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Supply Chain Modeling and Simulation using SIMAN ARENA® a Case Study

Azougagh Yassine[1], Benhida Khalid[2], Elfezazi Said[3]
Laboratoire Process, Signaux, Systèmes Industriels et Informatique (LAPSSII)
Ecole Supérieure de Technologie de Safi, Cadi Ayyad University, Marrakech, Morocco

***Abstract*—The control of supply chains passes often by identification of various constraints and optimization of the different links and parameters associated to the functioning of the supply chain. To attain these goals, it is vital to get the best knowing and understanding of the supply chain diversity and complexity also to anticipate its behavior, which requires, a pertinent modeling that will offer the necessary information to evaluate the supply chain performance. The present paper focuses on modeling and simulation of a case study of a supply chain using SIMAN ARENA® Rockwell software, mainly transport and different operations in this chain. The purpose is creating the simulation models and how to use in a case study to diagnose and master the operation and functioning of this supply chain. The objective is creating simulation models to determine the performance of the supply chain by calculating the transportation time in each travel, number of travels, number of transported fertilizers and sulfur wagons and unloaded acid talks and finally the waiting times in train station, in order to optimize this performance indicators.**

Keywords*—*Supply Chain; transport; simulation; modelling

I. Introduction

Today in an uncertain economic context, the evaluation and analysis of models or experiments results allows firms in a supply chain context to measure and evaluate the performance of their supply chains and to predict their behavior and reactions to the fluctuations of their environment in terms of innovation, concurrence and competition. To evaluate this performance, it is important to use modeling and simulation techniques, which are powerful tools that have proven their ability to analyze complex systems specifically, supply chain. The performance evaluation is hard work, and the recourse of models reflecting the reality of systems and then simulating their behaviors, provides answers to conduct this work in Supply Chain. However, there is some related research of modeling using simulation especially in discrete event systems modeling and analyzing [1-5]. To the best of our knowledge, there is a deficiency of research works interesting in the modelling of supply chains, especially for a reel study case.

With regard to complete the existing works, this paper focuses to propose a conceptual approach which models the processes of a reel supply chain and developing simulation models using the simulator ARENA® [6,7]. Specifically, the logistics flows modelling in a supply chain of a real firm in the phosphate field. This study is realized by the development of models from a case study to show their interest in the analysis of logistics systems performance.

The present manuscript is organized as follows. The next section presents a basic terminology necessary to conduct this work. Third section exposes a review of different supply chains modelling approaches in the scientific literature. Fourth section shows a review of simulation approaches and tools. The Fifth section describes the conducted supply chain case study and, the adopted simulation models followed with Conclusion in Section Six.

II. Basic Terminology

In order to better understand and realize the context of this work and to provide the groundwork for the subsequent study, key terms are defined.

A. Logistic

Logistics is the management of the different flows (physical, information and financial) of an organization in order to prepare resources that correspond to well-defined needs [8,9]. Therefore, it is the set of operations that provide the right product, at the right time, in the right place and with the right cost.

B. Supply Chain

The supply chain is an evolution of the logistics concepts. It integrates management on upstream and downstream of the company (e.g. suppliers, manufacturers, distributors, third-party logistics providers, and retailers) to cover all the physical, information and financial flows [10, 11]. The supply chain is defined as the sequence of steps (see Fig. 1) in the production and distribution of a product from suppliers of suppliers of the producer to the customers of its customers.

The supply chain can be defined as a set of links or interdependent enterprises coordinating themselves in the execution of the supply, production and distribution activities [12] to ensure the products or services circulation from the conception to the end of life.

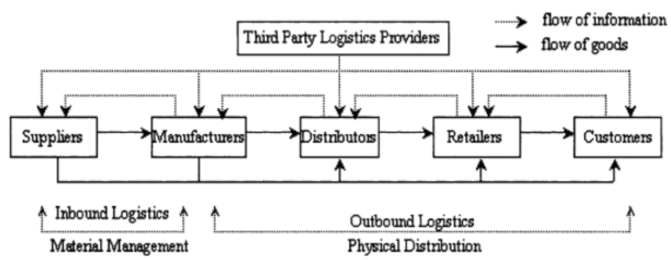

Fig. 1. The Supply Chain Structure.

