21	40	23	32	18	19	28	19
WIP- working in process	16	22	32	35	34	18	34	42	47	32
Order processing	41	11	18	18	35	33	45	35	45	34
Internal transports	33	33	43	25	23	22	35	26	34	45
Customer support	23	45	32	35	41	43	25	12	50	23
I. T. information technology	33	44	19	28	19	21	18	18	16	15

Source: Authors.

**Table 7.**

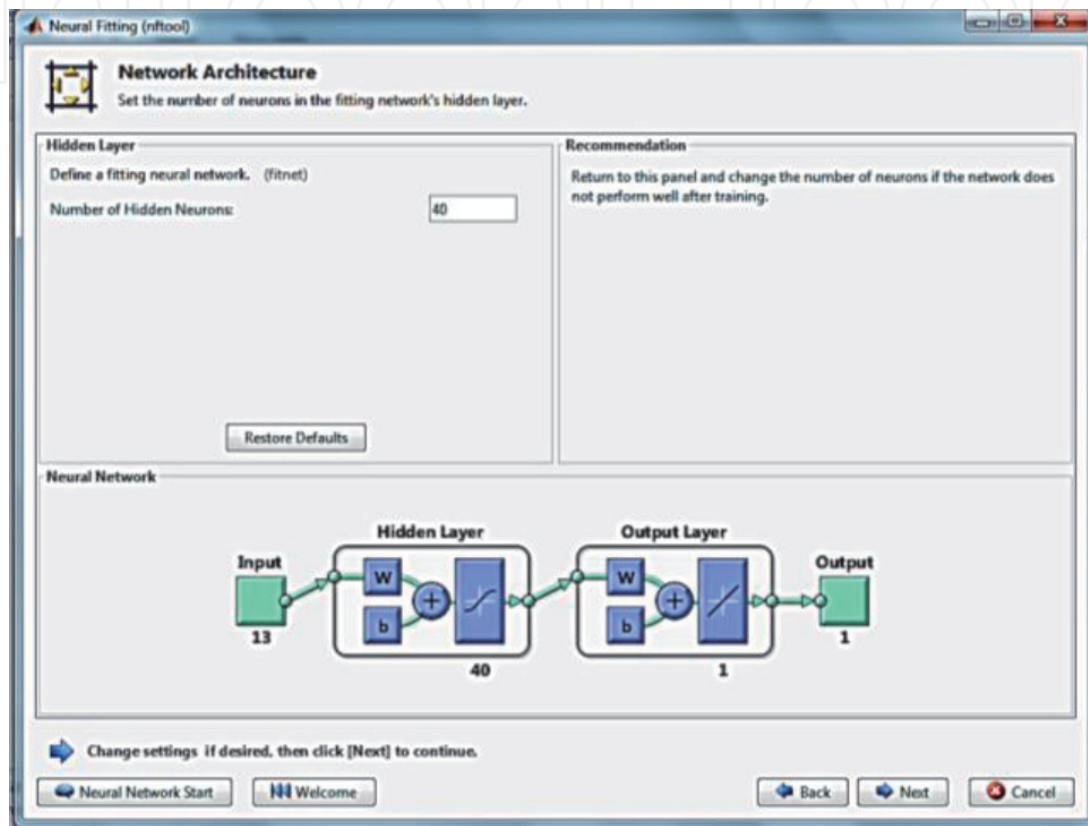
*Different properties that compose the Internal Logistic Index of a company and their values for the 10 companies evaluated.*

Company number and Internal Logistic Index possible according to the performance value of each property										
	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10
ILI	65	75	70	67	78	60	70	65	78	65

Source: Authors.

**Table 8.**

Possible internal logistics indexes (ILI) for each company (targets) for training the ANN.



**Figure 4.**

Artificial neural network implemented in MATLAB. Source: Authors (from MATLAB).

