Simulation Analysis of Ordering and Managing System Of Cricket Set

Vishesh M. Joshi
Master of Science in Industrial Engineering
Lawrence Technological University
Southfield, MI 48075, USA
vjoshi@ltu.edu

Ahad Ali, Ph.D.
Associate Professor and Director of Industrial Engineering
A. Leon Linton Department of Mechanical, Robotics and Industrial Engineering
Lawrence Technological University
Southfield, Michigan, MI 48075, USA

Abstract

E-commerce has emerged as an increasingly more applicable now a days by the customers due to more user-friendly experience and get the product as per their convenience. Sports products has now been relied on e-commerce due to the returns and exchange policy and the customers are more dependent on it due to the COVID pandemic to avoid contact. In this work, a Simulation model was created for ordering and managing the system. It faces some issues with machine knocking process, packaging and individual packaging which makes the model less effective and more time consuming. To resolve this issue a design of experiment was taken into account where the most effect process is been generated with optimal readings and the model is developed which increases the customer's satisfaction and ultimately increases the business

Keywords
E-Commerce, Arena Simulation, Bottleneck, Design of Experiment (DOE)

1. Introduction

E-commerce has flip out to be an increasingly applicable business enterprise in North America. Effective warehouse management in phrases of order choosing is a key aggressive reap in this industry. Sports products are particularly hard to successfully manipulate in a warehouse as they have immoderate demand variability, with a short shelf-life and very little replenishment. Warehouse operations and administration as been a relevant lookup neighborhood for a massive time and is still applicable today. Gu, Goetschalckx, and McGinnis (2007) and Gu, Goetschalckx, and McGinnis (2010) provide distinctive opinions on warehouse operations inclusive of order picking. Order deciding on is the most expensive operations in a warehouse as it is very labor and time eating (Frazelle 2001). The objective of the order choosing computing device (OPS) is to maximize the provider diploma (e.g. in phrases of order lead time) subject to aid constraints, given the warehouse diagram and stock storage locations. Since the bulk of the OPS time is spent on traveling, minimizing object choose cycle time (i.e. object and order retrieval time) is an equivalent goal (de Koster, Le-Duc, and Roodbergen 2007). It has additionally been determined that the throughput of the average OPS is inversely proportional to the cycle time (Manzini, Gamberi, Persona, and Regattieri 2007). Hence the problem will come to be imparting the most beneficial wave size, batching, item-picker mission and routing for these pickers to retrieve the assigned items such that the object cycle time is minimized. The world has started to initiate the life further by buying online and people are trusting more into valuable online goods instead of instore goods. Over the last 15 years businesses to its consumers have elevated in the western part of the market where people are more concerned about buying online rather than in store. Online sports business has been increased in the past 5-7 years where people are able to find better quality products in cheaper price which increases customer satisfaction and increase the value of the company.

Focussing on online retailing, wide-ranging environmental results may additionally additionally derive from a number of factors, such as an make bigger data technological expertise usage, the redesign or use of greater packaging (Williams and Tagami, 2003), and the bodily distribution of items. Among these factors, logistics things to do such as transportation and warehousing certainly signify a key component of the environmental sustainability of the entire supply chain (McKinnon et al., 2012). E-commerce companies like Amazon, Nike, Adidas, etc are the companies that looks for a greater number of customers than the profit margin of a single product which results in getting more reach of a product and company to customers.

In this paper, we present an overview of an emerging cricket sports company in the area of analyzing and solving simulation-based system of the order processing system. The problem states that the company is not able to complete the orders on time and facing backlash from customers due non punctual approach of the company towards customers. We first initialize the present environment and nature of the whole system with raw data and statistical analysis and then try to create equilibrium between the real system and simulation-based model. Moreover, with the help of DOE would present techniques to decrease downtime and backorder lead time of the product to make the system smoother and provide the cricket equipment to the customers in lesser time period. The paper is divided into multiple sections which includes flowchart to understand the system, raw data and analysis which gives real picture of the situation, ARENA model of the system to get the result for the actual process and improve it.

2. Literature Review

The digital commerce (ecommerce) refers to a organization model that approves companies and humans to purchase and promote items and choices over the Internet. Ecommerce operates in 4 necessary market segments and can be performed over computers, tablets, smartphones, and specific smart devices. Sim (2000) states and implements an algorithm that utilise various ranges of traders who buys and sells online with an agent with respect to prespecified customer profiles. It includes the process of matching and creating a connection between traders who buys, and sells are divided in four different stages which are selection, evaluation, filtering, and Assignments. On the other hand Santos (2016) believes that inventory control contains three different modules which includes a Simulink library for system design, an infinitesimal Perturbation analysis which is based on a simulator and a separate optimization process based in the Davidon-Fletcher-Powell algorithm. They showed the usefulness of the bundle with the aid of providing a variety of preliminary numerical outcomes for a three-machine single product tandem waft line. However, effective warehouse administration with respect to the picking up the order is a crucial factor which is challenging in this industry Pedrielli (2016). Their focus was particularly on fashion products which are been sold through e-commerce websites. It is eventually challenging to efficiently manage in a fashion warehouse as they have higher demand with reducing shelf-life. They used ARENA simulation modelling with hybrid strategies which outperform FIFO order which generally employed in the company. The situation in online store makes the stock-keeping work on the store makes more difficult than the conventional vendors as there are many types of stocks are being sold online. Chen (2015) considers a two-echelon supply chain composed of one supplier and one on-line store sailing daily supplies, popular goods, and fresh food.

Two primary methods to simulation model composition can be distinguished, depending on whether or no longer the unit of composition is a modelling specification in accordance with a positive modelling formalism or the factor is a simulation device wrapping the true model implementation. As per Rohl (2007) Simulation-based composition procedures explicitly distinguish between interface descriptions and model implementations and thereby facilitate a reasoning about compositions especially primarily based on publicized interfaces descriptions. However, compositional reasoning about interoperability at the conceptual stage and on typical model validity is presently now not very elaborated. Some industries, such as books and grocery, have largely been addressed, however, promising sectors in the e-commerce field, such as apparel and customer electronics, have only been considered to a sure degree. Moreover, no count number the rising feature of multichannel strategies, the environmental implications of the related logistics things to do have no longer however been studied in detail Mangiaracina (2015). Mainly, one of the best levels of the most sensitive designing element of ameliorating the performance are carried out by Ekren (2019) where statistical test named as Tukey's test was utilized which was carried out using ARENA 14.0 simulation with the technical graphs and summary by using Minitab 17 statistical software. Whereas Yarden (1997) gave more importance to general simulation model which can be taken under consideration to evaluate the performance of many e-commerce systems meeting the criteria with the customers through their real time access and cooperation needs.

Simulation can also be an effective way to generalise alternative decisions in Sense-and-Respond systems even before taking and actions to resolve whatever the mistake of problem is there in the system through simulation or anticipating the business situations (Huang 2004) and it is a key to increasingly recognise the competitive business process. It creates added value to business process in understanding, analysing, and designing by working into dynamic aspects Aguilar (1999). Similarly, Vorobeychik (2009) and Eatock (2009) presents the simulation-based games in e-commerce which works on methodology on first introducing problem of solving a simulation-based game which presents further some techniques for approximating equilibria in simulation-based games and close the e-commerce business with a series of applications.

There are some critical challenges for modelling and simulation in adoption of modelling and simulation techniques in healthcare Young (2009) development which fell short of the uptake of various sectors including business and commerce and the military. Moreover, there is a Simulation based optimization method adopted by Juan (2019) which are used to resolve complex problems with stochastic components. E-commerce business depends on two popular comparison which is the sample average approximation method and the simheuristic algorithms and they used both. Kumar (2021) E-commerce supports cultural, social, and economic interaction between buyer and seller which even helped more in amid the COVID-19 pandemic and hence home delivery services initiated maintaining a crucial role in contributing to economic activities.