III. Review of Supply Chains Modelling Approaches

In view of a wide choice of the supply chain notion, there are several taxonomies of modelling approaches used to describe and analyze the supply chains. Diverse researches in the literature interest to this kind of works [11, 13-22]. The principal classification of these modelling approaches is presented in the studies of Labarthe [18, 19] which classify these models in three main approaches as follows (see Fig. 2): the analytical approaches, the simulation approaches and the organizational approaches.

The study conducted in this paper presents a development of a simulation models for representing the comportment and dynamic of a reel supply chain. These models belong to the simulation approaches.

The simulation approaches [18, 19] represent supply chains using a set of methods, techniques, and mechanisms to present, to reproduce and to simulate, the behavior of a real system. Almost of supply chains simulation works is based on discrete event models.

The literature on modelling of many types of systems by simulations models is particularly wide. Several works and studies discuss this kind of problems on supply chains modelling and simulation. A few review researches are presented below:

- Chafik Razouk [1] proposes a new handling operation's design and simulation of empty containers using ARENA®.
- Bensmaine et al. [23] proposed a case study of supply chain simulation using ARENA®.
- Dhanan Sarwo Utomo [24] proposes a fuzzy chance-constrained programming model to include uncertainty in the biogas supply chain design problem.
- T.M. Pinho [25] proposes an approach and application to organize diverse planning levels and event-based models to control the forest-based supply chain using SimPy simulation tool.
- Malin Song [26] proposes a study to simulate a land green supply chain based on system dynamics and policy optimization.
- Sameh M Saad [27] proposes a framework integrated mathematical and simulation modelling techniques for planning and optimising petroleum supply chain.
- Fu [28], Boesel [29] and Abo Hamad [30] propose a framework using simulation and optimization in order to evaluate and ameliorate the supply chains performance.

The conducted review shows that supply chain modelling is of very interest to the researcher community. As a consequence, modeling, a case study of a reel supply chain using ARENA® simulation models are little used.

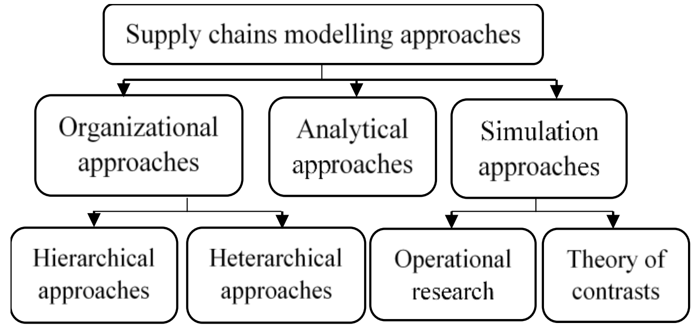

Fig. 2. Supply Chains Modelling Approaches.

IV. Simulation Approaches

A. Simulation Methodology

Simulation is a process with three mains iterative and interrelated components (see Fig. 3):

- System identifying: In this first step, the system is defined and the necessary data, of the system to simulate, are collected.
- Model design: It is about proposing the tools and structure of models using in the system to simulate.
- Model execution: In this step, the evolution of the conceived model is identified.
- Execution Analysis: Tests are done, on the model data, using specific analyzes. The most basic analysis would simply be to look at the data and derive conclusions from it.

B. Supply Chains Simulation Tools

Define the literature on supply chains modelling is mostly extensive, there are several tools and methods to approach simulation [31, 32] according to the case study, using:

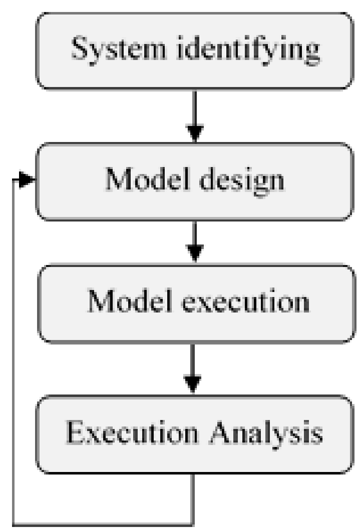

Fig. 3. Simulation Methodology.