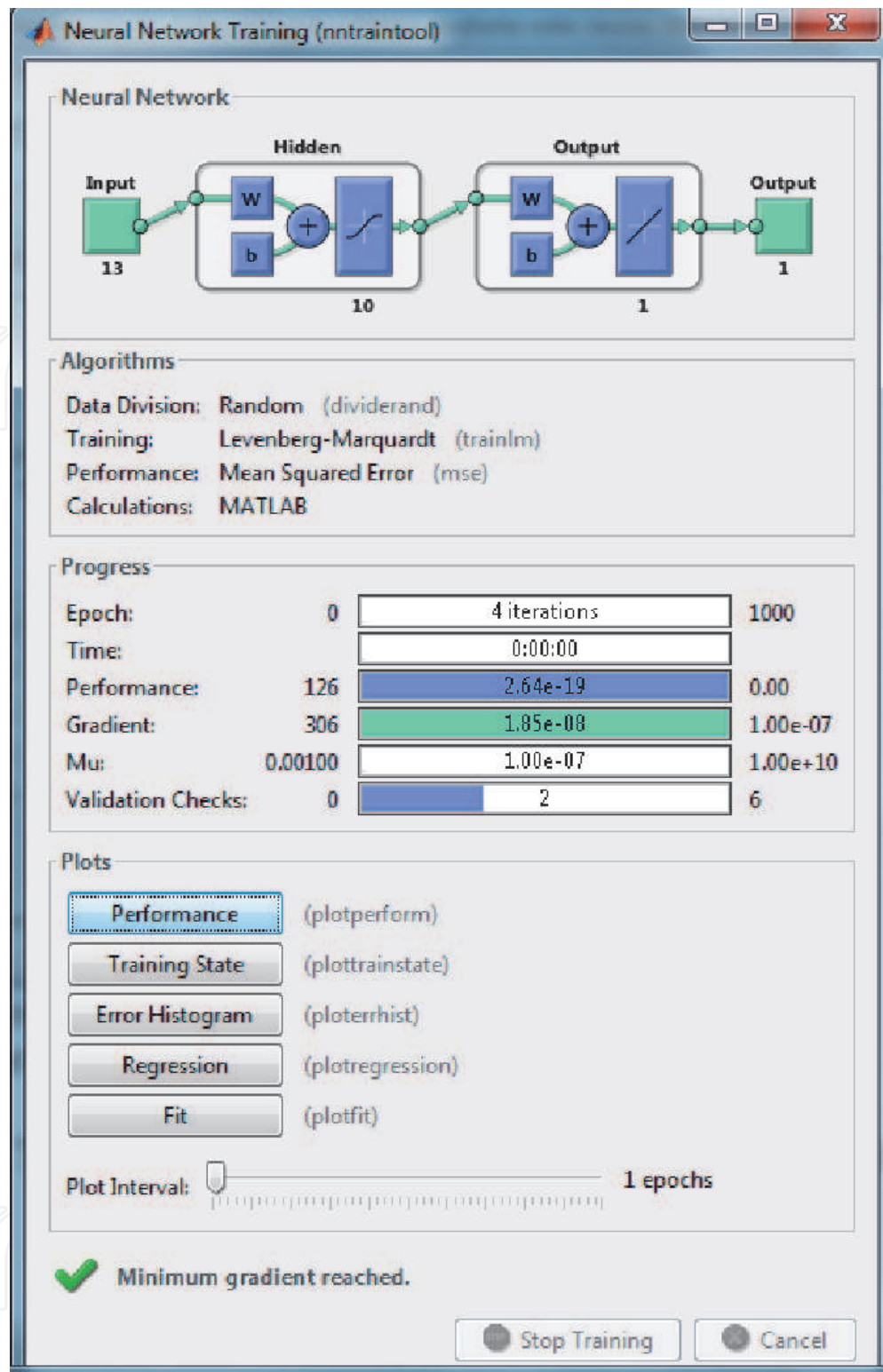
It was proposed to the ANN to determine the Internal Logistic Index of 10 companies in the industrial pole of Manaus. The values of the properties of the component parts of the 10 companies are given in **Table 7**.

The desired Internal Logistics Indexes for the aforementioned companies (supervised training), in order to train the ANN are given in **Table 8**.

In **Figure 4** it is showed the Architecture of the ANN implemented in MATLAB. In order to achieve reliable results, the network was trained five times. In **Figures 5** and **6** the training process is displayed.

