Collection and Distribution of Wheat, Dynamic of Theprocess of Shipping to International Markets: Case Study

Ernesto A. Lagarda-Leyva
Industrial Engineering Department, Instituto Tecnológico de Sonora, Ciudad Obregón , Sonora, México
ernesto.lagarda@itson.edu.mx

***Abstract*— This article presents the case study developed over five months in an agrofood company from Southern Sonora. The problem detected was the lack of quantitative information for decision making in the processes of wheat collection, transport, and sales in domestic and international markets. The aim was to build a dynamic interface that would allow observing the quantitative scenarios in the distribution link. The method included the prior analysis of the processes of wheat collection and delivery at the Port of Guaymas to attend to the demands of Algeria, Nigeria, and Venezuela. This article only presents information from deliveries to Algeria as an international destination, where the demand varies from 49 thousand to 86 thousand tons of wheat annually; the organization was looking into how to concentrate all the quantitative information and make decisions based on possible modifications of their collection and delivery policies. The system dynamics methodology employing Stella Architect® software generated the development of a dynamic and visual user interface that allowed them to observe each of the quantitative scenarios associated with the amount of wheat that was being moved from the wheat collection centers to the domestic and international destinations. The main findings are that decision making supported by a user-friendly and visual dynamic interface allows the interested parties to modify the higher priority indicators and in thus observe the scenarios according to current and future policies in wheat distribution logistics; this establishes that the system dynamics methodology is a practical and reliable development and analysis tool for solutions in the agrofood sector.**

Keywords: *Interface, supply chain, distribution, system dynamics, wheat, agrofood, simulation.*

1. Introduction

The latest forecast of the United Nations for Food and Agriculture, known as the Food and Agriculture Organization of the United Nations (FAO), on the global production of cereals in 2016 is at 2,544 million tons, 0.6 percent (15.3 million tons) more than was calculated in 2015 and slightly above last month's forecast. The perspectives improved mainly in the case of wheat, as well as in the cases of rice and barley, while the forecast for corn production was notably reduced [1].

The same source indicates that expectations for the global production of secondary cereals were revised downwards by 8.2 million tons in 2016, which amounts to 1,316.4 million tons today. This decrease is due mainly to the deterioration of the perspectives in Brazil, where the dry weather hurt the perspectives for a second corn harvest. Likewise, the forecasts for corn production in China were cut back when hiring the plantations after the government reduced its support. By contrast, the global production of wheat in 2016 is currently set to 732 million tons, 8 million tons more than the June forecast, although still slightly below the 2015 record.

The National Chamber of the Wheat Milling Industry states that wheat arrived to Mexico in the time of the conquest through Spanish shipments that arrived with large amounts of wheat, but history documents it differently. As the journeys from the Old World to America were long, the provisions were consumed and depleted before arriving to their destination. Apparently, the travelers were not concerned about saving some seeds to plant in Mexico. For that reason, it is said that the arrival of wheat to the country was a bit delayed [2].

On the other hand, the Secretariat of Agriculture, Livestock and Rural Development, Fisheries and Food (SAGARPA) mentions that wheat is cultivated mainly in the autumn-winter cycle in Mexico, due to being highly dependent on temperate climatic conditions and needing a large amount of available water for its irrigation. It is estimated that in 2011, under normal conditions, Mexico will produce more than four million tons per month, more than the three million tons per month produced in 2010 [3].

The states of Sonora, Guanajuato, Baja California, Zacatecas, Tlaxcala, Chihuahua, and Michoacán contribute approximately 80 percent of the harvested area of this grain. Furthermore, Sonora produces approximately 50 percent of the domestic production of this grain. The domestic consumption of wheat is projected to be 6.6 million tons per month for 2011, 2.2 percent more than in 2010. Considering an estimated production of 4.2 million tons per month, it is expected that 64 percent of the wheat demanded this year will be covered by domestic production and the 36 remaining percent by imports. The sustained increase in demand

International Journal of Supply Chain Management
IJSCM, ISSN: 2050-7399 (Online), 2051-3771 (Print)

suggests that wheat is grain that has been increasingly accepted in the Mexican diet, in addition to corn.

In this context, the company under study is located in the municipality of Cajeme in the state of Sonora, denominated Southern Sonora Agricultural Organizations Association, A.C. (AOASS), which was incorporated on December 7th, 1966 as an Organization of Producers from the private sector concerned about carrying out procedures and defending the interests of its unionized producers to integrate a solid and efficient company. Currently, it is composed of seven Producer Organizations that work together to seek a better integration of the agricultural sector, with the aim of achieving greater strength.

The Organizations bring together nearly 1,440 active agricultural producers that cultivate 136,000 hectares per year on average. The predominant production is wheat; additionally, corn, safflower, cotton, sorghum, soy, garbanzo, and bean are cultivated. At the beginning, AOASS assumed the role of stewardship for the farmers, but has broadened its scope and currently participates actively in the development of plans and programs benefitting the agricultural sector, even becoming an author and executing entity of the particular aims and of its unionized members (AOASS). Solutions associated with this growth that allow them to maintain the fluidity of the wheat product supply chain for export are required.

The case study arose from the analysis carried out during three previous projects. The first project that was carried out was denominated “Priority Project Proposals for the collection, transport, and sales of Wheat in the Mayo Region,” carried out in three sections: 1) the collection process , 2) the wheat transport process, and 3) the wheat sales process [4, 5, and 6].

With the information and evidence presented in the three projects and arising from the analysis carried out in the three previous studies, the following areas of opportunity associated with the development of quantitative models are established, which allow observing the modes of behavior in the areas of opportunity mentioned in each.

1. Collection centers: The proposal is to store only what is allowed; in some collection centers, the storage amounts are excessive and in some, the production surpasses warehouse capacity. The area of opportunity is in the warehouse of each collection center in which the storage capacity is surpassed.
2. Transport: An effective transport system allows reducing losses and so increasing profit in the organization and optimizing resource with the improvement of the critical indicators found in the previous studies. It will likewise benefit its customers, who will receive the product in due time and manner. The areas of opportunity detected are in the logistics and administrative areas of the organization, as well as in the customers.
3. Sales: The development of control panels, which seeks to assess the performance of the key sale indicators and to ensure that the wheat product continues being a main contributor to the total production of cereals in the region. The detected areas of opportunity are in the shipment ports in Guaymas and the area in charge of logistics for the organization.

From the previous problem, it was possible to more accurately identify the problem in the case study, which is posed as follows: What actions must be considered to generate quantitative information in the processes of wheat collection, transport, and sales that allow decision making under different situations?

The objective proposed to respond to the problem was to build the quantitative scenarios for the processes of wheat collection, transport, and sales that allow making more appropriate decisions through the user interfaces of the Southern Sonora Agricultural Organizations Association, by employing system dynamics.

2. Literature Review

The supply chain is defined as the integration of the main functions of the business from the end user to the original vendors that offer products, services, and information that add value for the customers and other interested parties (stakeholders); it is the set of functions, processes, and activities that allow the raw material, products, or services to be transformed, delivered, and consumed by the end customer [7].

Therefore, the supply chain is in charge of establishing the functions, processes, and activities within an organization, with the aim of transforming the raw material into a finished product, and arranging its arrival to the customer for consumption; one element of the supply chain is the distribution link [8,9].

