Simulation of Supply Chain Management System using Arena

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Summary
Information and communication technology offers organization to build up their business structure more creative, diligent, and smart to deal efficiently in any situation. This research is focused on analyzing the impact of latest technologies on one of the business integrated systems known as supply chain management (SCM). Collaboration, time management, effectiveness and managing demand and supply are some major tasks performed by the SCM, which works in an integrated environment. To analyze the performance of SCM, a model proposed in this study, built on the traditional working theme of SCM. Furthermore, the model validated using simulation techniques implemented with the help of Arena Simulator; a tool provides a facility to simulate the real world scenario and optimize the solutions. The results emphasized that suppliers are most important key workers in the SCM; therefore, they need more resources to perform their duties efficiently. The simulation model can help the organization to understand and measure the performance of suppliers and other stakeholders, whether the variation in selected attributes can further help for model optimization.

Key words:
Supply Chain Management; Arena Simulation; SCM model validation; performance measurement.

1. Supply Chain Management System

Nowadays, organizations are more dependent on technology due to its large impact over efficient business processes and overall growth. Supply chain management (SCM) is one of the management systems that organizes and integrates the business processes associated with suppliers, retailers and other stakeholders [1]. Apart from the major business hurdles such as dealing with competitors, increasing revenue and profit, their struggle to deal with suppliers is creating another big obstacle to beat competitor's supply chain [2]. This scenario is actually making the organization to workout on making SCM more effective and progressive.

Basically, the issues behind the performance of SCM are of many as discussed earlier by different scholars. One of the biggest challenges to build an effective SCM is the uncertainty in demand and supply and their variation based on the current market environment [3]. The solution to manage the ratio of uncertainty is discussed by [4] that it can be reduced by proper information exchange according to the sales data and correct demand prediction. Another article emphasized on the same issue that information technology is there to store and manage data centrally, which can help the organization to lessen the gap between supply and demand uncertainties and to improve the performance of SCM [5].

For the enterprises, although SCM has been playing an essential role for business development, but at the same time the collaboration in the complex manufacturing environment makes it critical to deal appropriately [6]. Distributer is another factor highlighted for SCM, which is quite challenging as well due to its vast range and connection with multiple groups [7]. For the same issue, [8] proposed an integrated distribution system based on the multi-echelon technology, where the author described that this situation can handle in multiple layers. The idea was to provide stability between inventory, demand, and supply using back up and flow metrics working in different tiers. The lack of performances in distributions has many reasons as described by [9] that it could be due to inefficient raw material sources, inventory control, flow of production, transportation issues, and all of the above information exchange and management.

The dynamic market scenarios always keeping the organizations to improve their business structure using upgraded and integrated system such as supply chain management. The dynamism has further explained in a research that it exist at different levels; (i) supply chain, (ii) organization, and (iii) organization's components [10]. It shows that dynamic environment is one of the challenging reasons, which can affect the performance of SCM over business growth. The SCM can fail if it cannot fulfill according to the variation in customer's demand [11]. In order to improve the efficiency a research proposed the scenario by combining the models of inventory and service providers [12]. The idea of controlling the dynamism has presented by proposing a system which can control the situation at three different levels; manufacturers, suppliers, and through proper decision making process [13]. Author described that the way of handling the dynamism situation at three different stages can improve the performance of SCM. Finally, it will control the flow between inventory, supply, and ultimately increase the business growth and list of benefits.

The discussion in this section describes the major functions perform by SCM. In addition, it also explained the main issues and concerns related to SCM and has been highlighted in previous researches. This study is focused on

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to overcome those issues by simulating the real world scenario of SCM using Arena simulation tool. It will help to enhance the working environment of multiple stakeholders associated with SCM, such as suppliers, retailers, wholesalers and others. The paper is further organized as follows. Section 2, defines the major simulation techniques with examples. Section 3, describes the methodology and proposed model for simulating the SCM. Section 4, illustrates the details of experiment conducted and result analysis, using arena simulation strategy. Finally, the paper concludes in last section.

2. Simulation Techniques

The purpose of simulation is to build, measure and analyze the real world abstraction model to understand its successful implementation for long run. As described by [14] that the simulation model proposed was based on knowledge based approach. The model was helpful for providing number of benefits to the partners of SCM and its stakeholders. The simulation methodology is known as modeling the real world system, convert it into computing environment, and repeat the experiment using replication parameter. After implementation and running the experiment several times, the results can be analyzed and evaluated by measuring independent and dependent variable [15]. Overall, the simulation methodology consists of multiple steps; it starts by defining the problem until real implementation as shown in figure 1.