- Specialized software: ARENA®, SIMIO®, WINISK®, EXTENDSIM®, Witness®.
- Simulation languages: SIMULA, SIMAN, GPSS, QNAP2.
- Libraries for simulation: JAVASIM, C ++ SIM
- General programming languages: C, JAVA, DELPHI

In this study, a specialized software is chosen, which offers the possibility to describe the models graphically, as a result avoid writing thousands of lines of programming code. For this purpose, the choice of simulation tool, depends on its characteristics beside the other simulation tools, discussed in the study of Dias et al. [33] and Yuri et al. [34], especially in the work of Tewoldeberhan [35] whose reports a benchmark survey of simulation tools by evaluating, a package of discrete-event simulation software, according to the following criteria: vendors, model development, input modes, testing and efficiency, execution, animation, output, user, experimental design and coupling simulation-optimization, as presented in Table 2.

According to Table 2, which presents the results of the benchmark study according to the selection criteria, it appears that ARENA® Rockwell Software [7] is the most powerful tool in this study, which justifies its use in many simulation studies. For these reasons, ARENA® is the tools to model and simulate the case study.

ARENA® is a simulation software based on the SIMAN language originating from two words "SIMulation and ANalysis". This language provides the ability to graphically describe the model using d a scheme, which allows avoiding writing programming thousands of lines of code.

V. Supply Chain Case Study

A. Phosphate Case Study Description

The system studied in this paper is a phosphate supply chain constitute on multi-sites of production and a logistic platform at seaport. The distance between those entities is 13 km. The following Fig. 4 presents the configuration of the studied supply chain.

The production sites transform the raw materials in goods (Phosphate and Sulfur to phosphoric acid and fertilizers) which are transported to and from the logistic platform, which are designed for exporting goods and importing raw materials [36, 37].

The products transportation is done normally by trains 24/24 hours. Exactly by 3 reams towed by 2 locomotives, the first one to transport fertilizers ream, the second ream is mixed to transport Sulfur and phosphoric acid. Table 1 summarizes the equipment available for transportation.

This supply chain is known for its logistical limitations due to many constraints. The main constraint is the distance between production sites and logistic platform, and existence of a single rail for transportation. The aims of this study of modeling is to control and diagnose the supply chain performance of the case study, by relying on the product transport process, which represents a bottleneck and restricts the supply chain ability to provide the necessary products in the various entities of this chain quantities.

B. Simulation Models

Using ARENA® SIMAN Rockwell software, the global simulation model of the phosphate supply chain (see Fig. 5) is constructed by connecting the appropriate blocks of the simulation tool, which shows the physical flows on this supply chain. In order to organize models, a various sub-model is used that constitute every part of the studied supply chain, and to avoid cluttering the models with links between the sub-models and the different blocks, a 'route' and 'station' blocks is used.

The initialization sub-model presented in Fig. 6 groups all modules responsible to generate the several entities in this supply chain exactly reams, locomotives, wagons, tankers and products that are presented in Table 1.

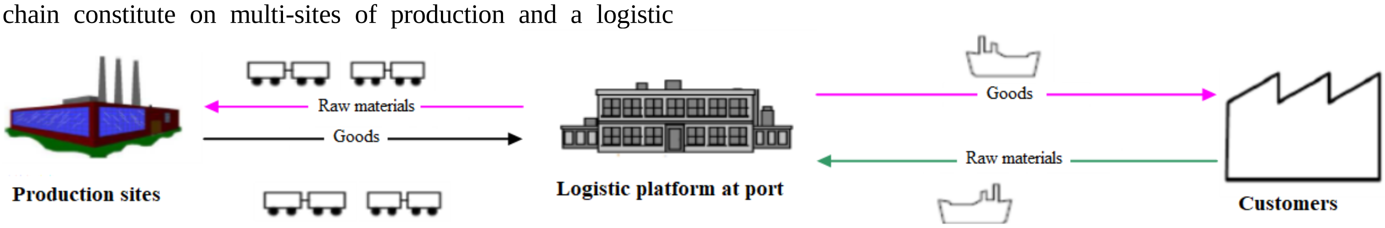

Fig. 4. The Supply Chain Studied.