The distribution process is associated with the activities necessary to put the product in the hands of the customer or at its final destination with the aim of facilitating its purchase. This process includes the set of individuals and organizations that interact in the completion of these activities. Distribution is that part of the business activity focused on the forecast, organization, and control of the flow of materials and information from the primary supply sources to the end customer, which has five subsystems: material transport, storage, packaging, loading/unloading, and transport of finished products [10 and 11].

Logistics is the part of the supply chain process that efficiently and effectively plans, carries out, and controls the flow and storage of goods and services, as well as the related information, from the point of origin to the point of consumption, with the aim of satisfying the customer's requirements. It is possible to see logistics as that which is in charge of uniting production and market through techniques and strategies. Logistics is the art of planning and coordinating all activities and processes necessary for a product or service to be generated and arrive where and when the end customer requires it, optimizing the cost [11].

To assess the performance of the supply chain, it is necessary to measure the behavior of the indicators. Performance assessment is a tool for appraising the concrete results obtained by the occupant of a post in a determined period of time, according to the aims established for that period. It is a periodic and systematic quantitative qualitative estimation process of the degree of efficiency with which people perform the activities, tasks, and responsibilities of their posts, carried out through a series of instruments. Currently, the Society for Performance Improvement defines it as a systematic approach for improving productivity and competency that uses a series of methods and procedures related to the systems of human activity [8, 12].

Considering the definitions of logistics, supply chain, and performance assessment, methodologies such as that of system dynamics integrate the three concepts for the development of quantitative models, in which the construction of the causal relationships between endogenous and exogenous variables is allowed, as well as parameters that exist in the entire supply chain and that can be translated into certain indicators associated with the parts that make up an organization, where it can be observed that the effect upon an indicator in the supply link will affect (positively or negatively) the remaining links, and vice versa [13].

Systems theory and systemic thinking are a fundamental part of understanding organizations; with the development of models and the use of methodologies, the spectrum of applications has been widened for use in the companies' supply chains. A review of the literature to substantiate the proposal here presented is based on definitions of several important authors in this field. In 1940, it was established that a new science would systematize the parallelism of general cognitive principles in different fields of scientific and social activity, where a logical and practical leap to the natural and social sciences was assumed. This principle gave rise to the general systems theory, where analysis of the totalities and their internal interactions and the external interactions with the environment allow explaining of the phenomena that occur in the reality and also makes predicting the future conduct of that reality possible. While the mechanism saw the world sectioned into smaller and smaller parts, the systems model discovered a holistic form of observation that unveiled new phenomena and more complex structures [14 and 15].

Another approach establishes it as a way of thinking about the systems and their components. When studying a phenomenon, the objective must be identified first and only then its structure [16]. The general systems theory is to see everything as a supra system, and at the same time, to see subsystems and systems within it, with the aim of seeing a system as fully integrated as well as the interactions between them [9].

Systemic thinking is a conceptual framework, a body of knowledge and tools that have been developed in the last fifty years to make the total patterns clearer and help to modify them. Although the tools are new, it implies a extremely intuitive view of the world [20]. Systemic thinking is the abilitiy to link a limited number of variables and parameters according to their patterns of behavior in such a way that is possible to transform the complex into simple through a language of causes and effects in a time horizon in a system of human activity. Learning is the main objective, since without learning one is condemned to do the same and to obtain the same result. Linear thinking is the opposite of systemic thinking [18 and 19].

Likewise, [20], in his book on the fifth discipline, considers system dynamics as precisely that, and in this sense [21], establishes that it is a generalized methodology for modeling and studying the behavior of any type of system and its behavior over time as long as it has characteristics of the existence of delays and feedback loops. System dynamics is a tool that studies the characteristics of information feedback in industrial activity, in order to demonstrate how the organizational structure, expansion (of policies), and delays (in decisions and actions) interact with and influence the success of the company.

On the other hand, combine analysis and synthesis, providing a concrete example of systemic methodology. System dynamics provides a language that allows expressing the relationships produced inside a system, explaining how its behavior is generated, and representing this in a model as the representation of reality in its graphic, abstract, and mathematical character, which are of vital importance in determined processes or phenomena with the purpose of presenting, detailing, studying, and analyzing them. As a complement, from the perspective of the system dynamics methodology, every model is built with the aim of helping to resolve a concrete problem.

In some cases, the model allows making predictions; that is, it reaches such a level of precision that it can be used to accurately predict what values some variables will take in a previously defined instant of time. According to this use, the models do not attempt to anticipate the future, either accurately or loosely, but rather to supply elements for a disciplined reflection about how they might function in the system under study. The use of simulators such as Stella Architect® are an important support for finding solutions according to the complexity of the model, generating responses under different policies that allow observing the behavior of variables included in the model [13].

Stella Architect® and Vensim PLE Plus® softwares are employed in this research, as they contain the necessary and sufficient elements for modeling complex systems. Vensim satisfies the conditions for developing the structure of causal diagrams more simply and visually, while Stella Architect® allows capturing all mathematical relationships and the simulation is visually more powerful for creating the user interface. The model simulation is based on numerical methods such as those proposed by Runge-Kutta or those from Euler for *n* order differential equations; both are from simulation algorithms programmed to operate and provide information through the graphic user interface for quantitative observation and interaction of the variables and parameters of a model to model the wheat distribution link supply chain, considering its collection, transport, and sales in domestic and international markets.

3. Methodology

The methodology was carried out in six stages; this is an adaptation of the proposal of several authors, notably [21, 25], generating a proposal for studies in the agrofood (wheat) sector.

1) State of the art of system dynamics cases applied to the agrofood sector;
2) Mapping of the actual system of the wheat distribution process;
3) Creation of the causal diagram drawn from assumptions;
4) Creation of the Forrester diagram;
5) Simulation of the current, optimistic, and pessimistic scenarios;
6) Validation and development of the user interface.

The proposed methodology is presented in Figure 1, where each of the abovementioned stages is explained.

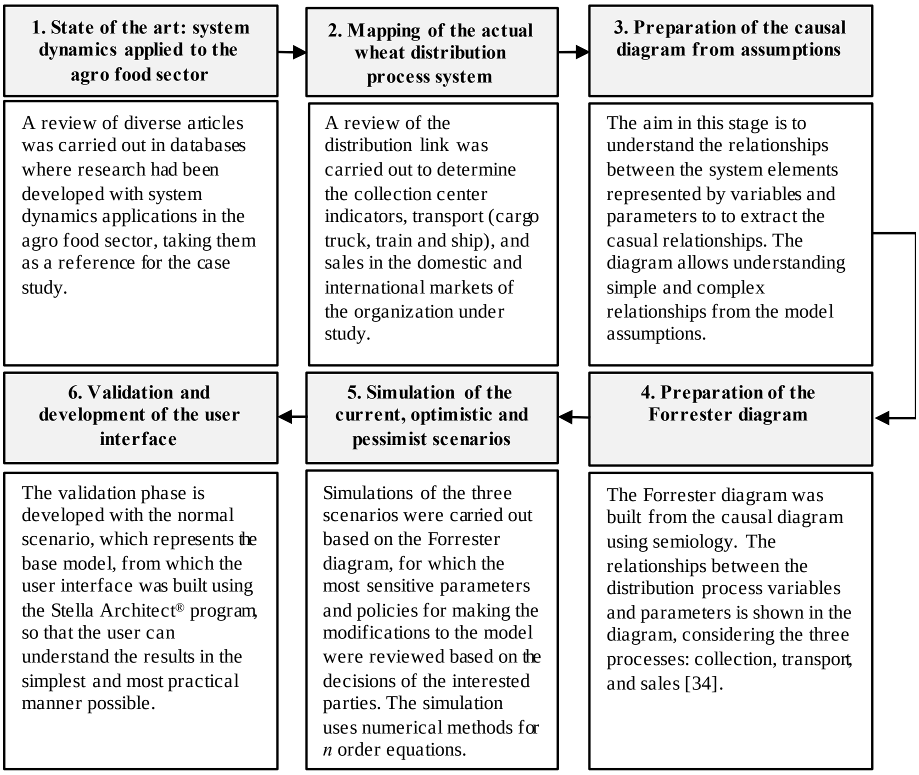


Figure 1. Procedure for the development of a dynamic model in the agrofood sector.