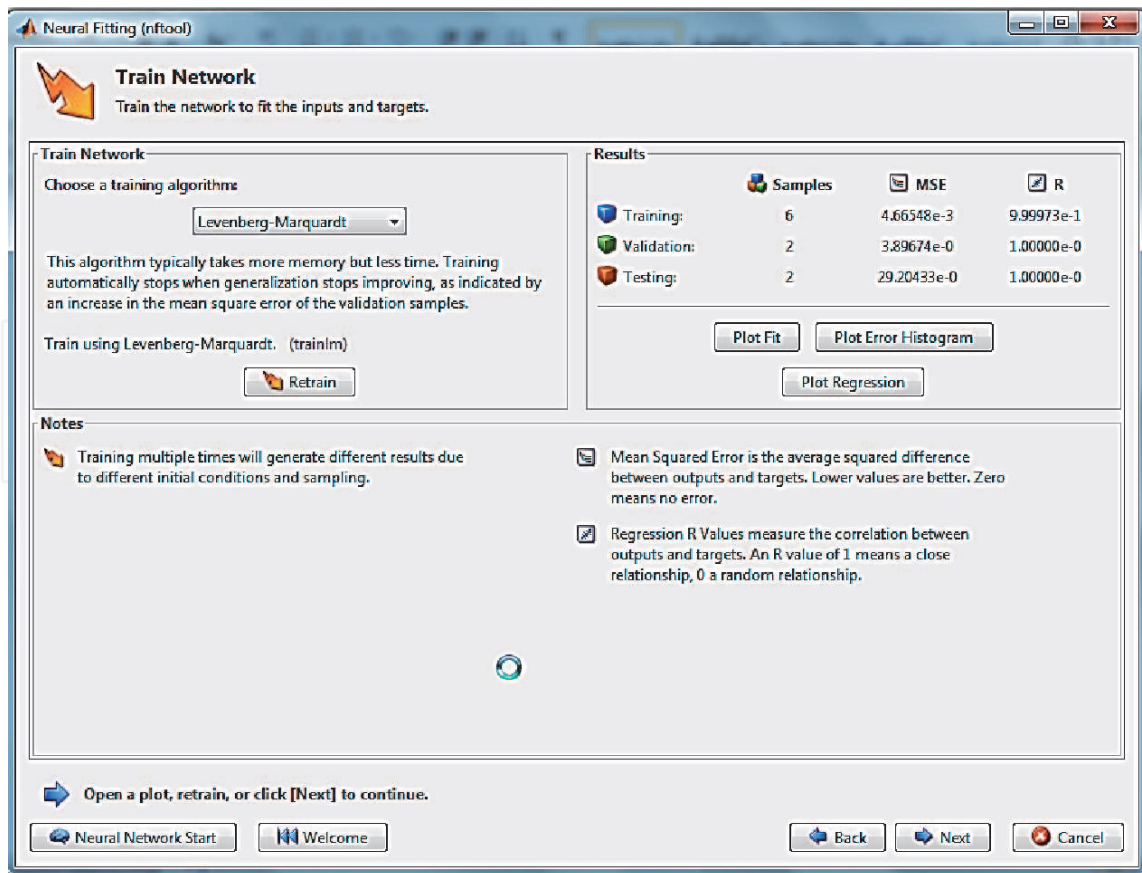
#### 4. Result analysis

It was chosen randomly the company three to answer questionnaires regarding the 13 elements or components parts of internal logistics. This company filled the Excel tab, reaching a score in% of each property that was multiplied by the weights assigned in Table to each property. This company reached a general index of 79.17% for Internal Logistics as it is shown in **Table 9**.



**Figure 5.** Neural network training state. Source: Authors (from MATLAB).

It was found that depending on the company and its respective sector, the priorities and the degree of importance may be subject to changes and therefore affect the performance index of internal logistics. The maximum score that each company can get is 65 points, which is the result of the multiplication of the 13 items by the maximum value of each item according to the Likert scale. It is noted for example that the company 1 attributed a very low note for the items: Storage, WIP and internal transport, while companies 2 and 3 attributed notes 5, 5 and 4 respectively for these same items, therefore, it follows which depending on the



**Figure 6.** Training and retraining of the ANN. Source: Authors (from MATLAB).

	Property	Performance		
		Percent	Weight	Points
Component elements of the Internal Logistics	Receipt	96.00	6.8	6.53
	Handling and movement	88.00	5.1	4.49
	Picking/packing	90.00	6.8	6.12
	Storage	86.00	8.5	7.31
	Stocks management	86.00	8.5	7.31
	Supplying	46.00	8.5	3.91
	PMC- planning and material control	94.00	8.5	4.62
	PP - planning and production control	92.00	8.5	4.62
	WIP- working in process	88.00	8.5	7.48
	Order processing	88.00	8.5	7.48
	Internal transports	90.00	6.8	6.12
	Customer support	88.00	8.5	7.48
	I. T. information technology	84.00	6.8	5.71
General Internal Logistic Index	79.17			

Source: Authors.

**Table 9.** General internal logistic index of a company.



sector and the type of production, whether continuous or discrete, the degree of importance may change. An arithmetic mean of the values of the 3 companies was also developed in this tabulation and it was noted that from the maximum possible score of 65 points, the company 1 scored 35 points, followed by 61 points by the company 2, then the company 3 with 59 points, and the arithmetic average was 51.67 points.