TABLE I. Transportation Equipments

For the products	Available wagons	Divided reams	Transportation locomotives	Handling locomotives
Phosphoric acid	19	3	1	1 in production sites.
Sulfur	12	3		
Fertilizers	24	2,5	1	

TABLE II. RESULTS OF BENCHMARK STUDY OF SIMULATION TOOLS

Criteria	Weights	ANYLOGIC	ARENA	AUTOMOD	ENTREPRISE DYNAMICS	EXTEND	FLEXISIM	PROMODEL	QUEST	SIMUL 8	WITNESS
Vendors	5,70	1,10	3,10	2,51	2,00	2,68	2,01	2,01	3,01	2,23	3,01
Development of models & data inputs	9,40	2,99	2,61	2,29	2,60	2,70	2,69	2,01	3,01	2,50	2,49
Coupling simulation and optimization	8,00	2,50	2,50	2,70	2,60	2,50	2,50	2,70	2,50	2,50	2,50
Simulation execution	7,70	2,01	2,01	2,10	2,34	2,20	1,99	2,01	2,49	1,95	2,01
Animations	6,20	2,49	2,66	2,90	2,32	1,32	2,99	1,67	3,01	1,01	3,01
Testing and efficiency	7,50	1,90	2,39	2,60	2,40	2,29	1,49	2,01	2,49	1,8	2,01
Data Outputs (results)	6,70	2,59	2,32	1,90	1,66	2,23	2,69	2,01	2,01	2,69	2,01
Experimental design	5,80	2,01	2,99	2,10	2,01	2,11	2,03	3,01	2,01	2,01	2,01
Users experience	5,70	1,10	2,01	2,01	1,61	2,49	1,49	1,94	1,01	2,99	2,45
Points total		**134,82**	**156,44**	**147,45**	**139,**00	**144,33**	**140,07**	**134,84**	**152,84**	**137,71**	**148,86**
Benchmark rank		**10**	**1**	**4**	**7**	**5**	**6**	**9**	**2**	**8**	**3**

In order to minimize the influence of the initial conditions of the final results after simulation, that well affect the supply chain performance evaluation, all reams are assumed loaded and distributed in the entire supply chain, and both locomotives are in circulation.

Starting from the train station, the fertilizer ream goes to the production sites and the mixed ream to the port.

The fertilizer loading sub-model in production sites (see Fig. 7), is used to place empty wagons (Using the block ‘dropoff’) transported from the port to be loaded in factory station, also to tow the loaded wagons (Using the block ‘pickup’) to the port. In loading process, the wagons are placed 12 by 12 (Using the block 'decide') to be loaded one by one under two filling hoppers. Then, the full ream is placed to be connected to the locomotive (Using the block 'Hold') to route it to the port.

The fertilizer unloading sub-model in port (see Fig. 8), is used to place (Using the block ‘Dropoff’) the ream, divided on twelve wagons (Using the block decide), in the two unloading naves, and to connect (Using the block ‘pickup’) the empty waiting ream (Using the block ‘hold’) to the locomotive in order to route it to the production sites.

The acid unloading and sulfur loading sub-model in port (see Fig. 9) regroups the following processes: the drop of the mixed ream (Using the block 'Dropoff') from the locomotive and separating it (Using the block 'decide') to two small reams acid and sulfur then the acid ream is directed to the unloading area (Using the block 'delay') and the sulfur ream to the loading area. At end, the locomotive tows both the full sulfur ream and the empty acid ream (Using the block 'pickup') which are waiting (Using the block 'hold') to be directed to the production site.

The acid loading and sulfur unloading sub-model in port (see Fig. 10) regroups the blocks responsible for sulfur unloading starting by introducing the full ream in the unloading area, and ends with the towing of the empty ream to form the mixed train. The process of acid loading is carried out according to two modes (Using the block 'decide') according to the quality to be loaded and the appropriate method (normal or special quality).