4. Results

4.1 State of the art

The empirical studies reviewed using the system dynamics methodology and scenarios consistent with this research show applications and the use of complex models employing the simulation for the support in decision making based on current and future policies proposed by each of the links of the wheat distribution supply chain. The information is presented in Table I and are the contributions of [22, 23, 24, 25, 26, 27, 28, 29, 30, 38, and 39].

Table 1. Empirical studies carried out through system dynamics

Author	Result
Huertas, Clavijo, and Buitrago (2011)	Set amounts related to expenses, income, and profit within the planted area to benefit the passionfruit supply chain by using system dynamics.
Lagarda (2012)	Develop a strategic planning methodology under a dynamic modeling approach and through scenarios as a proposal for the economic and social development of the regions in which the universities, companies, and government are involved.
Sanjida Binte Islam & Md. Mamun Habib (2013)	The empirical research, based on primary and secondary data, represents the overall fish distribution system of Bangladesh. This study encompasses the supply chain model of distribution of the fishing industry.
Gil and Valadez (2013)	Build scenarios that show the current relationship between the distribution and export levels of hothouse tomatoes with the aim of contributing to the creation of courses of action by the producer that lead to the improvement of such levels.
Amésquita and Chamorro (2013)	Obtain variation parameters regarding the number of hectares planted and harvested.
Rojas, Román, and others (2015)	Propose a periodic stock review policy through forecasts, coordinating many levels and minimizing costs.
Portillo and Salazar (2015)	Develop a model for the MSEs of the municipality of Cajeme that allows cold assessment of the white shrimp supply chain performance and drives decision making based on results employing the system dynamics methodology and scenarios from the secondary economic sector.
Aguilar and Castillo (2015)	Develop a wheat product supply chain performance assessment model employing system dynamics and scenarios for decision making in MSEs in Cajeme.
Noriega and Burboa (2016)	Build different quantitative scenarios to generate information that supports decision making in the planning of three new distribution routes for a chemical product in a diesel transport company.
Rodriguez-Alvarado, L., Tamayo-Meza, P., Silva-Rivera, U. (2017)	Dynamic behavior and scenario analysis of the production system on stamping line. Case study.
Farah Hanim Abdul Rahim, Nurul Nazihah Hawari & Norhaslinda Zainal Abidin (2017)	The finding of this study will be helpful to assist the government in better understand the causes and effects of the factors related to improve the policies of the production of rice in Malaysia.

The following proposal is based on the procedures set forth for the development of the success cases. The proposal was carried out in six stages in which there are indications on what was done, how it was done, and the results of their implementation; other issues associated with the abovementioned scenarios were reviewed in [31, 32, and 35].

4.2 Mapping the actual system of the wheat distribution process

In order to carry out the mapping of the actual system, the state of the art was performed; that is, research was carried out on the previous projects with the aim of obtaining information referring to the current state of the organization's distribution system. Figure 2 shows the diagram of the wheat product distribution process of the organization under study.

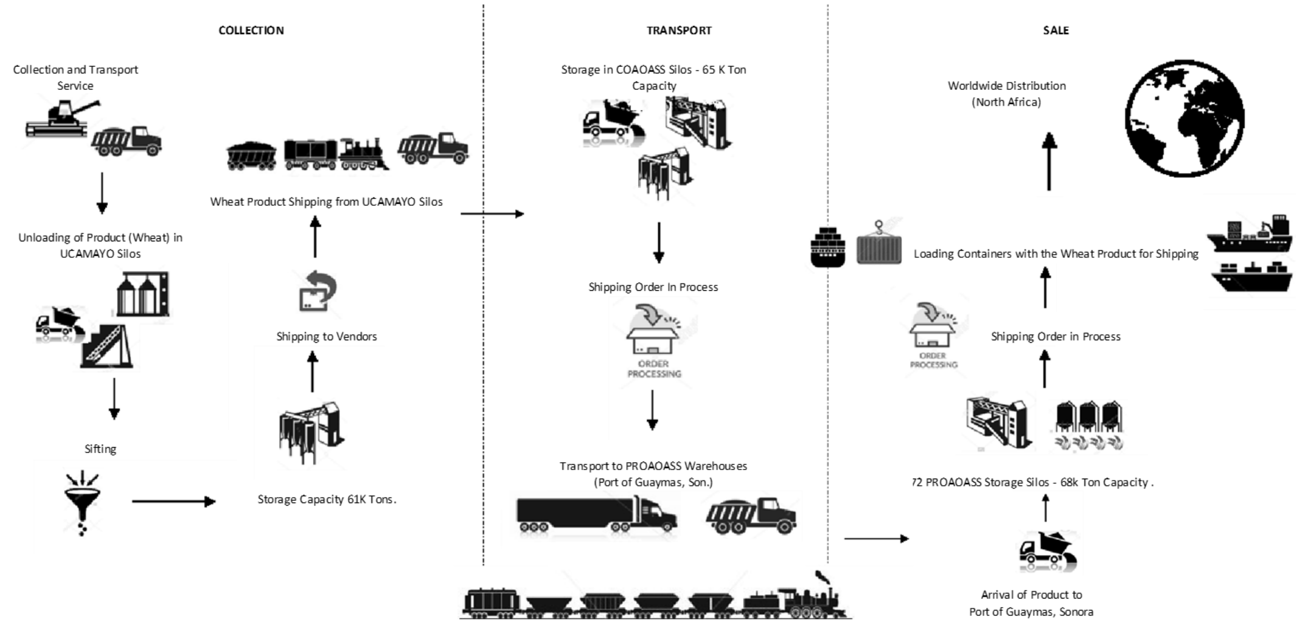


Figure 2. Flow diagram of the wheat distribution process.
Source: prepared by the author with information from [4, 5 and 6].

The wheat product distribution process consists of three stages, which will be described below:

1. Wheat collection: this stage begins when the user or the farmer requests the collection and transport service for the wheat product that has been planted on the croplands. Once the thresher hopper is filled to maximum capacity, it proceeds to empty its load into the transport trucks, which once filled are directed to unload the product at the collection center (UCAMAYO Silos). After this, the wheat sifting and selection process is carried out in the same silos in order to comply with the quality specifications, with the aim of fulfilling the storage in the 61,040-ton capacity silos with the highest quality wheat. This stage ends when the Vendor of the Southern Sonora Agricultural Organizations Association (COAOASS) issues a requisition for wheat, which is transported by cargo trucks and rail from the UCAMAYO silos to the COAOASS silos.