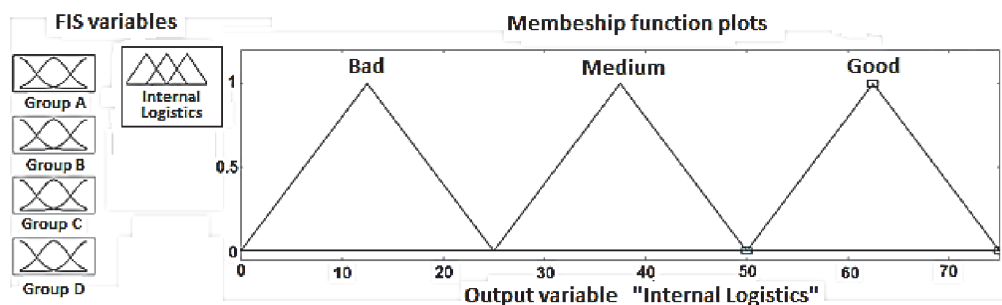
#### 4.1 Application of fuzzy logic to determine the internal logistics index of a company in the industrial pole of Manaus. Case study

##### 4.1.1 Internal logistics index company case study

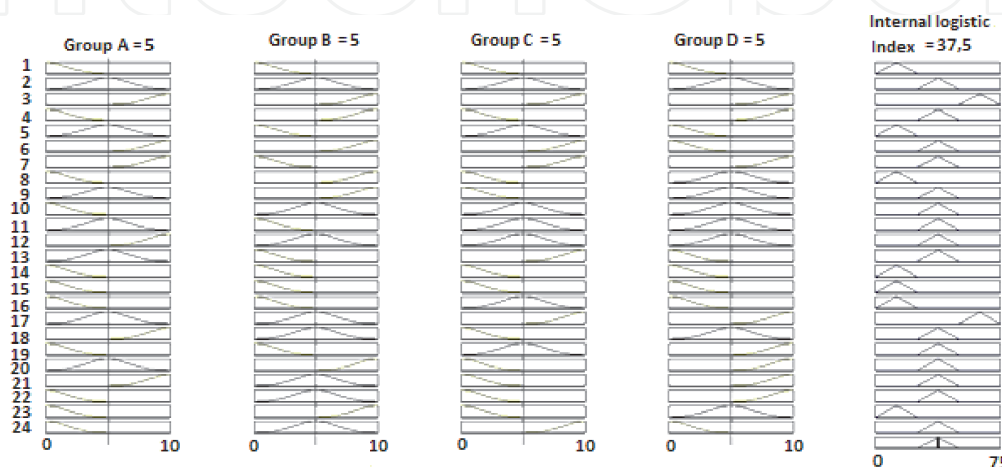
The toolbox of fuzzy logic implemented in MATLAB with the four groups of the diffuse model is shown in **Figure 7**. In **Figure 8** the values of Internal Logistics Index reached according to the input variables are shown. For example, if each group (from A to D) have an average value (5 points), then the Internal Logistics Index reaches a value of 37.4 points. The MATLAB allows vary input values, and consequently modifying the value of Internal Logistics Index.

Another way of demonstrate the results between two groups and the Internal Logistic Index can be analyzed from **Figure 8**, where there are represented the A and B groups with the value of 5 points for each group. The maximal value of the Internal Logistic Index in this case will be of 37.50% as it is shown in **Figure 9**.

It was established a comparative analysis between results of both models: Excel Tab versus Fuzzy Logic. The obtained results of the Internal Logistic Index by using the Excel tab was of 79.17% when assessing the 13 component parts. These



**Figure 7.** Fuzzy model for evaluating Internal Logistic Index. Source: Authors (from MATLAB).



**Figure 8.** Internal Logistics Index according to the input variables. Source: Authors (from MATLAB).



component parts of the same company were grouped how was cited before in four groups: A, B, C and D, supported by 24 rules developed and applied in the Fuzzy Logic toolbox from MATLAB. Each input variable can reach a value between 0 and 10. If each input variable reach the average value of 5 points, the Internal Logistic