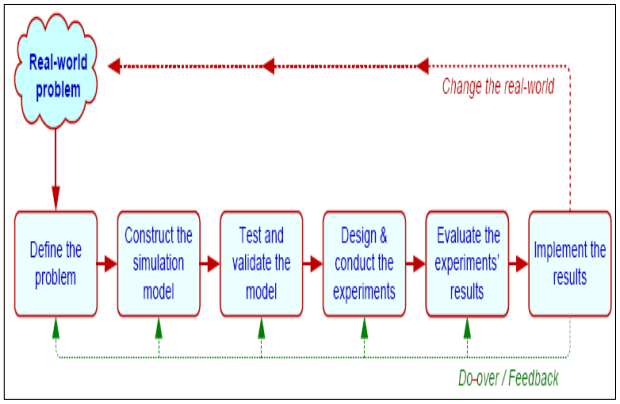

Fig. 1 Steps of Simulation Methodology [15]

Simulation can be performed using different tool and techniques such what-if analysis, spreadsheet simulation, Arena simulation as discussed in the subsequent section.

2.1 What-if Analysis

What-if analysis is a scenario based approach uses for assessing the solution by changing the attributes selected for data analysis. It helps to generate multiple solutions according to the changes occurred during the experiment. A typical example of what-if analysis can be like what will happen if increase the number of suppliers. The possible impact on sales and supply after improving the supplier and point of sale channels. What-if analysis has been used in different situation in order to analyze the decision variables by changing the independent variables [16], [17].

What-if analysis can be implemented in excel [18] or some other tools such as planners lab [19]. It can be applied using different type of variables like dependent variables, independent variables, and uncontrollable variable [15]. It has vast implementation of application related to marketing, supply chain, manufacturing, accounting and others. The assessment can perform using backwards approach (i.e. changing in decision variable creates impact on independent variables) or forward approach (i.e. modification in independent variables affects the decision variables) [15]. The results indicates the summary of changing cell in the model and their impact on decision variables as illustrated in figure 2.

Scenario Summary

	Current Values:	60% highest	70% highest	80% highest	90% highest	100% highest
Changing Cells:						
C4	60%	60%	70%	80%	90%	100%
Result Cells:						
D10	$3,800	$3,800	$4,100	$4,400	$4,700	$5,000

Notes: Current Values column represents values of changing cells at time Scenario Summary Report was created. Changing cells for each scenario are highlighted in gray.

Fig. 2 The Result Summary of What-if Analysis [18]

The result summary identifying that what will happen if we increase the percentage of profit and its impact on result cell. It can provide the facility to apply this multiple time and generate a comprehensive report of all possible changes and their effects.

2.2 Spreadsheet Simulation

Another improvement in the modeling and simulation world is known as simulation using spreadsheet. "Spreadsheet Simulation" is famous for applying simulation experiments using spreadsheet; most of the time excel. Spreadsheet simulation is useful for many purposes as discussed by [20]:

- It provides an easy environment to build logical and mathematical models.
- A platform where the financial rules and formulae embedded in spreadsheet can further improve the capabilities of the simulation model.

- A fast process to change the variables and repeat the experiment several times using data tables.

In addition, the data representation and analysis options in the form of graphs and charts can further enhance the performance of the spreadsheet simulation. As compare to what-if analysis, spreadsheet simulation has more powerful capabilities. The dynamic environment make it more feasible to build a simulation model for those who are experts in excel rather than learning a new simulator tool.
Spreadsheet modeling and simulation plays significant part on decision making for an organization. It can use for many application such as medical industry, supply chain management, marketing, finance, and manufacturing. For making decision making process, there are multiple activities can perform using spreadsheet simulation [21] as described below:

- Linear Programming
- Mathematical Programming
- Investment Plan
- Risk Analysis
- Sensitivity Analysis
- Graphs and Reports

Spreadsheet simulation model works using input and output variables, where the changes and their impact can be recalculated by refreshing the sheet. Moreover, it provides the facility to add different types of graphs to visualize the performance of independent and decision variables. At the same time sensitivity and risk analysis can enhance the decision making process before applying the system in the real world.