2. Wheat transport: This stage begins when the product is received at the COAOASS silos, as noted above. After the wheat is stored, a requisition issued by Agricultural Products of the Southern Sonora Agricultural Organizations Association (PROAOASS) is received, with the aim of shipping the product via cargo trucks and rail from the COAOASS silos to the 72 68,000-ton capacity PROAOASS silos located in the Port of Guaymas, Sonora.

3. Wheat sales: This last stage begins when the wheat product is received at the PROAOASS silos, as noted above. It is stored in the silos until a requisition is received for the product, after which the product is stored in the maritime containers to later proceed to be shipped and exported to Venezuela and North Africa (mainly Algeria and Nigeria).

4.3 Preparation of the causal diagram drawn from assumptions.

For the preparation of the causal diagram, Vensim PLE Plus® software and the causal relationships between the variables with the greatest effect on the wheat product distribution system of the organization under study were used. Figure 3, shows the causal diagram of the wheat product distribution process of the organization under study.

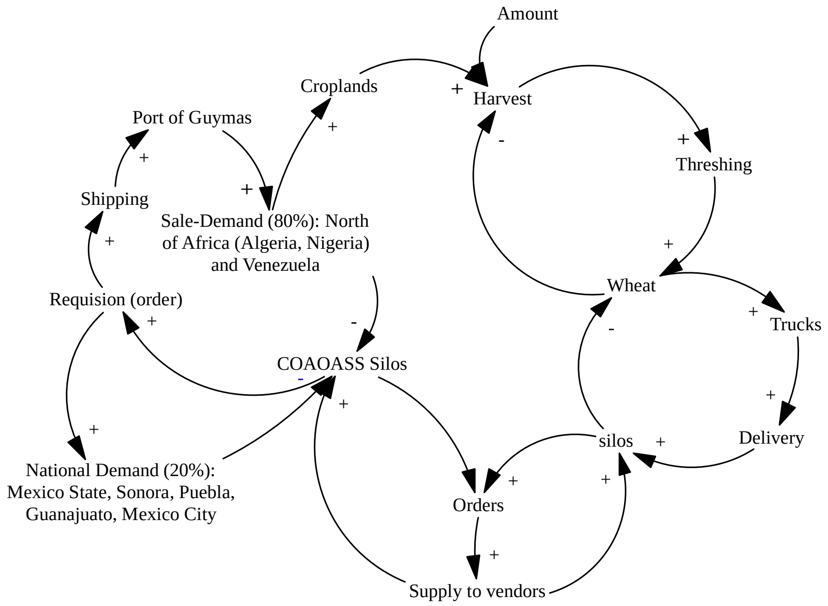


Figure 3. Causal diagram of the wheat product distribution process of the organization under study

In addition to the causal diagram of the wheat distribution process, the wheat product is distributed to the State of Mexico, Guanajuato, within the same state of Sonora, Puebla, and Mexico City, totalling 20% of production in the marketing stage in the domestic sphere. Conversely, with respect to the field international sphere, 80% of the total remaining production is distributed to Algeria, Nigeria and Venezuela.

The model assumptions were determined to be:

S1: What would happen if a "Freeze" affected 85% of a wheat crop?
S2: What would happen if the COAOASS warehouses were filled?
S3: What would happen to the excess product in the UCAMAYO warehouses?
S4: If only 50% of the forecast were delivered to the PROAOASS warehouses, how would this affect international commerce?
S5: If there were a greater demand for 2022 in the Domestic sphere than in the International sphere, how would the organization's distribution system be affected?

4.4. preparation of the forrester diagram

The causal diagram was taken as a reference for the preparation of the Forrester diagram. Figure 4 shows the Forrester diagram of the wheat product collection process in the distribution link of the organization under study, prepared in Stella Architect®. This process consists of planting, threshing, loading wheat product onto the trucks, and shipping the three different types of trucks to the UCAMAYO warehouses.

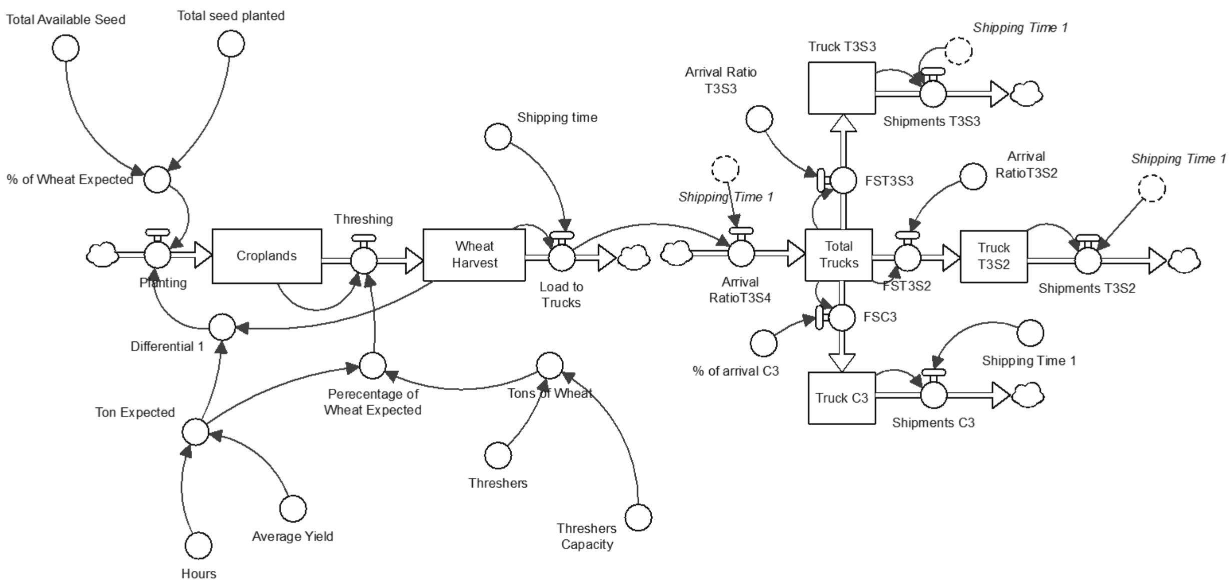


Figure 4. Threshing and truck loading processes from the wheat harvest (collection)

Figure 5, shows the Forrester diagram of the wheat product transport process, consisting of the arrival flow of the wheat product to the UCAMAYO warehouses, where the different types of trucks form to be filled with the product, some to take the product to the train container loading area, and others to take the product directly to the COAOASS warehouses. Once the product is in the COAOASS warehouses, the wheat sales requirements are analyzed to proceed to delivery to the PROAOASS warehouses via train and trucks.