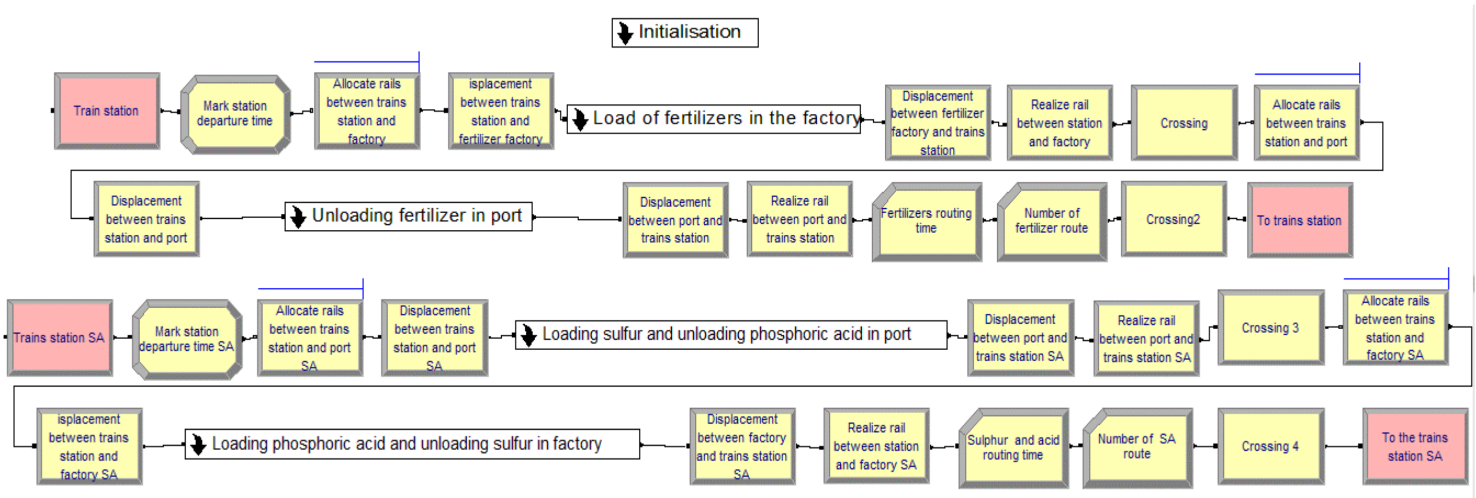

Fig. 5. Global Simulation Model.

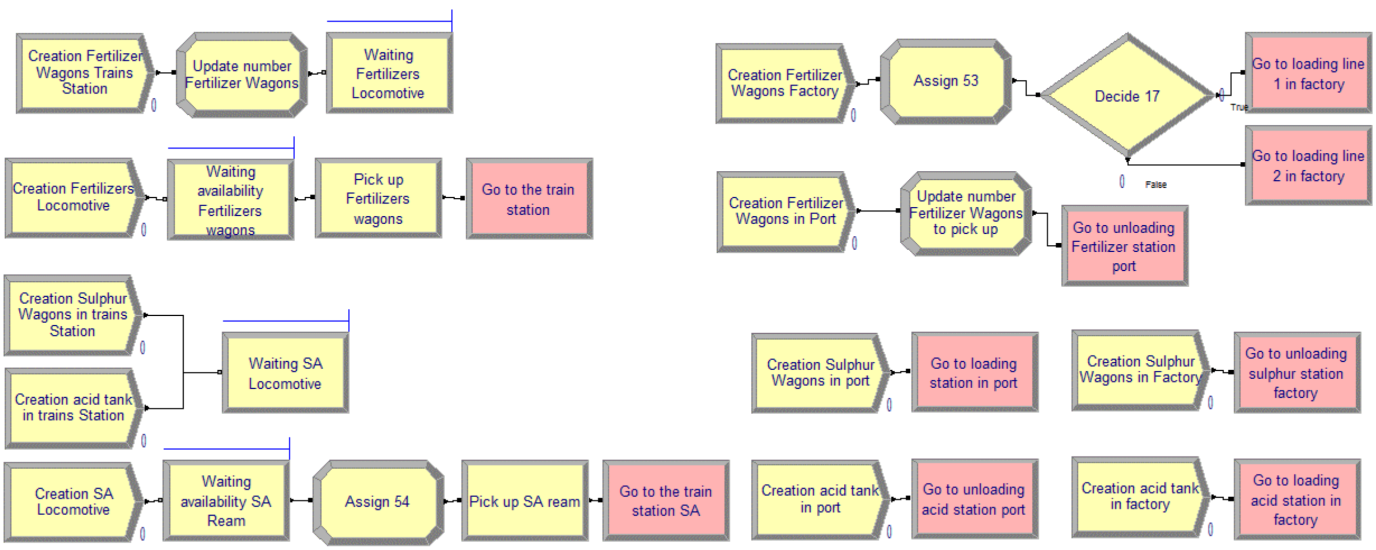

Fig. 6. Initialization Sub-Model.