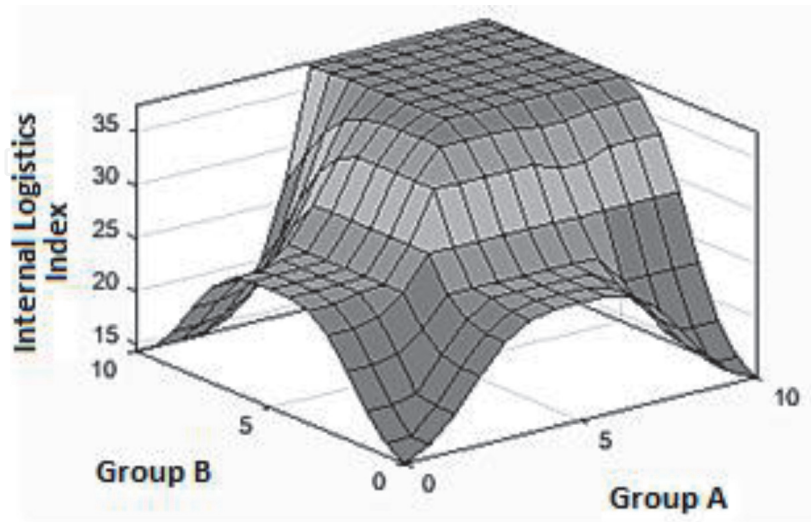


Figure 9.  
Surface of values of the internal logistic index according to the input variables. Source: Authors (from MATLAB).

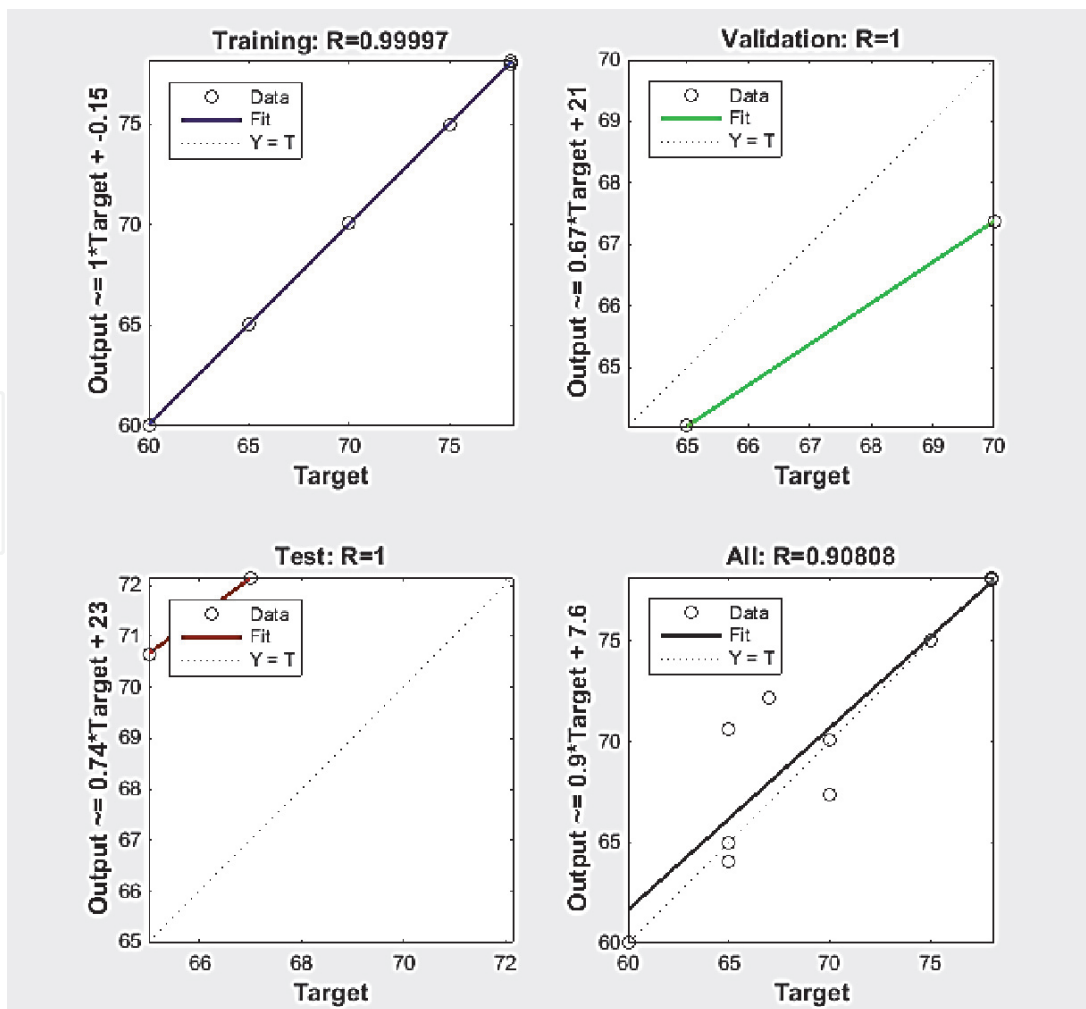


Figure 10.  
Validation of the artificial neural network errors. Source: Authors (from MATLAB).