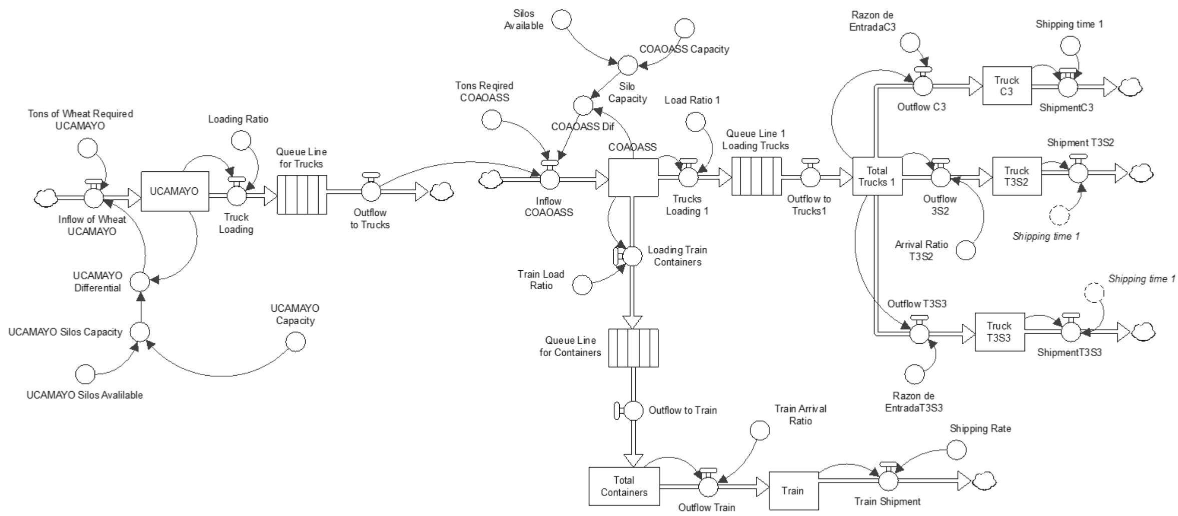


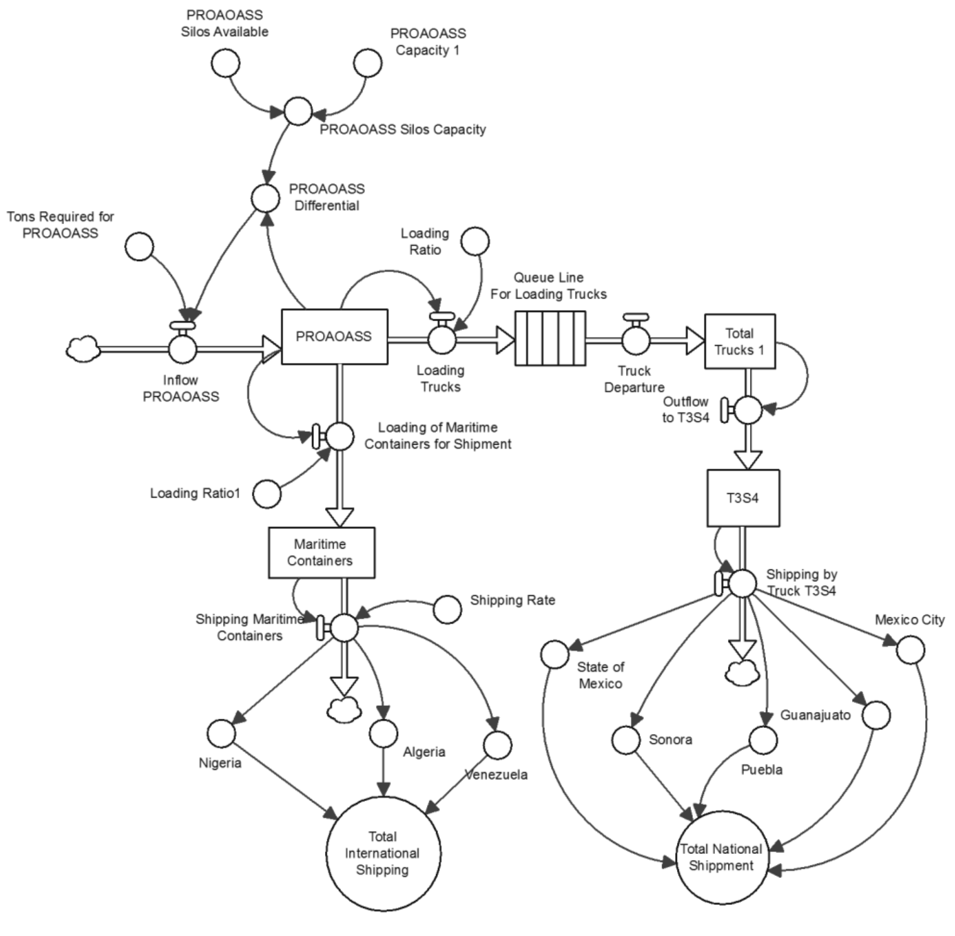
Figure 5. Forrester diagram for collection as UCAMAYO and transport to COAOASS.

As can be seen in Table 1, UCAMAYO received 66,234.96 tons of wheat the second month, PROAOASS 35,648.65 tons, and COAOASS 3,408,704.26 tons, which is continually increasing and decreasing in the different UCAMAYO warehouses, as the product is always being stocked from the croplands, and for PROAOASS and COAOASS, due to the existing demand of the different domestic and international customers.

Table 2. Tons of wheat from the different organizations in Southern Sonora

Month	UCAMAYO	PROAOASS	COAOASS
1	0.00	0.00	0.00
2	66,234.96	35,648.65	3,408,704.26
3	19,870.49	0.00	-430,352.20
4	71,673.47	31,313.71	3,870,986.15
5	21,502.04	0.00	-1,519,386.02
6	72,810.50	5,318,176.81	2,739,255.67
7	22,506.80	1,033,635.36	240,127.49
8	65,448.20	5,487,600.85	4,197,136.19
9	48,458.09	1,067,520.17	-923,657.51
10	56,079.45	4,067,553.88	3,267,033.48

At the end of the month, there is a certain accumulated value for each of the organizations and it is COAOAS who makes the final shipments to domestic and international destinations, with 3,267,033.48 tons available to satisfy the demands. Figure 6 shows the Forrester diagram of the wheat product sales process in the distribution link of the organization under study.



Figur 6. Forrester Diagram for the wheat sales process link.

This process consists of the arrival of the wheat product to the PROAOASS warehouses by the different types of trucks (C3, T3S2, and T3S3), as well as the arrival of the product shipped by train. Once the product is in the PROAOASS warehouses, the requirements of the different domestic and international customers are attended to in order to have the required product shipped to them by land and by sea, as the case may be.

The Forrester diagram connects the three structures that represent the processes threshing and harvest, of wheat collection, and of transport to domestic and international markets. Each diagram considers a set of mathematical relationships represented by differential equations employed in the model to assess the performance of each of the variables arising from the operating logic of the Forrester diagram. All the equations have been generated with Stella Architect® software, and the numerical method solution is the Runge Kutta for *n* order differential equations [36].

$$k1 = hf(ti, yi) \tag{1}$$

$$k2 = hf(ti + h\tfrac{1}{2}, yi + \tfrac{1}{2}k1) \tag{2}$$

$$k3 = hf(ti + h\tfrac{1}{2}, yi + \tfrac{1}{2}k2) \tag{3}$$

$$k4 = hf(ti + h, yi + k3) \tag{4}$$

$$yi + 1 = yi + \tfrac{1}{6}(k1 + 2k2 + 2k3 + k4) \tag{5}$$

Some of the supply chain equations are presented below, categorized by type.

Level Equations:

$$COAOASS(t) = COAOASS\,(0) + \int_0^{10} (FET - CCT)dt \tag{6}$$

Where:
COAOASS (t) = Amount in tons of wheat in the Vendor of the Southern Sonora Agricultural Organizations Association.
FET (t) = Arrival flow of the wheat.
CCT (t) = Loading of containers in Train.

$$CTEArg\,(t) = CTEArg(0) + \int_0^{10} (FEArg)dt \tag{7}$$

Where:
CTEArg(t) = Amount of wheat shipped to Algeria
FEArg = Arrival flow of wheat to Algeria

$$CT\,(t) = CT(0) + \int_0^{10} (TC - CC)dt \tag{8}$$

Where:
CT (t) = Wheat harvest.
TT (t) = Wheat harvested.
CC (t) =Trucks loaded with wheat.

$$CM\,(t) = CM(0) + \int_0^{10} (CCME - ECM)dt \tag{9}$$

Where:
CM (t) = Maritime containers.
CCME (t) = Loading of maritime containers for shipment.
ECM (t) = Shipping of maritime containers.