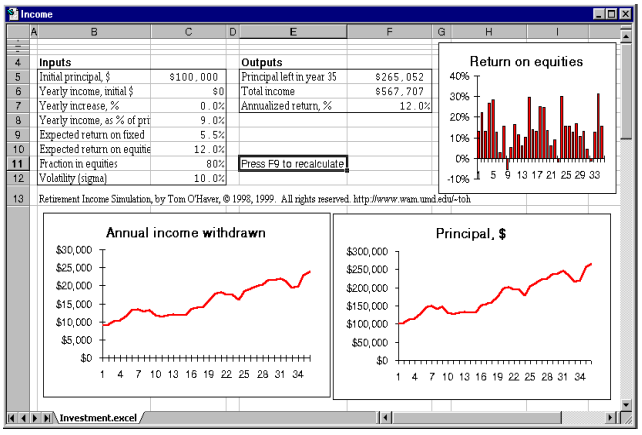

Fig. 3 Spreadsheet Simulation – An Example [22]

2.3 Arena Simulation

Arena simulation tool is an advanced tool provided by Rockwell Software Inc. [23]. The software has large implications, uses by several industries such as manufacturing, healthcare, supply chain, port & terminal, logistic, and others. The software can deal with variety of business challenges and provide solutions to simulate their business problems using fast, easy, and user friendly environment [24]. The flexibility and variability of the tool make it prominent from other simulation tools. It possesses advanced capabilities and can support other tools to be call into arena [25]. An example of data warehouse model implementation in arena is shown in figure 4 designed by [26] to understand the loading and unloading factors of orders.

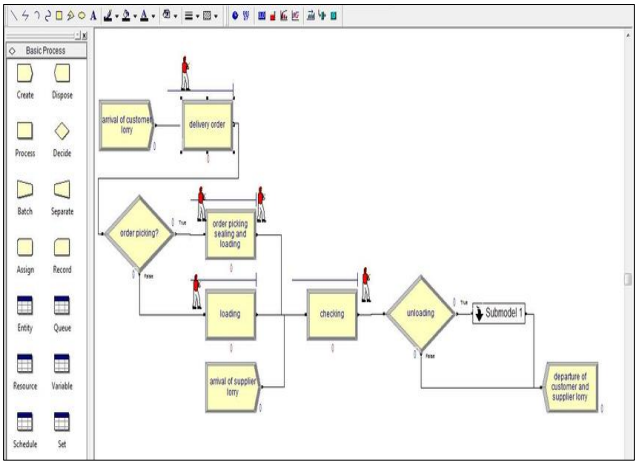

Fig. 4 Data Warehouse Implementation in Arena [26]

Based on the experience during this study, we learnt the major characteristics of "Arena Simulation Tool", as mentioned below:

- Build and replicate the real world model and analyze their behavior.
- Adding an animations and graphs to create the reality in developed models.
- Embedded objects and their connection in sequence to run the model while minimizing the chances of errors.
- Creation of data table for each entity in excel format.
- Importing UML diagram into arena to build the simulation model.
- The software provides the facility to run experiment based on working hours.
- The setup options are given where the simulation can run in different phases such as; warm-up time, actual time, and repeat multiple times as per the requirement.
- Generate report in PDF format, which further categorized based on entities, resources, and utilization of resources.

3. Methodology – Proposed Model

To illustrate the proposed idea in this study, the graphical representation of the model is shown in figure 5. The figure explained the fundamental structure of supply chain, illustrated from the discussion of previous section. As discussed in the introduction section that, SCM is the system, which integrates the multiple stakeholders that are working individually or incorporated with the business organization. Whereas stakeholders have their own characteristics and working environment as described in the following figure.