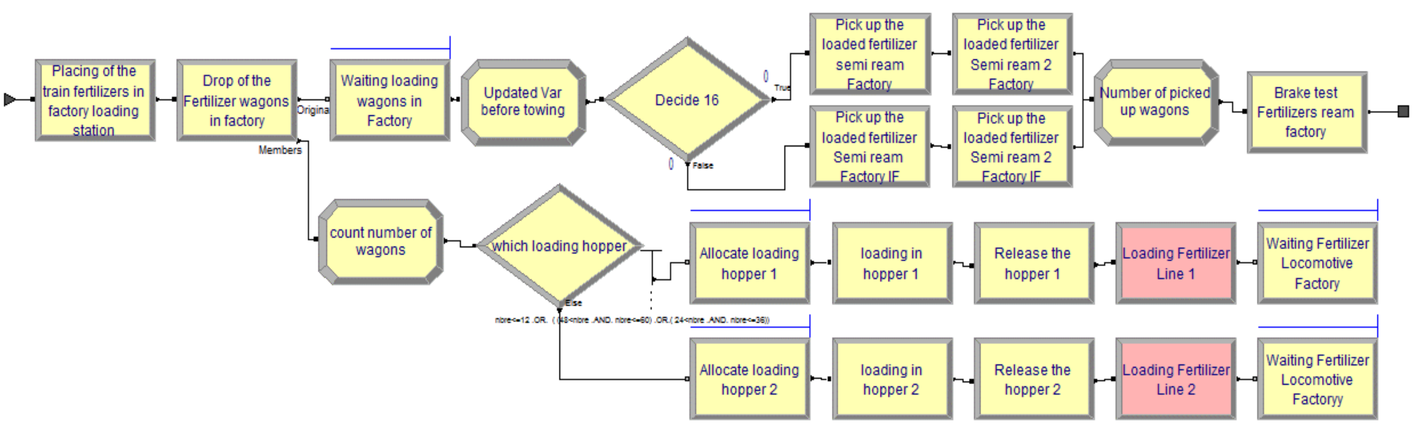

Fig. 7. Fertilizer Loading Sub-Model.

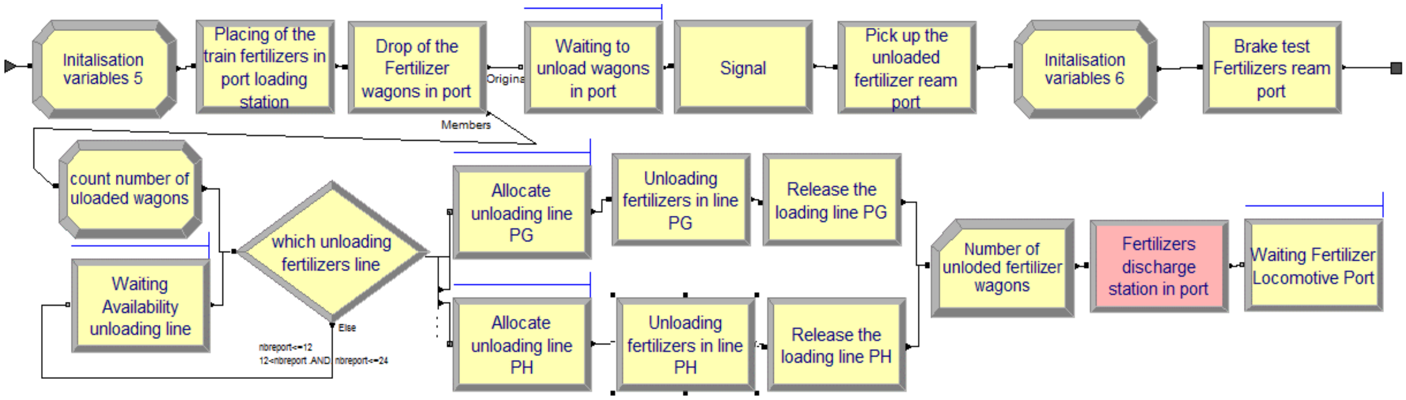

Fig. 8. Fertilizer unloading Sub-Model.