Inflow and outflow equations:

$$FEA(t) = STEP\,[IF(ECM * REA > TRA, Then\,TRA, Else\,DIF, 5] \tag{10}$$

Where:
FEA (t) = Arrival flow to Algeria.
ECM (t) = Shipping of maritime containers.
REA = Arrival ratio to Algeria.
TRA= Tons required by Algeria.
DIF (t) = Difference.
STEP = (Equation, time step).

$$CCME(t) = TA\,(t)/RC \tag{11}$$

Where:
CCME (t) = Loading of maritime containers for shipment.
TA(t) = Wheat collected.
RC= Loading ratio.

$$FST(t) = CT\,(t) * RET \tag{12}$$

Where:
FST = Train departure flow.
CT=Total containers.
RE=Train arrival ratio.

Equations for the Conveyors:

$$FCC\,(t) = FCC(0) + \int_0^{10} (CC - SC)dt \tag{13}$$

Where:
FCC (t) = Departure flow of flour to the packing hopper.
CC (t) = Flour Silos.
SC (t) =Response rate to Packing.

Auxiliary Equations.

$$ETI(t) = CTEN\,(t) + CTEA(t) + CTEV(t) \tag{14}$$

Where:
ETI (t) = Total international wheat shipments.
CTEN (t) = Amount of wheat shipped to Nigeria.
CTEA (t) = Amount of wheat shipped to Algeria.
CTEV(t) = Amount of wheat shipped to Venezuela.

$$DCT(t) = TEPH\,(t) + CT(t) \tag{15}$$

Where:
DCT(t) = Difference in the amount of wheat.
TEPH (t) = Tons expected per hectare.
CT (t) = Wheat harvest.

4.5 Simulation of the current, optimistic, and pessimistic scenarios

Only the current scenario of the wheat distribution process is presented in this section, from its collection to transport and sales. The graph in Fig. 7 shows the trend of three variables: the planting, the threshing, and the wheat harvest product. These variables are given for the croplands in the Valle del Mayo, Sonora.

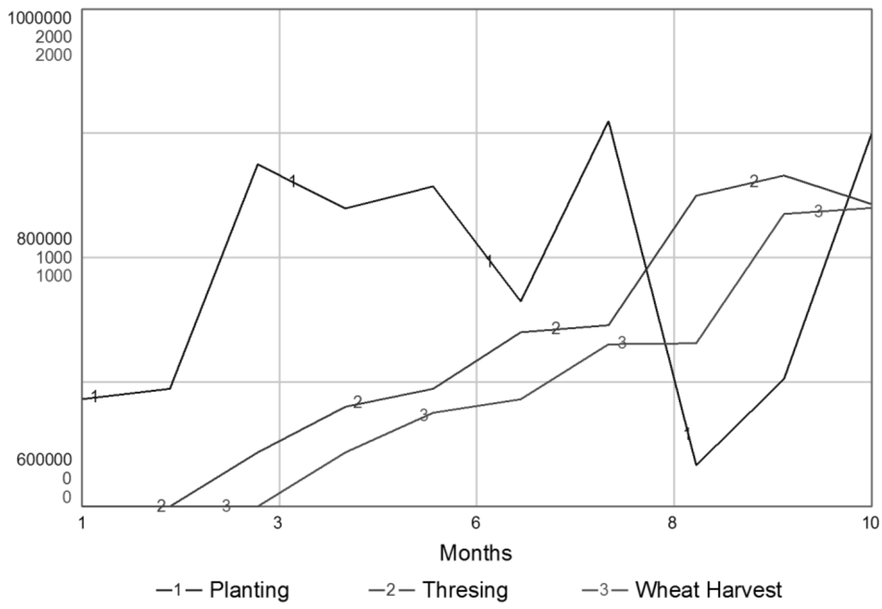


Figure 7. Behavior of the production variables in a current scenario.

The graph shows that from period 0 to period 10 there was a total accumulated planting of 899,692.34 hectares, of which an average yield of 1,199.68 tons per hectare harvested was achieved; the harvests began on the fourth month. At the end of the simulation, it is observed that the expected yields would be 1,119 tons. However, in order to avoid a decline in wheat product production, farmers should continue cultivating the same hectares, or plant more hectares of these lands in the Valle del Mayo, if possible. As can be observed, the wheat harvest begins from the fourth month and concludes in December of the same year. The data from the different scenarios show that at the end of the cycle, some are different from others due to the difference in the values assigned to the model parameters for the wheat distribution process. It can be seen that the difference between the normal and the optimistic scenario is 224.85 tons of wheat, while the difference against the pessimistic scenario is barely 149.92 tons.

Conversely, in Table III, shows the amount of product supplied to the international customers located in Algeria, for the three scenarios (current, optimistic, pessimistic); only the information from Algeria is shown to keep the data from the remaining international destinations confidential. It can be seen that at the end of the simulation (September), the tons of wheat were placed at the three international destinations, and in this sense, the optimistic scenario for the three destinations surpasses the current scenario for Algeria by 4,837.72 tons (53,214,72 – 48,377.02).

The pessimistic scenario, however, shows less (43,539.31 tons) than the optimistic and pessimistic scenarios in the month of September, which is where the accumulated data on the tons of wheat moved to international markets remain. For the purposes of this article, only the information from Algeria is presented.

Table 3. Scenarios: normal, optimistic, and pessimistic.

Scenario / Month	Current (Ton/month)		
	Current	Optimistic	Pessimistic
June	86,000.00	94,600.00	77,400.00
July	34,000.00	37,400.00	30,600.00
August	86,688.51	95,357.36	78,019.65
September	48,377.02	53,214.72	43,539.31

Notes: *Comparison of the amount of wheat product supplied to the different international customers according to the three*

4.6 Model validation and user interface

This section presents the interface designed for the users, in which by only manipulating buttons and modifying parameters, graphic behaviors and interesting data can be observed during and at the end of the simulation. The validation process was developed from a perspective of the model structure and with validation of the interested parties.

From a structural point of view of the model, it is the consistency in the operation units and logic of the dynamic model which are taken into account; from the statistical point of view, the absolute value of the mean error technique is employed, where the actual data from the assumptions created by the system are compared to the data generated by the model simulation. To this effect, [37] establishes that a model will be valid if the error ratio is lower than 5%. Error calculation is established by the following mathematical expression

$$\%\ of\ Relative\ Error\ = \frac{I(Ds - Dr)}{Dr} I * 100 \qquad (17)$$

Where:
Ds = simulated data
Dr = real data

Table 4, shows the %values of the relative error in absolute value, where it can be seen that the model presents the data from the four months below 5%.

Table 4. Model validation with a sample of the data from Algeria

Algeria (tons/month)			
Months	Simulated Data	Actual Data	% Error
June	86,000.00	82,688.51	4.87
July	34,000.00	31,234.00	8.85
August	86,688.51	85,273.00	1.69
September	48,377.02	49,000.00	1.27

Figure 7, presents the interface that will show information for the ten-month simulation period regarding the amount of wheat stored in the different collection points (UCAMAYO, COAOASS, and PROAOASS), as well as both domestic and international supply.