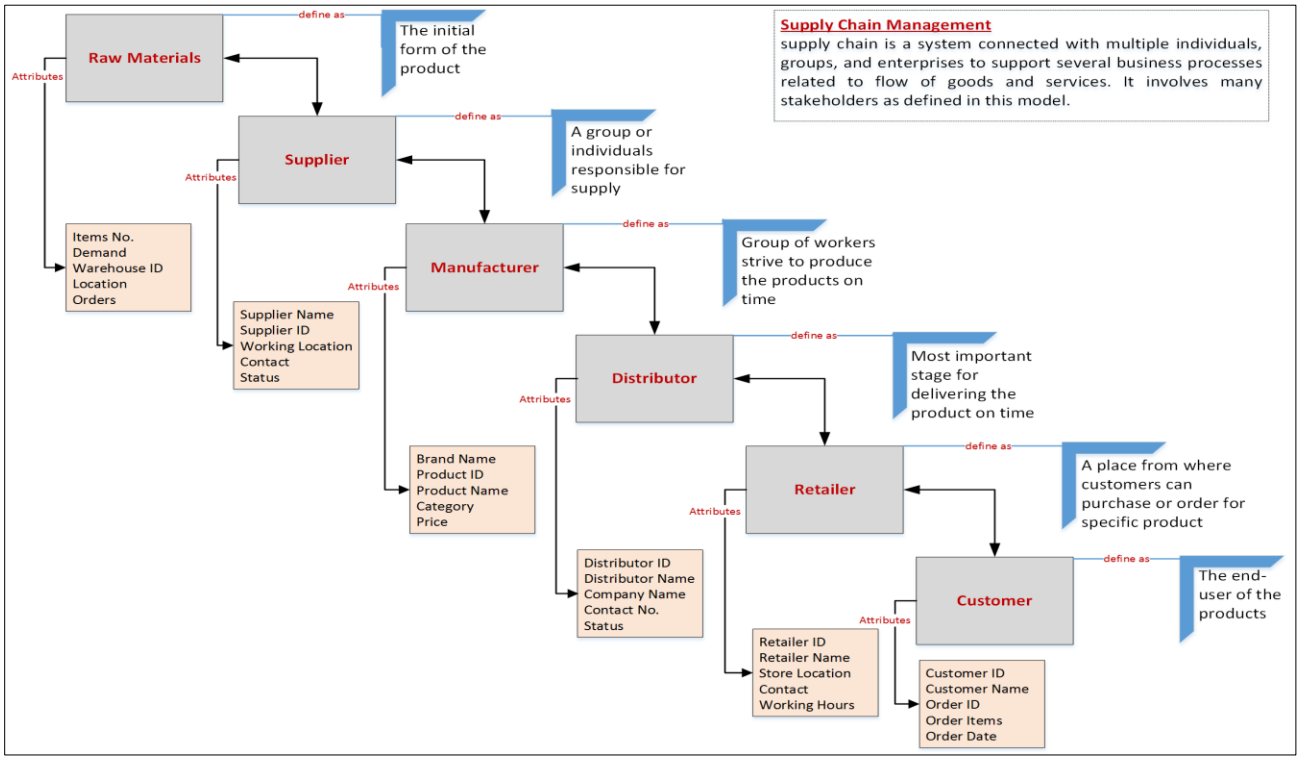

Fig. 5 Proposed Structure of SCM Model

Therefore, it can be easily conclude that the success of SCM is depends on many factors, the availability of raw material, efficient response from manufacturer, timely delivery by supplier & distributor, and finally retailer's action on each order. In addition, the performance and behavior of each entity described in the model have different criteria based on their working conditions.

The proposed model used six different kinds of collaborators working in order to complete the chain of supply. The working atmosphere of supply chain is two ways communication most of the time, means all stakeholders are connected from both corners and they can communicate with each other. Therefore, at both corners they are talking directly and indirectly with others. For more clear understanding, the description of each is described as follows:

Raw Material – considers an initial form of the product to be reached at the manufacturer. Normally, the process starts from supplier or vendors, which are responsible to supply the required items to the manufacturer based on given order. Logically, it can be further characterize using different attributes such as; item numbers, demand, location of the store, warehouse ID, and orders details. The database can be organized using those attribute.

Although, we applied the model in arena which only required sample distribution and number of product details. The event ID and required time used with the help of internal clock of arena.

Supplier – the next step in the model is to provide the items in required format to the supplier. Suppliers are the group of worker responsible to deliver the items to the manufacturer. The items are in raw format, which can further sub-categorized in inbound logistics. The main features of suppliers can be defined as; supplier name, supplier ID, location, contact, and status.

Manufacturer – the next business process of supply chain is related to department of manufacturing. The processes belong to this section is to convert the raw materials into a

complete product. The final product that needs to be gone through the complete procedure of quality control and assurance. Finally, the products need to be reached in the market with the help of suppliers/distributors. The major attributes of manufacturer are product ID, product brand information, product category, price and other details.