To summarise the process, many tools and methods have been used by various authors in the papers which fulfils the objective of the paper. Similarly, to bolster the objective of the paper in E-commerce sports business, ARENA simulation and the methodology including various tools like minitab and design of experiment will come into place to improve the uptime and downtime problem with various statistical tools used in the paper. By reducing the back-order time, it reduces the failure rate and output time

3. Project Plan and Project Charter

The project focuses on a Cricket E-commerce company which sells the cricket equipment all around the globe and the figure 1 shows the project charter which mentions the blueprint of the whole project. The problem with the company is that they are lacking the clear plan of around how the system and its components are performing and the failing with the back-order lead time which creates inherent stress which makes customers dissatisfied. However, the objective this project is to improve its decision-making plan for the back ordered products to make the inventory of the cricket gears more accessible in the company with the optimized model to reduce the customer returns. Fulfilling this thing will reduce the lead time and make the business value stronger and will improve the business relations with vendors and customers which leads to get more business.

Simulation-based Optimization for Solving a Sports e-commerce company decision making Problem	
Project Charter	
Problem Statement	Scope
Lack of transparency around how components and systems are performing and failing in real world conditions across common system in sports e-commerce company reasons inherent stress and negative decision making in Inventory. Customers are not happy with the lack of components which they need. .	IN: Using online software tools like ARENA and Minitab to analyse current behaviour. OUT: Results will be depending on the observations on the behaviour of the Warehouse plant. So, no other adulterate will be added
Objective Statement	Timeline
The objective of this project is to improve the decision making of inventory of the cricket gears in the company with optimized model to reduce customer returns and increase sales of the product.	Hassle Modelling: 10/10/2021 Data Collection: 11/25/2021 Improvement development: 11/30/2021 Results: 12/5/2021
Business Case	Team Member
Reduction in Time will lead to strong business relation and the solution can be benchmarked and can be deployed across other customers and suppliers.	Vishesh Joshi Graduate students of Lawrence Technological University Professor: - Ahad Ali

Figure 1. Project Charter

With the guideline of the project charter in place we need to look further into the timeline to make sure we can complete all tasks in the required time. Normally the timeline for some projects may be drawn out in order to effectively cover all aspects of the project in as complete of a manner as possible. This project being fit into a single semester needs to be streamlined and the timeline needs to be strictly followed in order to complete all aspects on time. With the use of the software like Arena Simulation Modeling and Minitab. Hassle model was roughly created to make the imaginary picture of the modeling with the help of the actual warehouse where the ordering process is initiated. Further data is been collected for 4 days and implemented in to the ARENA model which creates the result which further is improved with new data plan.

4. Flowchart of the sports E-commerce company

The Chicago based E-commerce sports company undergoes their business in online sector where they sell the cricket equipment like bat, ball, helmet, pads, gloves, etc. As they sell the products all over the globe, there has to be a specific system of the order which is been received so that the process works smooth, and customer gets correct product which they ordered. Figure 2 shows the flowchart of the company where the order is arrived from the website portals and apps which is been collected in data file and then the employ checks whether the product is in stock or out of stock. If it is in stock, then the product is sent for further processing however if the product is out of stock, then it has been check if the business value of the ordered item is feasible or not. If a customer ordered a good English Willow grade bat, then the order is been back ordered and the company orders the number of respective bats from the main company source outside the United States and takes around lead time of 5-6 days to get back to the company.

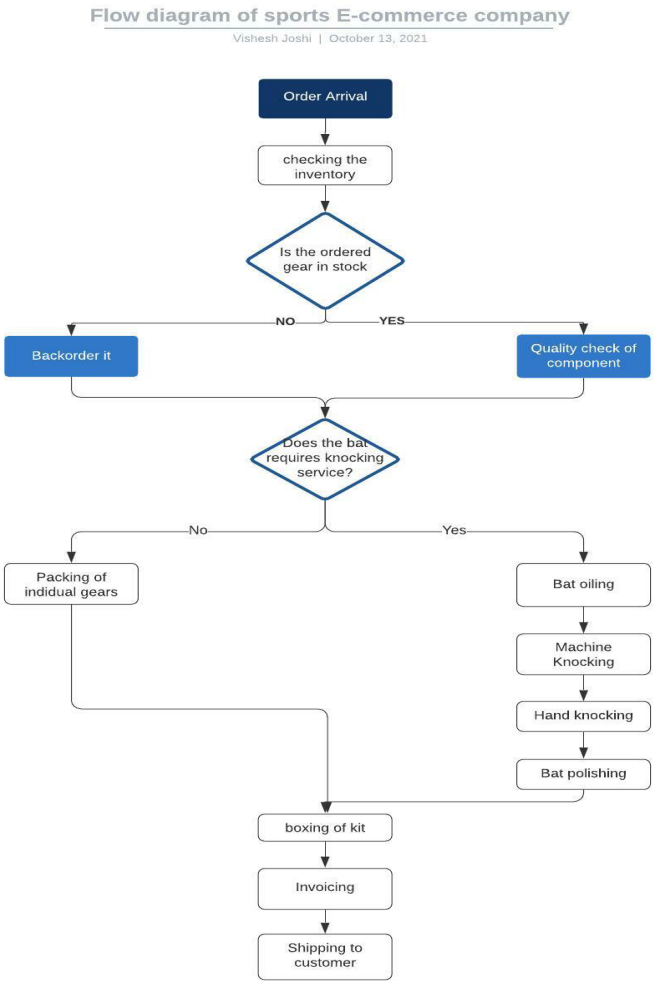


Figure 2. Flowchart of Sports E-commerce Company

Further it is checked whether the product is a cricket bat and require bat knocking service, if yes then the oiling has been done which leads to machine knocking, hand knocking and bat polishing. The products are then packed in the box and then invoiced and shipped. The quality of the process is smooth as in the travel time from one department to other is almost constant without the seaming problematic situations. On the other hand below are the main factors and reason to make this flowchart:

- To support understanding of how a system is done
- To study a method for improvement of backorder
- To talk to others how a machine is done.
- When better communication is wished between humans involved with the equal process
- To file a process
- When planning an undertaking process implemented.

5. Data Collection

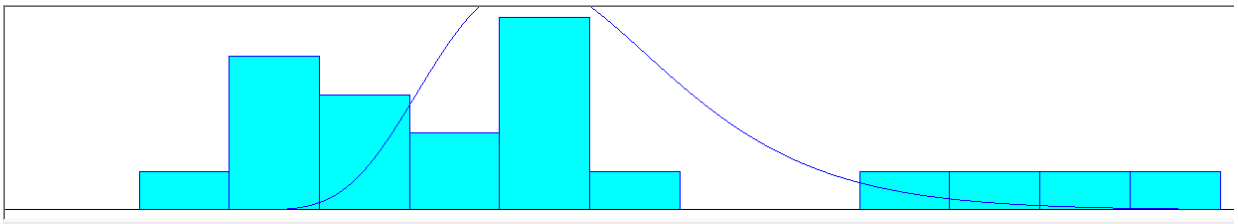
Data collection is defined as the device of collecting, measuring and examining correct insights for search for the usage of general validated techniques. A researcher can think about their speculation on the groundwork of gathered data. In most cases, data collection is the main and most necessary step for research, irrespective of the area of research. The method of information series is special for one-of-a-kind fields of study, relying on the required information. Data collection in this paper is done in every process from order arrival to order shipping. Each and every process have its own time consumption and usability. Table 1 shows the data collection of all the processes with the proper distribution of it. The first process in the shipment process is receiving an order from the customers from all over the globe. These customers are ordering any product or products like bat, ball, helmet, etc. and the data base is filled with the purchase