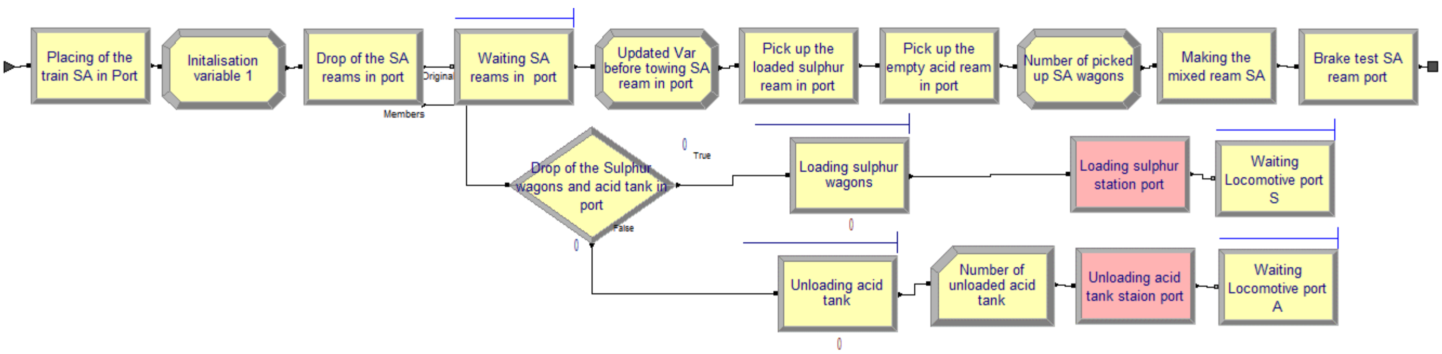

Fig. 9. Acid unloading and Sulfur Loading Sub-Model.

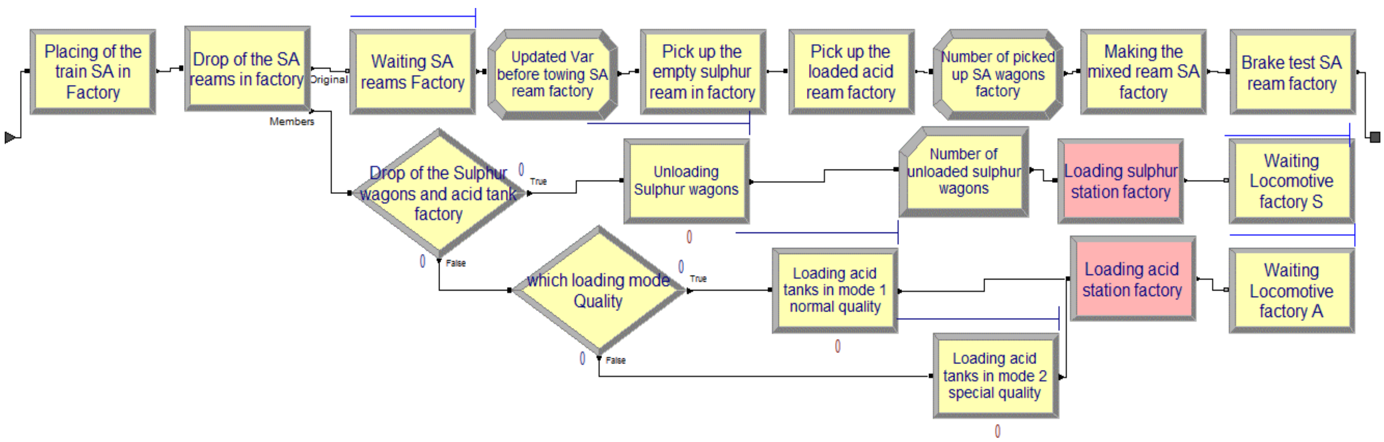

Fig. 10. Acid Loading and Sulfur unloading Sub-Model.