Company	1	2	3	4	5	6	7	8	9	10
ILI	70.65	75.00	67.37	72.13	78.15	60.03	70.05	65.0	78.0	64.04
Error in %	2.65	0.006	2.62	3.13	0.15	0.03	0.059	0.004	0.009	0.95

Source: Authors (from MATLAB).

**Table 10.**

Obtained values of the internal logistics indexes and errors of these values in the 10 companies studied.

Index will be of 37.50%. Following the same procedure and way of thinking the top possible value of Internal Logistic Index will be of 75%, versus 79.17% obtained by Excel Tab method, demonstrating similarity between the both tools and a precision on the order of 95% of the results.

## 4.2 Application of neural networks to determine the rate of internal logistics of an industrial company. Case studies

Validation errors of the neural network are shown in **Figure 10**.

## 4.3 Internal logistic indexes of the studied companies

The ANN enabled in MATLAB with data values of the 13 Internal Logistic Properties from the 10 companies was processed. The values of the indexes of Internal Logistics as well as their possible are given in **Table 10**.

## 5. Conclusions

In this chapter three approaches and their expressions to assess the internal logistics of a company are established. The first method was based on dividing the internal logistics in 13 properties, having each property 10 indicators that were evaluated between 1 and 5 points. This leads to the maximum value of Internal Logistics Index (ILI) for each company can reach up to 100 points according to the weight established for each indicator.

The second approach was based on the fuzzy logic and the third one was based on neural networks.

When assessing the Internal Logistics Index using the Excel tab developed or by the method of Artificial Neural Networks, very similar values consistent with the reality of the companies studied were obtained, demonstrating the validity of both methods.

The methodological approach developed for the definition of the three models contains all the steps and procedures, allowing replication of the research, which is as important as the application of the developed models at the companies.

When assessing this parameter, using the Excel tab or developed by the method of fuzzy logic, similar values were obtained in line with the reality of the company analyzed, indicating the rationality of both methods.

The approach through the Fuzzy logic allows assess the rate of internal logistics for any position of the input variables, which can obtain a value between 0 and 10, depending on the appreciation of the user of this procedure. In the case of the company studied, specialists gave more emphasis to groups A and C.

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## **Conflict of interest**

The authors declare no conflict of interest.

## **A. Appendix**

On a scale of 5 (high) to 1 (low), how important are the following issues in your firm’s logistics efforts?

### **A.1 Customer service**

1. Is the team geared to provide quality and always prioritize customer?
2. Is there any ERP system that allows integration and exchange of information between companies?
3. Is there an analysis of customer satisfaction?
4. Is there guidance for team procedures?
5. Is there guidance on the importance of customer response speed?
6. Are there a scheduled visit and contacts with current customers and potential and no formal or research and survey on competitors and new niches?
7. Is there a metric to analyze the value perceived by the customer as the supply of goods and services?
8. Are there procedures that allow flexibility for customer service?
9. Is there a division of the teams and the calls of customers by importance – ABC and analysis or particular strategy?
10. All valuable contacts with customers are recorded in minutes or similar?

### **A.2 PCM – Planning and materials control**

1. The PCM is responsible for planning and control of all production inputs of the company?

2. Is there a defined routine priority of PCM activities?
3. Is there an ERP information system that supports the planning materials, e.g. MRP and no analysis of the messages: Action, Exception and Correction?
4. Is there a schedule to run MRP, e.g. weekly, monthly or every 15 days, and metrics to analyze the effectiveness?
5. Is there a time horizon that the PCM plans to purchase inputs; e.g. monthly or every three months or 20 weeks of purchase orders range?
6. Is there a working definition for supply based on MTO - make to order or MTS - make to stock; or customer sales plan?
7. Is there a performance evaluation of the inputs delivery compliments the company (supplier evaluation)?
8. Is there analysis of purchasing volumes for technical ABC analysis or other?
9. Is there a systematic review on the BOM list of theory versus practice?
10. There are policy setting for Horizon Planning, Redesign, expediting and follow-up?