orders and the enquiries of the products. We took 20 readings of all the processes including order arrival process. The graphical summary of the actual raw data of the order arrival in a 95% confidence Interval. As per the summary, the order is received every 4.85 minutes on an average with standard deviation of 1.98 and to be specific they receive the order every 2-9 minutes to start the process with. By putting the data, the best distribution is generated. The next process id the inventory checking process where the data is been checked whether they have a certain kind of product which was order by the customer or need to do back order. So, after taking 20 readings of it. The graphical summary of the raw data for Inventory Checking. The graphical summary states that it takes on an average of 8 minutes to check the inventory of the product whether it is in stock or out of stock with the standard deviation of 3.9868 in 95% confidence Interval. Moreover, the checking specifically is done within the range of 4 to 20 minutes depending on the product of pair of products. Furthermore, the best distribution for the raw data is carried out for the model. The quality of the required products is checked and only the good products are given to the customers as per the quality value. The quality checking is one of the important processes in the plant where 20 reading are taken and figure 9 shows the graphical summary of raw data for the quality checking.

Table 1. Data Collection of all the process of ordering with distribution

Data Points	Order Arrival (Min)	Inventory Check (Min)	Quality Check (Min)	Individual Packing (Min)	Bat Oil (Min)	Machine Knocking (Min)	Hand knocking (Min)	Bat Polishing (Min)	Packaging (Min)	Invoicing (Min)
1.	5	5	7	5	5	70	30	10	15	5
2.	6	6	6	8	8	80	25	20	18	8
3.	2	4	15	10	9	60	23	15	14	6
4.	3	7	14	13	6	65	45	14	11	4
5.	4	8	18	8	7	80	36	20	26	7
6.	5	12	13	6	5	74	28	24	17	8
7.	9	20	11	9	5	84	26	23	25	10
8.	5	6	8	19	8	87	35	16	24	7
9.	3	5	20	25	4	72	24	18	16	6
10.	6	8	15	5	6	65	36	12	19	4
11.	7	9	14	9	15	68	39	24	23	5
12.	8	15	16	7	12	64	28	22	22	8
13.	4	4	7	11	8	72	30	17	29	5
14.	2	5	10	8	7	79	34	14	34	6
15.	4	7	9	16	8	64	36	16	18	7
16.	6	8	15	10	6	68	35	20	36	8
17.	2	5	18	9	8	73	38	10	27	9
18.	4	6	22	14	13	70	45	13	19	5
19.	5	11	13	17	5	64	30	21	28	15
20.	7	9	17	11	14	73	33	26	20	12
Distribution	Poisson	Lognormal	Beta	Weibull	Lognormal	Weibull	Poisson	Beta	Triangular	Erlang
Expression	POIS(4.85)	3.5+ LOGN(4.7,5.28)	5.5+17* BETA (1.18,1.37)	4.5+WEIB (7.07,1.33)	3.5+ LOGN (4.61,4.16)	59.5+ WEIB (13.5,1.67)	POIS(32.8)	9.5 + 17 * BETA (1.04,1.11)	TRIA (10.5, 18, 36.5)	3.5 + ERLA (1.88,2)

The graphical summary for the quality checking states that it takes on an average of 13.4 minutes to check a product with damages or failures with standard deviation of 4.535 in 95% confidence intervals. Moreover, the process takes minimum of 6 minutes to maximum of 22 minutes to check the betterment of the goods. Furthermore, by putting it into the consideration to get the best distribution for the model figure 3 shows the best result of distribution. The best fit of quality check for the model is Lognormal with expression of 3.5 + LOGN (4.7, 5.28) have a square error of 0.015952 with the histogram ranging from 3.5 to 20.5 in 17 intervals and then is implemented in the ARENA model for the further processing. The bat oiling is done to make the quality of the bat wood much better for the future use and not to be damaged. It usually takes 12-14 hours to keep oil absorbed in the bat wood which makes the wood stronger to last long.



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        Distribution Summary

Distribution:   Lognormal
Expression:     3.5 + LOGN(4.61, 4.16)
Square Error:   0.037605

Chi Square Test
  Number of intervals   = 3
  Degrees of freedom    = 0
  Test Statistic        = 3.35
  Corresponding p-value < 0.005

        Data Summary

Number of Data Points   = 20
Min Data Value          = 4
Max Data Value          = 15
Sample Mean             = 7.95
Sample Std Dev          = 3.19

        Histogram Summary

Histogram Range         = 3.5 to 15.5
Number of Intervals     = 12
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Figure 3. Distribution Summary and graph for Inventory Check

The graph from the quality check shows that the data points are fluctuating, and it makes a normal distribution curve which makes the process to go less smooth due to some of the data points are too high and some are too low.

6. Methodology

Arena Simulation approves the assessment of the contemporary system, which helps with capital funding choices and improves decision-making with minimal cost. It permits you to pick out desktop constraints and boundaries and the reasons behind specific gadget conditions. It helps you to assume of the 'what if' eventualities and gives system-specific parts to measure performance. On the other hand, E-commerce is the buying for and promoting of top or choices through the internet, and the transfer of money and data to entire the sales. It's also recognized as digital commerce or internet commerce. In this project the methodology works in a sports e-commerce company where figure 4 shows the basic model of the ordering system from order arrival to shipping after packaging and invoicing.

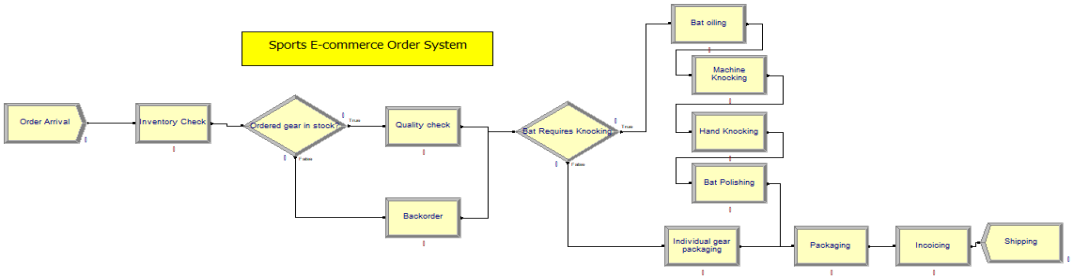

Figure 4. Overview ARENA model of the Sports E-commerce order system

As a basic ARENA model, it gives an idea of how the actual system is working where the order is received by the company from the company around the world. Further the inventory is checked whether the ordered goods are in stock or out of stock. However, if the product is out of stock and it is a A grade English Willow cricket bat then it has been back ordered and ordered from UK or India which ever country is convenient for it. After quality checking of existing products and receiving backordered bats after 5-7 days it is checked whether the bat needs to be serviced with oiling or not. After servicing and individual packing of each products the kit boxing is done and shipped to the customers by shipping. The downtime and failure time is carried out in the backordered process where it is taking a long time from 5-7 days.