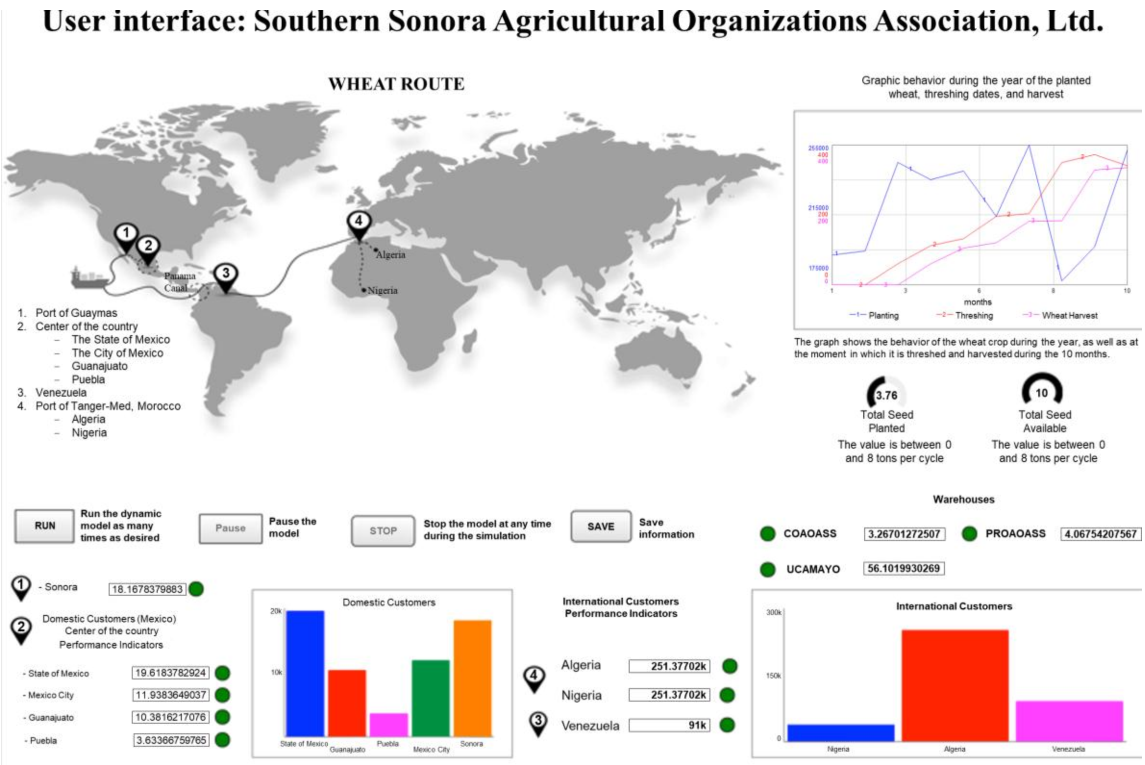


Figure 8. Dynamic user interface.

In this article, one of the dynamic interfaces built is presented. The map of the world is shown in the upper part to refer to the sales of the wheat product. The process begins at the departure by ship from the Port of Guaymas across the Pacific Ocean and the route to North Africa is through the Panama Canal. The ship makes a journey following a delivery logistics plan, first in Venezuela through Puerto La Guaira and later through the port of Tanger Med, in Morocco. This seeks mainly to supply the countries of Algeria and Nigeria with wheat from Sonora.

Conversely, domestic deliveries are made by train, mainly through the center of the country (Mexico State, Mexico City, Puebla, and Guanajuato). The remaining wheat remains in Sonora for companies in the Region; this is primarily transported on cargo trucks.

As can be seen, the interface can control the parameters, for example, that of the amount of seed to be planted for each cycle, and from there have information from the tons that could be harvested according to everything that happens in the model dynamic. The help is more visual when showing behavior graphs that are easier for the users to interpret, as they can modify parameters and know before implementing the decision about possible scenarios and anticipate events that could affect them economically. The development of the interface was carried out employing Stella Architect® software [36].

5. Conclusions and final considerations

The aim of this project was to build the quantitative scenarios for the wheat collection and delivery process that allow decision making through the user interfaces of an Association of Agriculture Organizations of Southern Sonora (AOASS). With this proposal, the interested parties have the opportunity to observe the different modes of behavior of the wheat product, from the collection process to the sales process.

With the proposed model reference, the companies in the region of the municipality of Cajeme with a line of business similar to that of the organization under study could adapt it to obtain data under different conditions as a support in decision making associated with the behavior of the distribution process.

From the theoretical point of view, the use of modeling and dynamic simulation represents a useful tool for decision making based on the consideration of exogenous and endogenous variables, as well as reference data present in the production systems. The use of general systems theory and systemic thinking approaches are fundamental for developing dynamic models and better understanding the use of the methodology employed in this case study. The creation of the interface is a way to provide the interested parties with information more simply and understandably through the use of buttons, controllers, and graphs, so that they can manipulate it and make decisions based on data.

From a practical point of view, the model allows concluding that the AOASS has the capacity to attend to the demand for its international customers, who were 80% (380,623 ton/year), and for the remaining 20% (95,155 ton/year) for the domestic markets (Mexico City, State of Mexico, Puebla, and Guanajuato as the main destinations) in 2016. The model is a support to improve the scheduling of shipments; likewise, it can be seen in the interface how the collection centers have sufficient capacity to attend to current and future demands.

The deliveries from PROAOASS as an end warehouse in Southern Sonora maintain sufficient wheat in stock to supply their main customers, both domestic and international, which prevents the delivery system from being an at risk element to satisfy the markets.

6. Acknowledgments

The author, as part of the National Laboratory in Transportation and Logistics-Consolidation Systems, the author is grateful for the support received through the National Science and Technology Council of Mexico (CONACYT) through the "National Laboratories" program. This Publication was funded with PFCE 2018 and as a part of PROFAPI-ITSON).

7. References

[1] FAO. *Nota informativa de la FAO sobre la oferta y la demanda de cereales*. Obtenido de Organización de las Naciones Unidas para la Alimentación y la Agricultura: http://www.fao.org/worldfoodsituation/csdb/es/, (07/07/2016)

[2] CANIMOLT. *Camara Nacional de la Industria Molinera de Trigo*. Obtenido de CANIMOLT: Camara Nacional de la Industria Molinera de Trigo: http://www.canimolt.org/trigo/tipos-de-trigo/estados-unidos, (8/06/2016)

[3] SAGARPA. *Secretaría de Agricultura Ganadería del Desarrollo Rural pesca y Alimentación.* Obtenido de SAGARPA: http://www.sagarpa.gob.mx/agronegocios/Documents/estudios_economicos/escenariobase/perspectivalp_11-20.pdf (11/03/2011)

[4] Calleros, R. L. *Propuesta de proyectos prioritarios para la distribución del trigo en una comercializadora de la región*. (Tesis de Licenciatura) Instituto Tecnológico de Sonora, Ciudad Obregón, Sonora, México, 2016.

[5] Campoy, M. *Propuesta de proyectos prioritarios para el acopio de trigo en la región del Mayo*. (Tesis de Licenciatura) Instituto Tecnológico de Sonora, Ciudad Obregón, Sonora, México, 2016.