C. Simulation Model Validation

Before drawing any inferences from the statistical results of this simulation model, it must make sure that it is correct and represents the real supply chain. To do this, the simulation results are compared with theoretical results calculated from collected data of the lead time of each process in the studied supply chain. The compared results (see Table 3), concerns the transportation time in each travel and the number of travels done in 24 hours.

D. Simulation Results

The model was simulated over a month. The performance indicators evoked by this simulation model are the transportation time in each travel, number of travels, number of transported fertilizers and sulfur wagons and unloaded acid talks and finally the waiting times in train station. The calculated times correspond to the average of the times. The simulation results of the studied supply chain are showed in Fig. 11 and 12.

TABLE III. COMPARING THEORETICAL RESULTS AND THE SIMULATION RESULTS

	Theoretical results		Simulation results
	Min	***Max***	
Transportation time in each travel	3,42	4,17	3,76
Number of travels	5	7	5

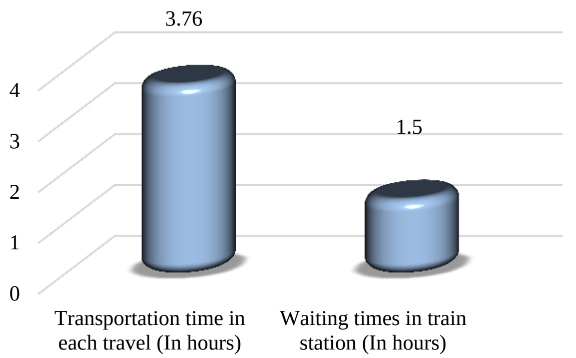

Fig. 11. Simulations results: Waiting and transportation times.

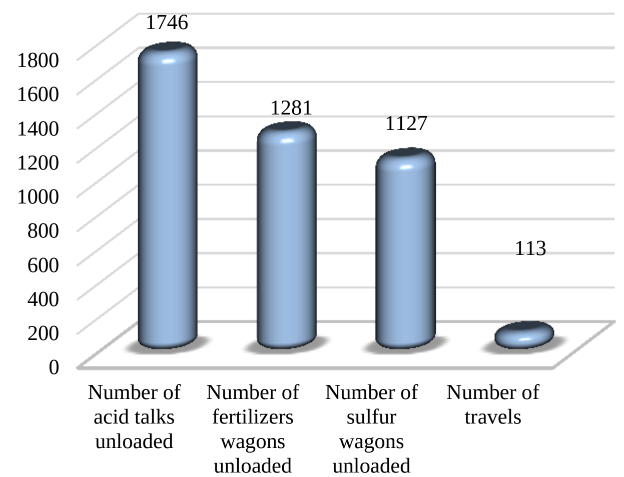

Fig. 12. Simulations results: The transported products.

Indeed, the established models are a very fine analysis of the current situation, allowing designing several optimization scenarios. The obtained results present the current performance of the studied supply chain that requires an improvement and optimization by studying several improvement scenarios in order to improve the simulation results. The mainly objective is to reduce the transportation time in each travel then to increase the number of travels, as well as the number of wagons / tanks transported, and finally reducing the waiting time in the train station.

VI. CONCLUSION

This work is a study describing simulation models of a real supply chain in operating phosphate industry using SIMAN ARENA® Rockwell software. The main objective of these models is determining a lot of performance indicators specifically the transportation time in each travel between entities of this chain, the number of travels, the number of products wagons transported, and the waiting time in the train station for the purpose to evaluate and improve the studied supply chain performance.

This work allows referring to the modeling and simulation according to the scale of complexity of the systems, with the aims to evaluate and check the system potential fluctuations and predict the future behavior.

Using the SIMAN ARENA® Rockwell software a tool for flows simulation, has become a necessity for the optimization of industrial processes and support for strategic decision-making.

Using these models, we are currently working on the study and simulation of several scenarios that can contribute to optimizing flows in this supply chain.

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