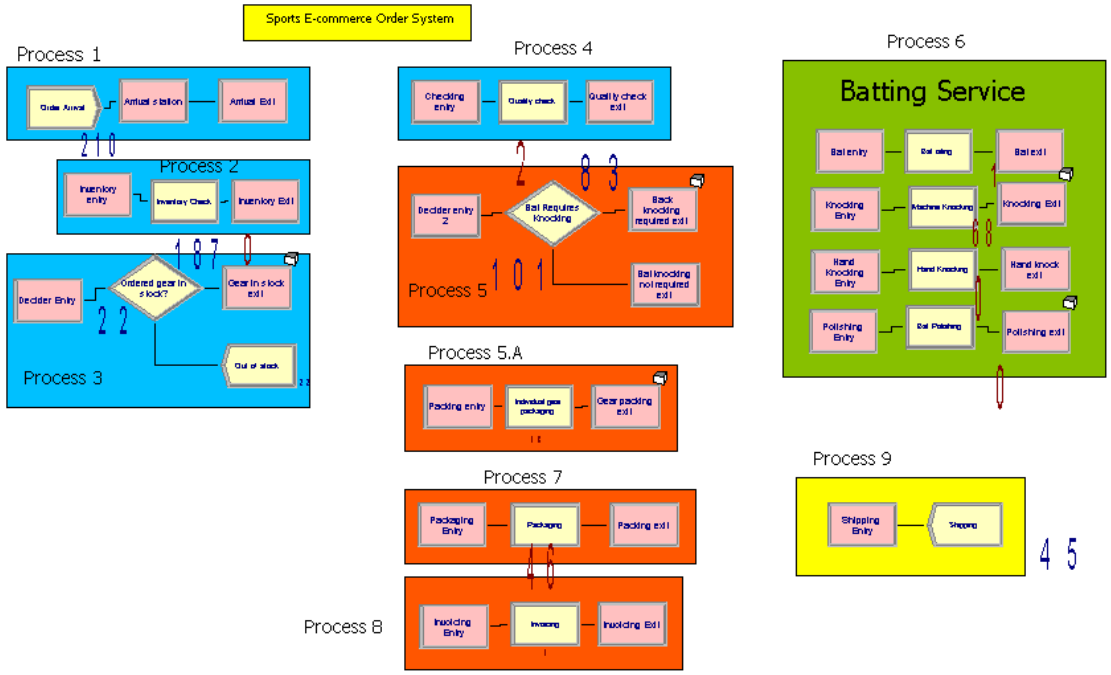

Figure 5. Actual ARENA Simulation model of order system

The main objective to create an ARENA Simulation model is to actuate the main process with raw data and analysis and with the actual data how the data is been played and how many orders are been sent to the customers is the main goal of it. Figure 5 shows the actual ARENA simulation of the company for ordering system where the simulation is run for 1000 minutes and in that time total 210 ordered were received to the company out of that at the end of the time 45 orders were completed with including the back ordering, bat servicing and shipping. Out of 210, 67 products were in stock and 22 were out of stock. Futrthermore, out of the completed 210 orders, 83 were needed bat service and 101 products did not need the bat oiling services which directly went to individual packaging and invoicing and then shipped.

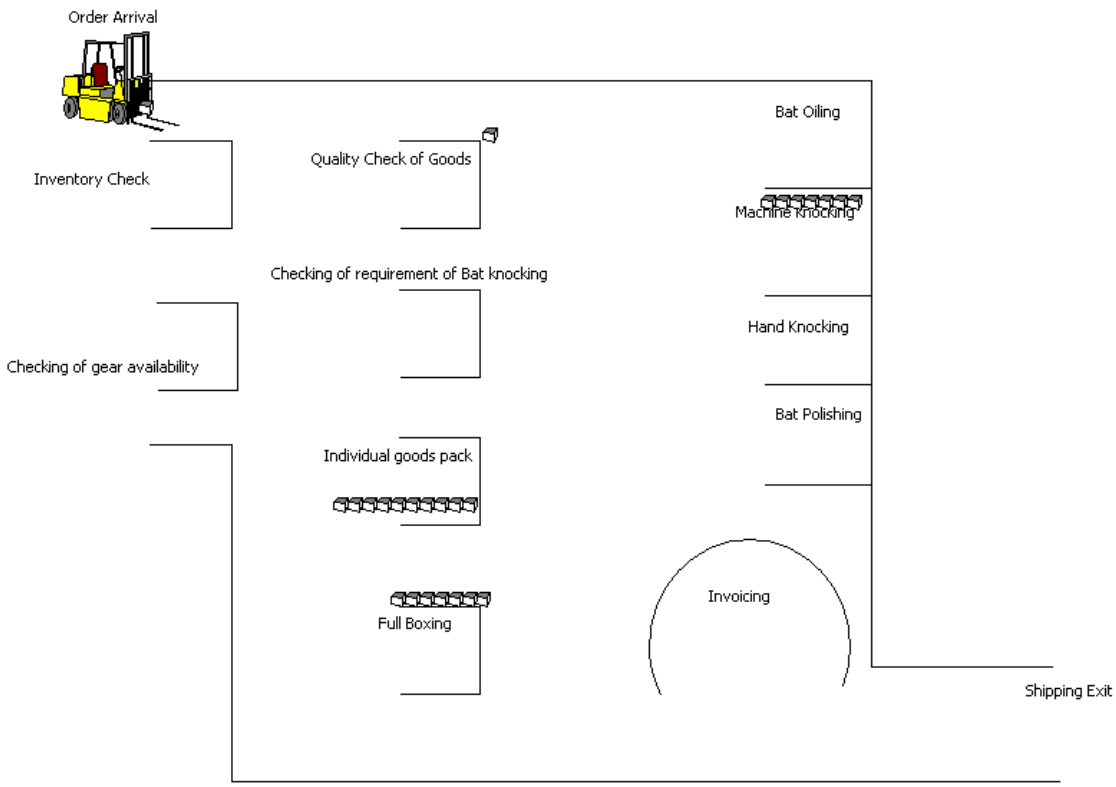

Figure 6. Animation layout of ARENA Simulation model of order system

The layout of the animation shown in figure 6 gives a particular idea of the warehouse plant where each of the sections are located. Moreover, it is an organized overview of the plant where order is received from on part of the warehouse plane and shipped from the other part of the warehouse. There are 2 trolleys which are used to transfer the products from one department to another.

6.1. Results of Actual Model

After running the initial model for 1000 minutes with the given actual data, table 2 shows the result of the model. At the end of the shift of 1000 minutes, they received 210 orders out of which they were able to completely ship only 67 orders with the work in progress of 7.78 on an average with maximum value of 143.

Table 2. Outcome of the result

Number In	210
Number Out	67
WIP	77.7853

The result itself in table 3 shows the model needs to be improved as there are some problems in the process of ordering where some of the processes are taking too long which need to be worked and improvised to make it better and smooth. In terms of time cycle table shows the time cycle data of the actual model and on an average value-added time is 50.0805 minutes complete the shifts with minimum of 5.9709 minutes and maximum of 182.15 minutes to complete it. On the other hand, the average waiting time for the process is 228.28 minutes where the products are in the queue and waiting for their turn to complete the process where the minimum is 0.9338 minutes and the maximum of 675.46 minutes. Meanwhile, the transfer time for the product from 1 process to another is on an average of 3.1045 minutes where minimum is 1 minute of time and maximum is 5.5 minutes of time. Finally, the total cycle time of the process takes on an average of 281.47 minutes where the minimum parts of the orders having minimum of 10 minutes and maximum of 859.38 minutes.

Table 3. Time cycle data of the actual Model

	Average (Min)	Half Width	Minimum Value (Min)	Maximum Value (Min)
VA Time	50.0805	Insufficient	5.9709	182.15
Wait Time	228.28	Insufficient	0.9338	675.46
Transfer Time	3.1045	Insufficient	1	5.500
Total Cycle time	281.47	Insufficient	10	859.38

The cycle time contrast is achieved each with dynamics and besides dynamics in the mannequin scenario. It is found that balancing the line and dynamics consideration significantly impacts the cycle time scenario. With the time cycle data for the model which is generated through the actual data table 4 shows the utilization generated of all the process with its usage value. Firstly, bat knocking is utilized as most in the process than any other process with 95.71% while on the other hand polishing hardly takes any time and consumption with the least utilization of 18.62%. However, individual packing is also seeming to be very busy with 98.42% of utilization where the individual gears are been packed and kit packing takes 96.17% of the utilization.