Distributor – this chain is further joint by list of distributors, a person or a group that proceed the supply chain process by supplying the product to the market. This group can further sub-categorized as wholesalers and sometime retailers as well. Distribution is the critical intermediary in this chain, where a small delay can give a big loss to the manufacturer and customers too. Distributors can be located by their unique ID, name and location.

Retailer – retailers can fall in the same category as distributors. Actually, in the study both of the stakeholders were taken separately as their job specifications can be quite different form each other. We consider the scenario that distributors are responsible to pick the products from manufacturers and deliver to the retailers. On the other side, retailers are the one who are sitting in the market and dealing directly with the end user that is consumer of the product. It means, most of the time if consumer have any complaint, feedback, or want to return the product, they can contact with the retailer not with the distributor. Retailers can be managed in the database using their ID, name, location of the store. Most importantly, as retailers are directly dealing with the customers, therefore their opening hours are important to be mentioned in supply chain database.

Customer – finally, the last knot in the supply chain system is known as customer or consumer of the product. The chain begins with the raw materials, until it reaches to the customer; the main purpose of producing any product. As described already, that every joint in the supply chain can communicate with other directly or indirectly. The customers mostly can coordinate with retailers and sometime (if facility provided), they can manage to talk with distributor or manufacturer. Customers are important factor of the supply chain, as order creates based on the demand and likeness received from the customer side. Therefore, we can say that the whole chain of supply system perform the tasks in order to facilitate the consumers of the product and all success and failure is depend on the acceptance and rejection of the consumer respectively.

Based on the proposed model the experiment conducted using arena in the next section. This simulation is trying to realize the working of supply chain life cycle.

4. Supply Chain Management Simulation – An Experiment using Arena Tool

Finally, using all the details and description of the SCM and proposed model, the experiment conducted using arena simulation tool. This simulation tool has advanced capabilities and provided with many functions to perform a simulation efficiently. It further strengthen the experiment by generating a comprehensive statistical and analytical report at the end of each simulation. The report is useful to understand and analyze the different aspects of the simulation such as; entities performance, resources utilization, assigning and recording user specified variables, and last but not the least time interval between different tasks.

The experiment specification provided in Table 1. Altogether, there are six different stations organized in this simulation where single or multiple workers are involve to perform their tasks. For example, the first one is "Raw Materials", which denotes the basic form of a product. The material has been sending through truck (attribute), while the sample distribution (trucks) is selected as "Random". It considering that after every hour the truck is loading and getting ready for departure. Whereas, the supplier are responsible to ship the raw materials using triangular distribution, which means they take around 1(minimum), 2(average), or 3(maximum) hour(s) for supply the material.

Table 1: SCM's each Station and their Specification

Station	Specification
Raw Materials	**Attribute:** Truck Loading **Distribution:** Random **Entities per Arrival:** 1 **Time Between Arrival:** 1 hour
Supplier	**Resource:** Supplier **Distribution:** Triangular **Process Time:** (1,2, or 3) hour
Manufacturers	**Resource:** Manufacturer **Distribution:** Triangular **Process Time:** (1,2, or 3) hour
Distributor	**Resource:** Distributor **Distribution:** Triangular **Process Time:** (1, 2, or 3) hour
Retailer	**Resource:** Retailer **Distribution:** Triangular **Process Time:** (1, 2, or 3) hour
Customer	**Resource:** Customer **Distribution:** Triangular **Purchasing Time:** (1, 2, or 3) hour
User Specified Variable	**Trucks Loading Time:** To calculate the time interval
User Specified Variable	**Products Count:** Number of Products Failed during inspection or reached to the customer

4.1 Model Implementation in Arena and Result Discussion

The simulation was designed and run using arena simulation tool. The screenshot of design window is showing in figure 6, which highlighting the series of entities connected with each other in proper sequences. The order

of connected boxes is according to the proposed model shown in figure 5. In arena, the arrangement and classification of entities is very important, as the process run from left to right direction (as per displayed figure), where mismanagement of arena modules can disrupt the output of simulation.

In this simulation, the supply chain is consisting of six major stakeholders; raw material, manufacturer, supplier, distributor, retailer, and customer. As per the previous discussion, for every delivery the supplier is working and logically it is in between of raw material→manufacturer and manufacturer → distributor. According to the figure we use supplier at once only.