### **A.3 PCP - Planning and control production**

1. Are there management decisions as: quality (what to produce - design and control characteristics); Process (how to produce - facilities, equipment); Capacity (when produce - planning and programming); Inventories (with what to produce and when - requirements of materials and market); Workforce (who produce - qualification, performance, motivation)?
2. Is there a definition as Frequency: Order one or more of an order demand and the demand is constant. Variable demand. Independent demand or demand dependent?
3. The Lead time or supply time are: Lead Team Lead time constant variable and how to support management systems use: Continuous review periodic. Revision or MRP?
4. The PCP is considered along with manufacturing as strategic for the company; and working with: Production Plan. Plan Master Production Scheduling and production?
5. The PCP adopts some criteria sequencing or prioritization techniques in planning the company's production?
6. The PCP has a flow of information and interacts with areas: Production, Capacity, technology, Human Resources, Quality, Engineering, marketing, Maintenance, Logistics and Development?
7. The PCP works with forecasting techniques?

8. The PCP - controls the analysis of the standard cost of open orders and there are closures routines of orders in the month of opening and has OEE indicator?
9. The CFP has the practice of daily or weekly schedule issue and if there is time production monitoring schedule time?
10. The CFP has operations in three hierarchical levels: Strategic, Tactical, and Operational?

#### **A.4 Picking/packing/packaging**

1. Is there a practice of picking?
2. Is there the practice of Packing?
3. Is there the practice of obliterating the specifications of inputs to be released to production?
4. The packaging used obey some amount of standardization, weight, color, or other?
5. The separation or preparation of the application or request follows a priority basis the production and or PCP?
6. Is there any guidance on the practice of picking by: zone, batch or discrete?
7. Is there any validity packaging control?
8. The practice of packaging or Packing takes place in the industrial area or shipping?
9. Are there specific areas for these packaging practices?
10. Are there teams trained in these practices? And if there is time control for each operation?

#### **A.5 Order processing**

1. Are there set procedures on specific date in the month of receipt of order or forecast customer?
2. Is there a lot of tolerance and or quantity for order fulfillment?
3. The customer demands, both firm orders and forecast are processed by the customer service area and PCP or?
4. Upon receipt of applications and or forecast undergo an analysis sieve critical about the information contained in it?
5. Is there any responsibility of processing the request on the internal expediting to delivery to the customer?



6. Is there any reports on request of the situation and this feedback is sent to the client?
7. Is there the definition of a physical flow and information on the application?
8. The order processing system influences the PCP or logistics performance as a whole?
9. The company uses some technology strategies: Edi- Electronic Data Interchange Barcode RFID- Radio Frequency Identification QR- Quick Response ECR- Efficient Consumer Response CPFR- Collaborative Planning, Forecasting and Replenishment;
10. Is there a setting to work taking into account the order cycle?

## **A.6 Receiving**

1. Are there procedure defining criteria for receiving the aspects: qualitative, quantitative, fiscal and administrative, e.g. variation of tolerance of quantity, quality criteria and time of receipt?
2. All supplies and materials are received only by formal authorization or by order?
3. Is there separation of powers between the fiscal and physical receipt?
4. Is there separation of powers of the incoming teams and warehouse?
5. Is there some defined criteria for quality assurance of production inputs?
6. Is there an area for segregation of inputs nonconforming when detected in receiving?
7. Are there different negotiations for tax problems cases: interstate, local and regional?
8. The flow of receiving inputs and or materials are balanced according to the available warehouse area?
9. Are there appropriate or docks and ramp leveler for the reception of the materials?
10. Are there standard definition pallets and loads unitized arrive?

## **A.7 Supply**

1. The supply of the manufacturing area is performed by the logistics team?.
2. Usually follows a daily schedule: OP, OM or OS?
3. The team that performs the supply meets the inputs?

4. The team practices management view?
5. Is there oriented practice of Housekeeping/5 s?
6. Usually communicate to existing higher losses in the process?
7. The team that performs the supply periodically receives training?
8. Is there control over the supply time to avoid any line stops and or machines?
9. Is there work instructions for each type of supply?
10. Is there a metric to determine the contents of delays and incorrect or supplies?

### **A.8 Warehouse**

1. Is there a procedure that meets the ISO 9000 or 14,000 or similar standards?
2. All warehouse operations are computerized with ERP system?
3. Is there any software that facilitates addressing allocation of material type: WMS or equivalent?
4. Is there a process to expedite the receipt of materials e.g. bar code or RFID?
5. The layout takes into account the minimization of the distance between the area of the warehouse and efficient supply and provides flexibility?
6. The warehouse is suitable for safety standards? And it takes into account at the time of storage: the density, selectivity, frequency output/consumption and costs?
7. The warehouse is structured with metal structures or equivalent within the technical standards and provides earning capacity allowing vertical storage?
8. There flexibility both the fixed storage as random to allow optimizing the use of available facilities?
9. Professionals working in the warehouse are trained, qualified and trained to operate equipment such as forklifts, monorails, and other equipment?
10. The warehouse professionals are aware about the importance of: store, locate, protect and preserve the materials purchased or developed?