Table 4. Utilization of all the process

Scheduled Utilization	Value	Percentage
Bat Knocking	0.9571	95.71%
Hand Knocking	0.4000	40%
Individual Packing	0.9842	98.42%
Inventory	0.8421	84.21%
Invoice	0.3494	34.94%
Oiling	0.7121	71.21%
Packing	0.9617	96.17%
Polishing	0.1862	18.62%
Quality	0.7390	73.90%

With the help of this results, we tried to figure out how the actual process is working in certain condition and as going through the whole process it can be figured out that the process is certainly not in control and more improvement needs to be done with the help of the bottleneck which is tried to create difficulties in the process and the model.

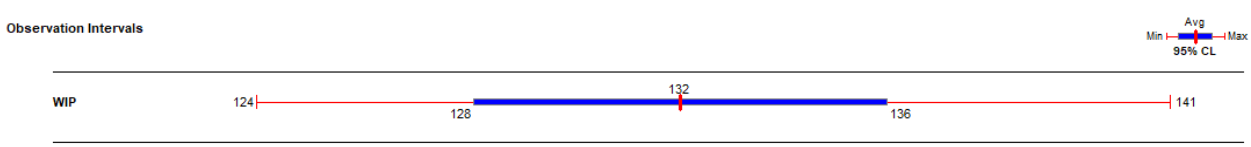

Figure 7. Output analysis of the existing model

After carrying out the output analysis figure 7 shows the results of it in a box plot where the minimum work done is 124 to complete the process whereas it takes 141 in some of the orders to get completed as a maximum work in progress. Moreover, on an average the work in progress for the existing system is 132 with first quadrant of 128 and third quadrant of 136.

6.2. Defining Bottleneck

A bottleneck is an element of congestion in a manufacturing desktop (such as a meeting line or a laptop network) that takes vicinity when workloads arrive too unexpectedly for the manufacturing system to handle. The inefficiencies delivered about with the aid of ability of the bottleneck frequently creates delays and higher manufacturing costs. The term "bottleneck" refers to the typical form of a bottle and the reality that the bottle's neck is the narrowest point, which is the most in all probability area for congestion to occur, slowing down the glide of liquid from the bottle. In this model the main problem is created because of the bottleneck effect. As per the model, the main bottle neck is shown in figure 8 in machine knocking. As it shows that 68 bats are still in queue in process which takes a very long time to pass the bat to the next level and because of it the whole process has been affected and slowed down.

Figure 8. Maximum bottleneck effect

Similarly, there are some other processes too which are creating difficulties while running the whole system while ordering and shipping in which figure 9 shows the bottleneck effect in packaging which is stuck while packing the whole items due to other process where the whole kit is packed and only waiting for bat to get the service done and then completes this process too. 46 orders are partially packing and waiting for bats to come in this process and then done with the packing process.

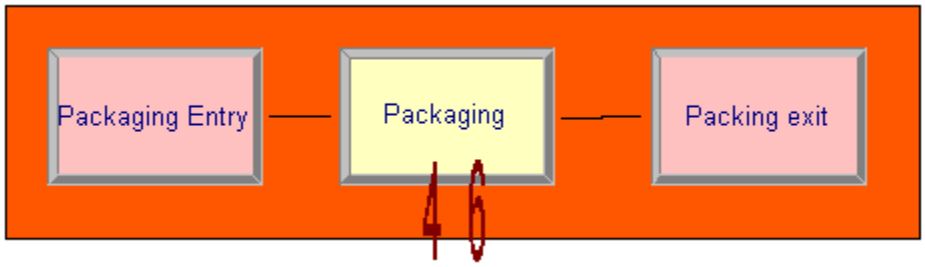

Figure 9. Another bottleneck effects

Finally, the last bottleneck which is affecting the whole system is in figure 10 of individual packing of gear process is somehow creating problems for the process and the whole system. Moreover 18 orders are in line and yet to be oacked but for some reasons they are taking too long to pack.

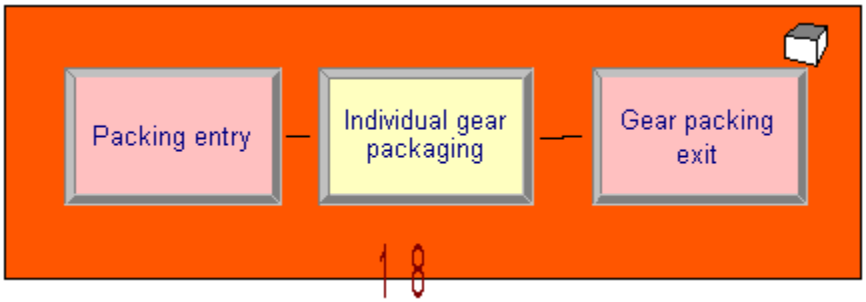

Figure 10. Bottleneck effect in Individual gear packing process

To improve the system, it's a challenge to improve these three-bottleneck effects work in the process and reduce the numbers which are in the waiting line which will reduce the trouble and make the system run more smoother, so the efficiency gets improved.

7. Improvement using Design of Experiment

Design of experiments (DOE) is described as a department of utilized statistics that offers with planning, conducting, analyzing, and decoding managed assessments to consider the factors that manipulate the price of a parameter or team of parameters. DOE is a effective statistics series and evaluation device that can be used in a range of experimental situations. It lets in for more than one enters elements to be manipulated, finding out their impact on a preferred output (response). By manipulating extra than one inputs at the equal time, DOE can identify important interactions that would possibly additionally be missed when experimenting with one problem at a time. All practicable combos can be investigated (full factorial) or totally a thing of the viable combinations (fractional factorial). Similarly in this case,

there are 3 bottleneck processes Machine knocking, Packaging, and Individual Packaging which are the main factors effecting the output of the model. So, by applying design of experiment analysis using those factors Table 5 shows its results which gives output of each of the factors using its minimum and maximum allowance of the actual data.

Table 5. Factors with output using DOE

Machine Knocking	Packaging	Individual Gear Packaging	Output
60	36	25	49
60	11	5	97
87	36	25	46
87	11	25	59
87	36	5	48
87	11	25	66
87	11	5	90
60	11	25	66
60	36	25	49
60	11	25	66
87	11	5	90
60	11	5	97
87	36	25	50
60	36	5	49
60	36	5	49
87	36	5	48

So running all the models replacing the expression of the machine knocking, packaging and individual packaging using their minimum and maximum values and carrying out 16 random factorials, the output is generated. With that output data the analysis of factorial design is carried out and Figure 11 shows its Coded Coefficients of the Bottleneck processes. The probability value of Machine knocking is carried out to be 48.7% which shows how important this process is and how it is affecting the model whereas, the other two processes are minimal in playing role but still it is in bottleneck which needs to be solved.

Coded Coefficients

Term	Effect	Coef	SE Coef	T-Value	P-Value	VIF
Constant		63.69	2.18	29.22	0.000	
Machine Knocking	-3.13	-1.56	2.18	-0.72	0.487	1.00
Packaging	-30.38	-15.19	2.18	-6.97	0.000	1.00
Individual Gear Packaging	-14.63	-7.31	2.18	-3.35	0.006	1.00

Figure 11. Coded Coefficients of bottleneck using the DOE

Each processes are having negative effect which concludes that these processes are effecting the output negatively and considering it to change its values. On the other hand Figure 12 shows the model summary of the data where the standard deviation of the distance between the data values and the fitted values is 8.71899. R-sq states that the model is well fit for the real world with 83.41% which can be improved with deterioating value to 70.50%.