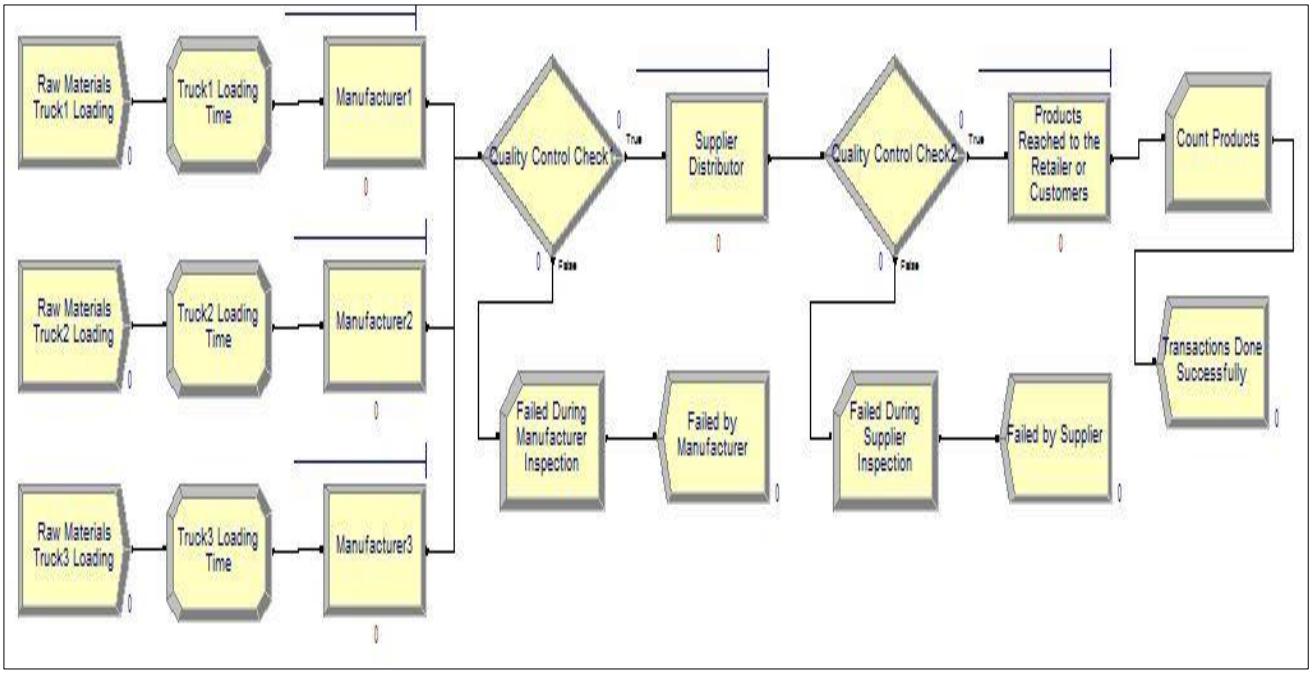

Fig. 6 Simulation of Supply Chain Management System Using Arena

The experiment started by creating number of products in the form of raw material. All squared-shape boxes are known as process module. For quality check at manufacturer and distributor station the decision modules used. Finally, assign and record modules connected for measuring different factors. The details of each module and the list of attributes already defined in Table 1.

Furthermore, suppliers transferred the raw material to the manufacturer with the help of trucks. We created three instances of trucks, whereas all trucks reached to the different manufacturers. Before sending the ready products to the distributor, all items were gone through the complete process of quality controller check. The same quality check applied before supplying of the products to the market, retailer, and to the customer.

As a result, Table 2 is illustrating the overall processing time at each station. As evident from the table, on average the supplier/distributor station took most of the time for processing, which is on average 76 minutes for each transaction. As suppliers was dealing with three different manufacturers located on separate locations. In this scenario, the suppliers had the maximum tasks to perform and connection with multiple stakeholders like manufacturers, retailers, and distributors. Overall, the retailer processing time is lowest that is 61 minutes (average) they took for placing the whole transaction at the store for customers.

Table 2: Overall Processing Time at each Station

Station/Time	Overall Average Values	Overall Minimum Values	Overall Maximum Values
Manufacturer Station	68 minutes	29 minutes	110 minutes
Supplier Station	76 minutes	28 minutes	121 minutes
Retailer Station	61 minutes	27 minutes	95 minutes

During simulation, waiting time at each station recorded to understand the possible delay during each transaction. Table 3 is representing the average, minimum, and maximum waiting time recorded at each point. Based on the result, it can be seen that most of the delay was measured at retailer station, which on average is 39 minutes for one complete transaction. Although, at each station the minimum value is recorded as "0" too, which shows that sometimes the products were processed without any delay.