### **A.9 Inventory management**

1. Is there inventory policy defined?
2. Is there harmony between: man versus machines versus materials and includes the integration of the materials and information flows?

3. It is known to capacity position and if there is flow control between inputs versus outputs of materials?
4. Studies aimed at harmony between the receipt flow and manufacturing supply?
5. The factory supplies: exit of warehouse supplies takes into account: the criteria: FIFO, LIFO, SHELF LIFE or other?
6. The low of the stock of inputs occur through: PICKING, GOOD, back flushing, or other?
7. Is there an ERP system that enables obtaining daily movement of input and output information?
8. Are there analyzes of: Giro, Coverage, Break, obsolescence, accuracy or automatic inventory replenishment?
9. Is it defined an inventory policy: Rotary, Cyclical, or Monthly and annual.
10. Is there specific team of executors?

#### **A.10 Movement**

1. Is there specific training for staff working with handling and movement of inputs?
2. Is there a checklist or guide to guide staff as to the appropriate local drive; attention to inputs and or equipment?
3. The movement of staff is the same answer: the receipt, allocation and industrial supply?
4. In case of handling trucks, the team has CNH or course forklift operator?
5. The staff is trained to obey some as NR or orientation CIPA?
6. Are there training program/periodic retraining the team?
7. All movements of stocks are properly recorded?
8. The movement of staff is responsible for the low inputs of stocks?
9. Is there any training on the observation of the symbols of packaging as stacking, storage and handling?
10. Is there a control or measurement standard time for handling between warehouse receipt versus plant?

#### **A.11 Information technology**

1. The Company uses a corporate ERP?

2. The company has systematically to collect, check and update information for decision making and performance?
3. The company's information system is aligned with the Strategic Planning?
4. The information system is available for the entire company and all activities are developed in the ERP environment, avoiding work in parallel spreadsheets?
5. Are there indicators available and understood by employees involved?
6. There ERP system integration with their customers through: EDI, CRM, VMI and or SAP?
7. The MRP and MRP II module is available for business?
8. The factory operating costs are closed monthly and compared with the initially foreseen (e.g. production order closure: standard estimated cost vs. actual cost occurred)?
9. Is there concern in updating and security of ERP (examples: Backup and version upgrades)?
10. Does the ERP provide: integration, speed, availability of information for decision making and the company has access management with logins and responsibilities levels?

### **A.12 Internal transport**

1. Is there a specific area to take care of this activity or if it is subject to internal logistics activities?
2. Are there monitoring the preventive maintenance of equipment?
3. In the case of trucks, repairs and repairs are carried out by specialized companies?
4. Is there an equipment replacement plan when they are with their completed depreciation?
5. The amount of internal transport equipment are adequate demand?
6. People who handle or operate and are trained and qualified?
7. The company has in its internal operations: manual operation of equipment and motorized equipment such as: strollers, manual and motorized lifts, forklifts, and others?
8. The company works with: monorail, monorails, overhead crane, conveyor belts, cranes, roller conveyors, tractors, dynamic roller conveyors?
9. Is there dangerous or flammable cargo transport, if so, follow some NR?

10. The people of this area have some equipment types: EPI and the company provides guidance on its use, compliance and aspects ergonomics?

### **A.13 WIP - work in process**

1. Is there a policy that defines the inventory level in the process: be semi-finished or finished products or raw materials?
2. There's definition to return the inputs to the warehouse when a production order and or service is interrupted before its completion in month?
3. Is there concern at the closure of production orders and or services within the pre-set period?
4. There criterion set when spare or missing inputs for conclusion of production or service order?
5. Are there practical for use of certain order input to meet other unspecified; (In the case of common items)?
6. Are there practices of use of inputs in the process, other than those specified in document production? And if so, are changed in the engineering structure?
7. Are there different control when the packages are not within specifications?
8. Is there control and segregation in the plant for not conforming items?
9. Is there concern in accountability with senior management and or sector responsible for the required inputs versus consumed/met?
10. Is there control and analyze the evolution of inputs processes in monetary values to each inventory?



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