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
8.71899	83.41%	79.26%	70.50%

Figure 12. Model Summary of the bottleneck

Similarly with that effect figure 13 shows the analysis of variance results where the analysis of each of the process is generated including F-value being 0.51, 48.55 and 11.25 respectively and the total DF value is found to be 18 with the total Adj SS of 5497.44.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	3	4585.19	1528.40	20.10	0.000
Linear	3	4585.19	1528.40	20.10	0.000
Machine Knocking	1	39.06	39.06	0.51	0.487
Packaging	1	3690.56	3690.56	48.55	0.000
Individual Gear Packaging	1	855.56	855.56	11.25	0.006
Error	12	912.25	76.02		
Lack-of-Fit	4	879.75	219.94	54.14	0.000
Pure Error	8	32.50	4.06		
Total	15	5497.44			

Figure 13. ANOVA of Bottleneck processes using DOE

Regression equation is on of the most important part in predicting values in an optimal level. Taking that into consideration figure 14 shows the regression equation which is fit for the optimal level of the model including Machine knocking, Packaging and individual packaging of gears which gives the output.

Regression Equation in Uncoded Units

Output = 111.7 - 0.116 Machine Knocking - 1.215 Packaging - 0.731 Individual Gear Packaging

Figure 14. Regression Equation in uncoded units

Pareto chart of the standardize effects in figure 15 shows that packaging process is facing lot of problems hence getting standardize effect to 7 and similarly individual gear packaging process is also crossing the red dotted line of 2.179 and getting the standardized effect of more than 3.

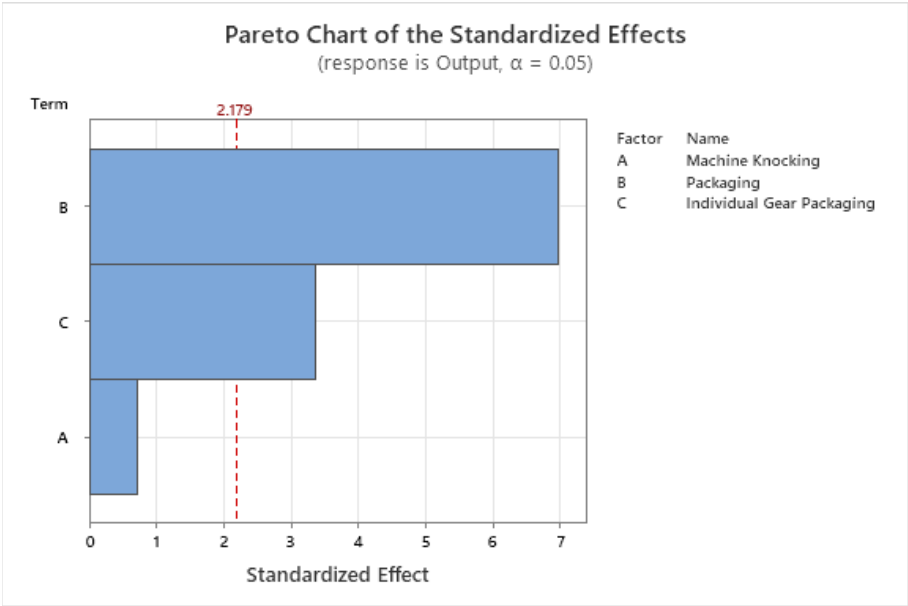

Figure 15. Pareto Chart of the effects

With the pareto chart the Residual plots for output has been carried out in figure 15 which shows the normal probability plot, Versus Fits, Histogram and Versus order. In normal probability plot the data points are little fluctuating near the red line however still being near to each other which shows feasibility. Moreover, versus fits shows how residual and fitted values are reacting with each other. Highest value for the residual is nearly 10 while the lowest is nearly less than -10 whereas the highest value for the fitted value is more than 80 and the lowest is less than 40. Like that histogram shows its frequency when it is -10 the frequency is 1 and when it is 10 then the frequency is 3.

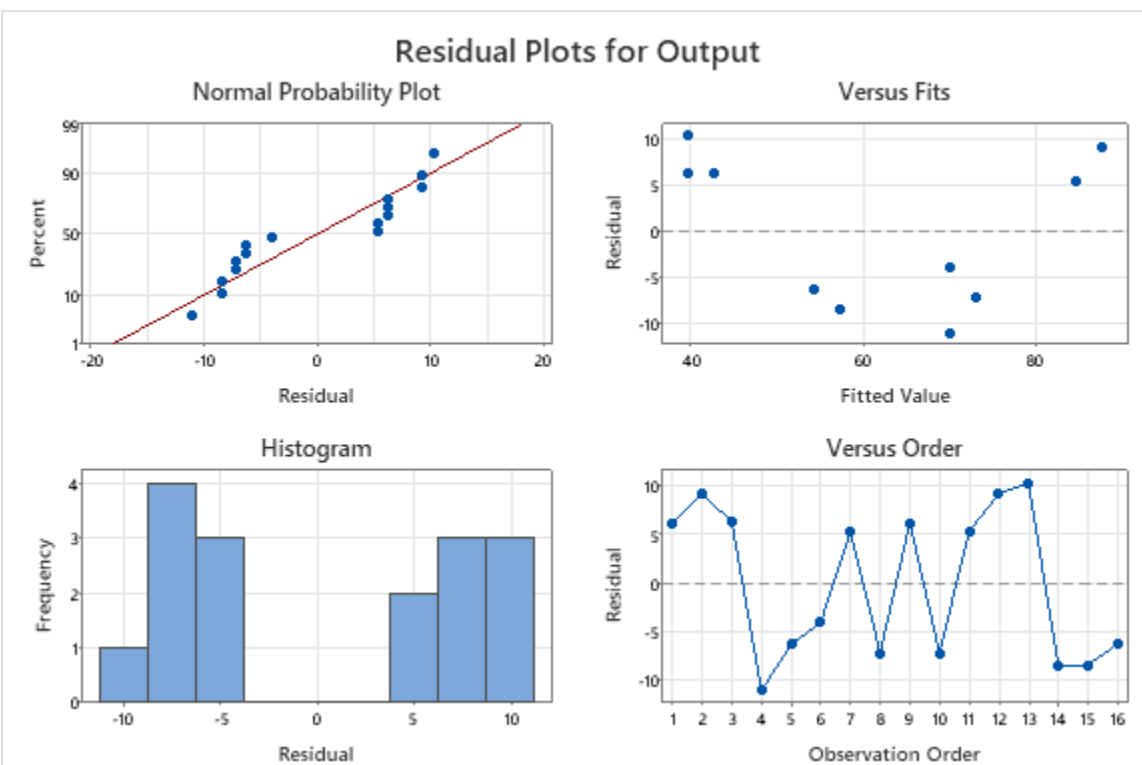

Figure 16. Residual Plot for Output

Finally, versus order shows the fluctuations in the data from -10 to 10 by maintaining non uniform line graph. On the other hand, figure 17 shows the main effect plot of the output. All the process are inversely proportional to time where the machine knocking process output is decreasing as the time is increasing to 87. Furthermore, as the time is increasing in packaging from 11 to 36 the output is gradually going down which also tell the fact that individual packing is dependent on it and showing the same nature.