Table 3: Waiting Time at each Station

Station/ Time	Overall Average Values	Overall Minimum Values	Overall Maximum Values
Manufacturer Station	30 minutes	0 minutes	88 minutes
Supplier Station	26 minutes	0 minutes	62 minutes
Retailer Station	39 minutes	0 minutes	48 minutes

Altogether, the manufacturers, as presented in Figure 7 sent 4,325 ready products. As the simulation was conducted using the time constraints, therefore some products did not reached to the destination. In this figure, it can be noticed that, total 4,325 products were processed and sent by the manufacturers. However, only 3,443 products were arrived and processed at supplier station. The possible reasons behind, is the delay of work at supplier and congest situation on retailer side as well. Finally, the last station received only 2,710 products, while one transaction were still in progress and the simulation time was finished.

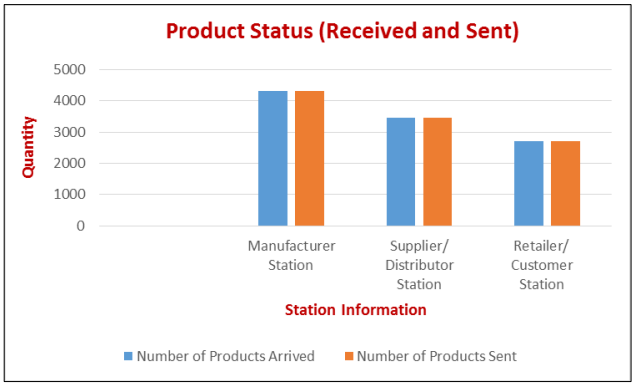

Fig. 7 Number of Product Seized at each Station

As described in the simulation design window (figure 6) about quality control check placed at two locations. Manufacturers and distributor has to check the quality of the product before supplying to the customers. Therefore, the status of the product is shown in figure 8, which describing the failure and success ratio of products at all points. During manufacturer inspection, 882 products were unable to pass the quality assessment test and recorded as defected material. In addition, 733 product were failed to get the clearance certificate by supplier quality controller, therefore counted as scrapped products. Finally, there were total 2709 good quality products were successfully received by retailers and reached to the customers.

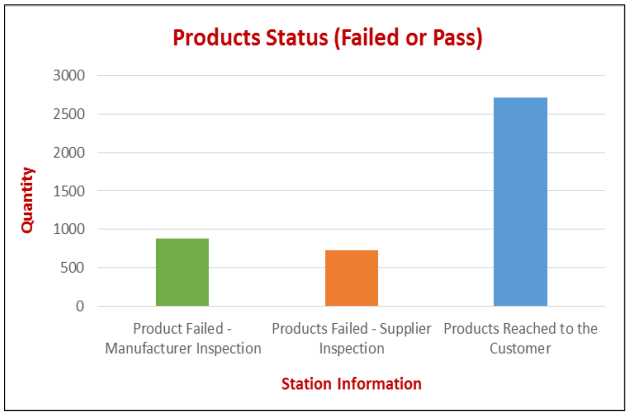

Fig. 8 Products Pass and Failure Status at each Station

In comparison with the previous work, [2] presented the idea of implementing the simulation on supply chain using arena. In that paper, the author illustrated the idea with the help of presenting different types of model such as, product manufacturing, ordering, retailers and consumers, but there was lack of statistical results to understand the performance of the simulation. Whereas, in this study, the statistical results and graphs presented in section 4.1, which identifying the behavior of the system in numbers. The basic reason for presenting the performance of the model is for better understating, and it can be helpful for the researchers to enhance and compare the idea with improved results.

5. Conclusion and Future Work

The paper simulated the real world example of supply chain management system using arena simulation tool. The study first proposed a model with the help of traditional approach uses by supply chain system. The model then implemented using all stakeholders that are actively involve for the success of supply chain system. The results indicated that from manufacture until the products received by the customers, the supplier performance was critical and measured as best. The maximum delay recorded at retailer's side, which shows that the processing of the products is based on the demand of the items from the customers. That is the main purpose of supply chain, which works according to the demand of the products initiated by retailers or customers. The idea can be useful for improving the performance of supply chain. In future, the model can be applied by adding more supplier stations to realize the waiting and processing time more clearly.

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