[6] Cabrera, A. *Propuesta de proyectos prioritarios para la comercialización de trigo del sur de Sonora*. (Tesis de Licenciatura) Instituto Tecnológico de Sonora, Ciudad Obregón, Sonora, México, 2017.
[7] Lambert, D., & Stock, J. *Strategic Logistics Management*. Irwin: Mc Graw Hill, 2011.
[8] Lagarda, E.; Bueno, A.; Cedillo, M.; & Velarde, J. (2018). Caso de estudio: Escenarios de la cadena de suministro de una empresa de envases de plástico, Nova Scientioa, Vol. 10 (1), No. 20, pp. 510-538.
[9] Alvarez, R & Armenta, M. *Evaluación de escenarios en el eslabón de distribución del trigo en una comercializadora de granos, empleando dinámica de sistemas* (Tesis de Licenciatura) Instituto Tecnológico de Sonora, Ciudad Obregón, Sonora, México, 2017.
[10] Gómez, J. M. *Gestión logística y comercial*. España: Mc Graw-Hill, 2013.
[11] Hussain, M., & Drake, P. R. (2011). Analysis of the bullwhip effect with order batching in multi-echelon supply chains. International Journal of Physical Distribution & Logistics Management, 41(10), 972-990.
[12] Crone, S. (s/f). *Distribución y logística*. Obtenido de http://www.distribucion-y-logistica.com/logistica/definiciones/logistica-definicion.html (03/06/2014)
[13] Lagarda, E., Portugal, J., Velarde, J. M., Aguilar, G., & Castillo, I. *Evaluación del desempeño en la cadena de suministro del producto trigo-harina*. En Cedillo-Campos, conferencia llevada a cabo en el Cuarto Congreso Internacional de Logística y Cadena de Suministro, AML, Merida, Yucatán, México, 2016.
[14] Johansen, O. *Introduccion a la Teoria General de Sistemas.* México: Limusa, 1993.
[15] Bertalanffy, L. V. *Teoria general de los sistemas. Madrid*: s.l. Fondo de Cultura Economica de España, 1976.
[16] Churchman, C. W. *El Enfoque de Sistemas*. México: Diana, 1973.
[17] Senge, P., Roberts, C., & Ross, R. *La quinta disciplina en la práctica: estrategias y herramientas para construir la organización abierta al aprendizaje*. Buenos aires: Granica, 2006.
[18] Lagarda, E. *Simulación de la cadena de suministros con Dinámica de Sistemas*. Obregón, Sonora, México, (16/10/2017).
[19] Rentería, M. J. *Pensamiento sistémico: Paradigma Holístico*. Abstracción sistémica. Armenia, Quindío, Colombia, 2010.
[20] Senge, P. *La quinta disciplina*. Granica, (1990).
[21] Forrester, J. W. *Dinámica Industrial*. Buenos Aires, Argentina: El Ateneo, 1981.
[22] Huertas Forero, I., Clavijo Rondon, J., & Buitrago Pérez, J. A. *Modelo de Dinamica de sistemas para la cadena de abastecimiento de la granadilla en Cundinamarca Colombia*. Bogota Colombia: Universidad Colegio Mayor de Nuestra Señora del Rosario, 2011.
[23] Amésquita López, J. A., & Chamorro Salas, K. M. *Dinámica de sistemas aplicado al análisis de cadenas productivas agroindustriales en el departamento de Bolívar*. S&T, 2013.
[24] Rojas Zuñiga, F., Roman Luza, D., Farias Soto, P., & Coluccio Piñones, G. *Propuesta de abastecimiento de medicamentos coordinando multiniveles de demanda.* Un caso ilustrativo Chile. Chile: Elsevier, 2015.
[25] Lagarda Leyva, E.A. *Propuesta metodológica de planeación estratégica bajo un enfoque de modelación dinámica y por escenarios,* (Tesis de Doctorado), Instituto Tecnológico de Sonora, 2012.
[26] Portillo Rentería, R., & Salazar Hernadez, C. *Evaluación del desempeño de la cadena de suministro con dinámica de sistemas y escenarios del camarón de agua dulce de las pequeñas y medianas empresas de Cajeme en el sector secundario* (Tesis de Licenciatura). Instituto Tecnológico de Sonora, 2015.
[27] Aguilar Valenzuel M.G. & y Castillo Rodríguez M.I. *Evaluación del desempeño de la cadena de suministro con dinámica de sistemas y escenarios para el producto trigo de las pequeñas y medianas empresas de Cajeme en sector secundario* (Tesis de Licenciatura). Instituto Tecnológico de Sonora, 2015
[28] Gil Gutierrez, F. A., & Valadez Garcia, J. F. *Generación de escenarios referentes a la distribucion de tomate invernadero* (Tesis de licenciatura). Instituto Tecnológico de Sonora, 2013.
[29] Noriega Aguilar, A., & Burboa Pacheco, L. I. *Construcción de escenarios cuantitativos para la unidad de negocio transportadora en una empresa local* (Tesis de licenciatura), Instituto Tecnológico de Sonora, 2016.
[30] Rodriguez-Alvarado, L., Tamayo-Meza, P., Silva-Rivera, U. *Dynamic behavior and scenarios analysis of the production system in a stamping line, case study.* Dyna, 92(5). 487-488. DOI: http://dx.doi.org/10.6036/8319, 2017.
[31] Ramírez, S. *Modelización de una cadena de abastecimiento (supply chain) para el sectror textil-confeccion en el entorno colombiano.* Universida Nacional de Colombia, Facultad de Minas. Medellín: UNC, 2010.
[32] Lagarda, E., Coronado, E., Portugal, J., & Cinco, J. (2013). *Grupo Latinoamericano de Dinámica de Sistemas.* Recuperado de XI Congreso Latinoamericano de Dinámica de Sistemas: http://www.onceclads.com, (4/10/2014)
[33] Arvis, J., Savslasky, D., Ojala, L., Shepherd, B., Busch, C., & Raj, A. *Connecting to compete 2014, trade logistics in the glogal economy*. The World Bank. Washington DC: The World Bank, 2014.
[34] Tseng, Y., Wang, W., & Weiyang, M. *A System Dynamics Model of Evolving Supply Chain*

Relationships and Inter-firm Trust. Tunghai University, Taiwan, Business Administration. Massachussetts: System Dynamics, 2012.

[35] Sterman, J. *Business Dynamics: Systems Thinking and Modeling for a Complex World.* New York: McGraw-Hill Higher Education, 2000.

[36] Cervantes, A., Chiappa, X., & Simoes, N. *Manual práctico de Stella, software de modelación dinámica*. Recuperado de http://190.254.1.202/ingenieria/DCTOS_SIMULACION/manual_ithink.pdf, (19/10/2017)

[37] Barlas, Y., *Model Validation in System Dynamics*. The 12th International Conference of the System Dynamics Society (pp. 1-10). Scotland: Clare Monaghan and Eric Wolstenholme, 1994.

[38] Islam & Habib. *Supply Chain Management in Fishing Industry: A Case Study*, International Journal of Supply Chain Management, Vol 2, No. 2, pp. 40-50, 2013

[39] Rahim, Hawari & Abidin. Supply and Demand of Rice in Malaysia: A System Dynamics Approach, International Journal of Supply Chain Management, Vol. 6, No. 4, pp. 234-240, 2017