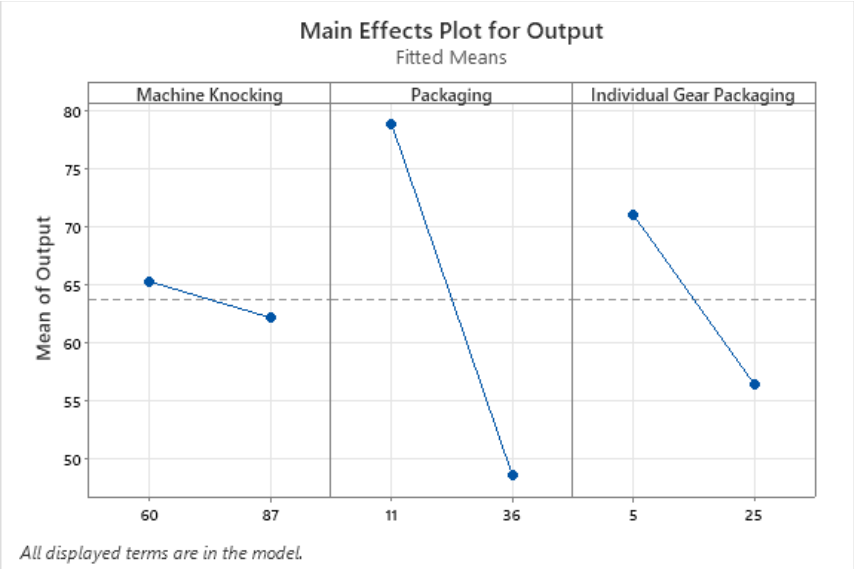

Figure 17. Main Effect Plot for Output

Figure 18 shows the interaction plot all the process with each other about how each one of them are reacting with other. Like machine knocking and packaging is not parallel to each other which shows that they are going to interact with each other at some point. Similarly, packaging, and individual packaging is clearly interacting with each other which states that it creates a lot of problems with each other for the whole model. However, it seems that the interaction between machine knocking, and individual packing is almost parallel to each other which means it is independent on each other's.

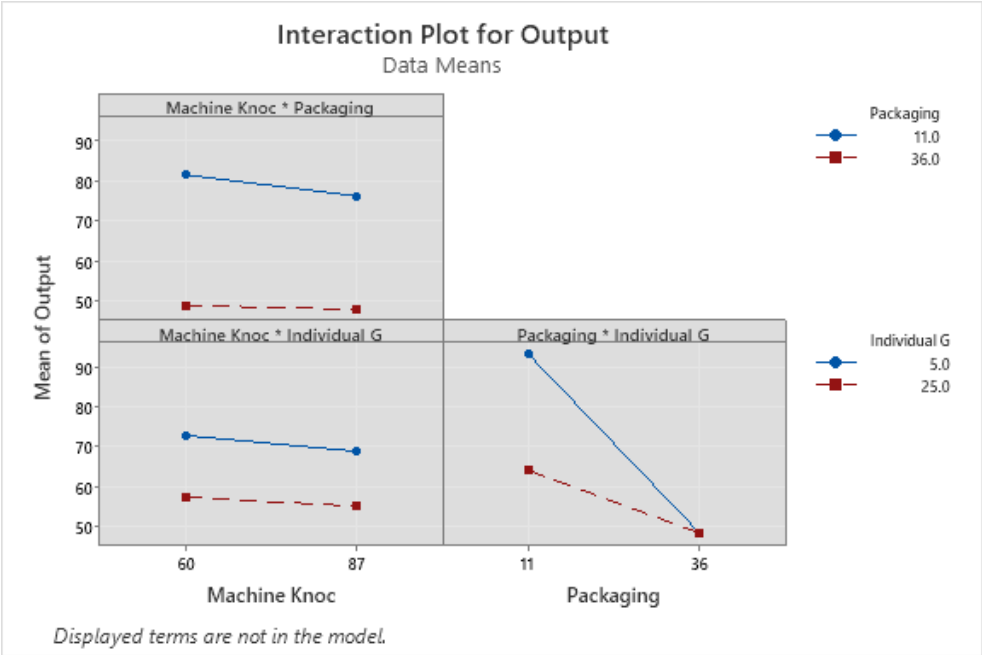

Figure 18. Interaction Plot for Output

With the whole DOE analysis, it can figure out that the processes are trying to damage the whole system and giving the results which are not acceptable. However, with the help of the pareto chart we know where to focus more and with the help of regression equation the optimal timing for each process can be carried out and then the output can be improved.

8. Improved ARENA Simulation model after doing DOE

After Going through the DOE, the minimum timing of each process is carried out with regression equations and then included in the data of the model which is shown in figure 19. The simulation model shows how the improved model is working as the input is around 199 where the received the orders in which 19 orders or products are out of stock or discontinued. Moreover, out of 172 orders 78 are for bats which needs bat service including bat oil, machine knock, hand knock and polishing. After going through it can be said that the bottleneck of the machine knocking has been reduced to 10 bats from the actual model whereas packaging and individual packaging bottleneck effect is almost solved in it. Finally at the end of 1000 minutes for total 98 orders are completing its all the process.

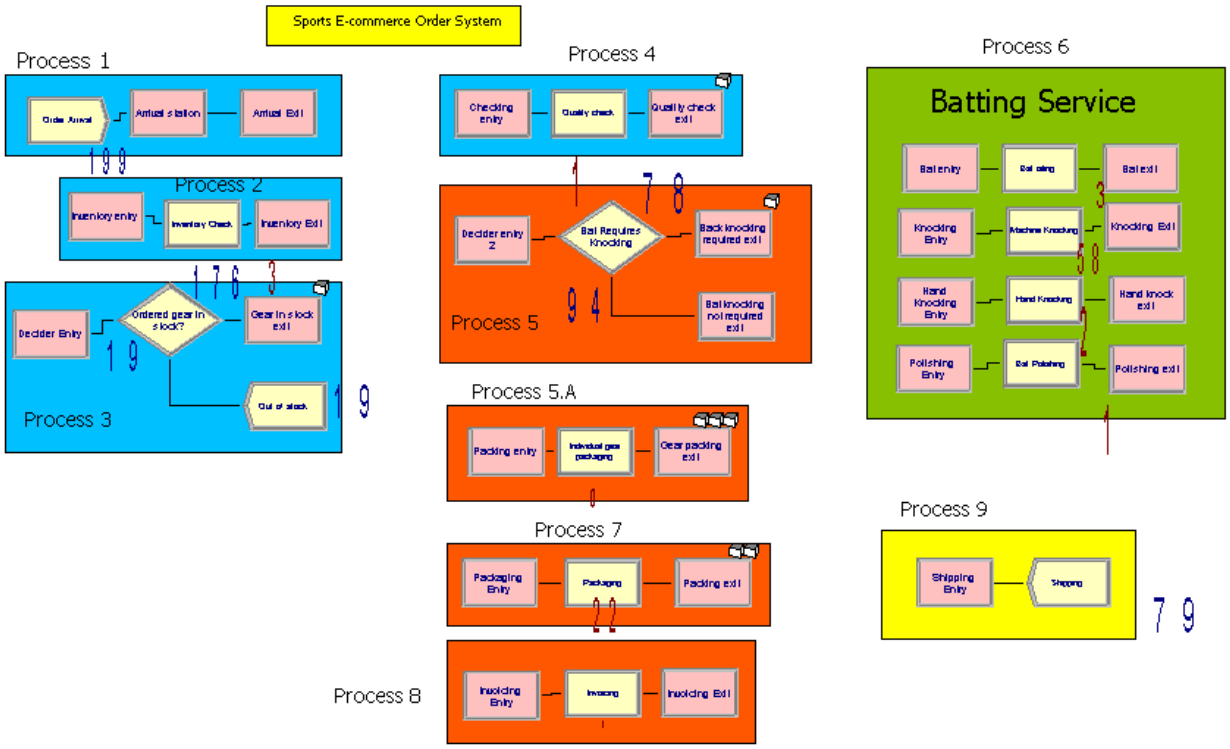

Figure 19. Improved ARENA Simulation model of order system

With the improved model, the result is shown in table 6 where the total number of 199 orders are received to the company where they can complete 98 orders in 1000 minutes which is better than the actual model. Similarly the Work in progress shows that the entities complete on an average of 53.7707 with respect to its orders with the maximum of 101 at some point.

Table 6. Outcome of the improved result

Number In	199
Number Out	98
WIP	53.7707

In terms of time cycle table 7 shows the time cycle data of the actual model and on an average value-added time is 46.3363 minutes complete the shifts with minimum of 5.8653 minutes and maximum of 243.16 minutes to complete it. On the other hand, the average waiting time for the process is 149.84 minutes where the products are in the queue and waiting for their turn to complete the process where the minimum is 0.7215 minutes and the maximum of 660.79 minutes. Meanwhile, the transfer time for the product from 1 process to another is on an average of 3.5714 minutes

where minimum is 1 minute of time and maximum is 5.5 minutes of time. Finally, the total cycle time of the process takes on an average of 199.75 minutes where the minimum parts of the orders having minimum of 8.5 minutes and maximum of 775.32 minutes.

Table 7. Time cycle data of the Improved Model

	Average (Min)	**Half Width**	**Minimum Value (Min)**	**Maximum Value (Min)**
VA Time	46.3363	Insufficient	5.8653	243.16
Wait Time	149.84	Insufficient	0.7215	660.79
Transfer Time	3.5714	Insufficient	1	5.500
Total Cycle time	199.75	Insufficient	8.5	775.32

With the time cycle data for the model which is generated through the DOE table 8 shows the utilization generated of all the process with its usage value. Firstly, bat knocking is utilized as most in the process than any other process with 95.78% while on the other hand polishing hardly takes any time and consumption with the least utilization of 25.3 %. However, individual packing is also seeming to be not very busy with 47.47% of utilization where the individual gears are been packed and kit packing takes 92.99% of the utilization.

Table 8. Utilization of all the process

Scheduled Utilization	**Value**	**Percentage**
Bat Knocking	0.9578	95.78%
Hand Knocking	0.4979	49.79%
Individual Packing	0.4747	47.47%
Inventory	0.7871	78.71%
Invoice	0.6037	60.37%
Oiling	0.5865	58.65%
Packing	0.9299	92.99%
Polishing	0.2530	25.3%
Quality	0.6920	69.20%

With the help of this results, we tried to analyze out how the improved process is working in certain condition and as going through the whole process it can be figured out that the process is certainly has improved and with the help of the improvement in bottleneck which is tried to create difficulties in the process and the model has been made better.

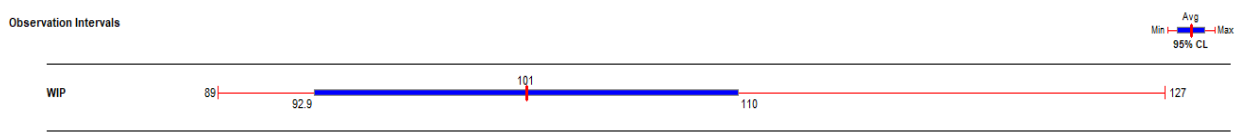

Figure 20. Output analysis of the Improved model

After carrying out the output analysis of improved model, figure 20 shows the results of it in a box plot where the minimum work done is 89 to complete the process whereas it takes 127 in some of the orders to get completed as a maximum work in progress. Moreover, on an average the work in progress for the existing system is 101 with first quadrant of 92.9 and third quadrant of 110.

9. Results And Discussion

After improvement in the model Table 9 shows the comparison of the previous and improved model in which in the previous model total only 67 orders were completed due to bottleneck in the system in 1000 minutes whereas in the improved model after doing DOE, 98 orders are completed with the shipping which states that there is improvement of 46.2% from the previous results and it can be applied into the real world.

Table 9. Comparison of Results with Actual and Improved model

	Result from Actual Model	**Result from Improved Model**
Number In	210	199
Number Out	67	98
WIP	77.7853	53.7707

After the actual difference in number out and getting the whole result, table 10 shows the reduction in percentage in bottleneck effect in all 3 processes. Machine knocking process was the biggest culprit of the model to get highest number of bottlenecks of 68 in actual model which is improved and reduced by 14.7% to 58. Like that kit packing process was the second process which was guilty for the real world model result of 46 orders which is reduced by 52.17% to 22 orders and finally the biggest improvement is in the individual gear packing process which is totally queue free as the initial results states that 18 orders were still stuck whereas now in the improved model with the improvement of 100% it is reduced to 0 which makes the model more smoother and more optimal in terms of ordering the products and maintaining inventory with the smooth process which do improves most of the problems.

Table 10. Reduction in Bottleneck effect in all effected processes

	Result from Actual Model	**Result from Improved model**	**Percentage change**
Machine Knocking	68	58	14.7%
Individual Packaging	18	0	100%
Packing	46	22	52.17%

Finally, the result states, that the implementation of the improved model will bring the company process more clarity in the work and they will be facing less trouble with the process and can work more to improve the machine knocking process in future after implementation of the improved processes and the total cycle time will be reduce which makes company more profits and more customers will be attracted.

8. Conclusion

Simulation is a fantastic way to consider alterative choices in an ordering and managing system. We developed a Simulation model which analyze the bottleneck of the e-commerce company ordering process and solve the problem using Design of experiment which improves the process and output as well. Finally, implementation of this project will build good business relation with the customers and ultimately earn more profits with improvement in the cycle of 46.2% overall and it is due to the improvement in bottleneck of 14.7%, 100% and 52.17% for Machine Knocking, Individual packaging and packaging respectively.

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Biography

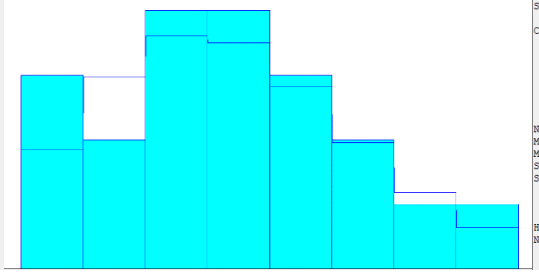
Vishesh Mahendrabhai Joshi is a student of Lawrence Technological University pursuing Master of Science in Industrial Engineering. He was graduated from Rai University, Ahmedabad, India, having Major in Bachelor of Technology in Mechanical Engineering. He has done 2 Internships for Heat exchanger and Color die machine manufacturing industry. Moreover, he has worked for 1.2 years as Design Engineer in Heavy Engineering Unit and worked for 7 months as production engineer in heavy Engineering production Unit. He is member of IEOM and ASME.

Appendix

Input Analyser

1. Order Arrival

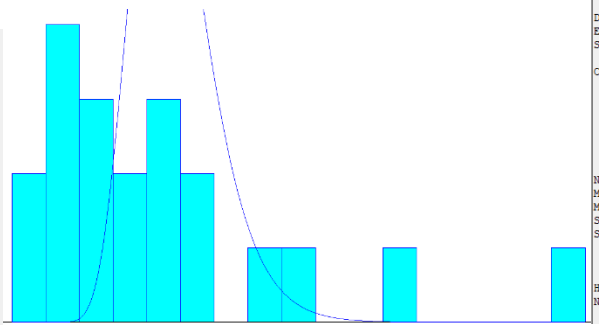
Function	Sq Error
Poisson	0.00402
Beta	0.00886
Normal	0.00893
Weibull	0.0123
Triangular	0.0149
Gamma	0.0185
Erlang	0.0187
Uniform	0.025
Lognormal	0.035
Exponential	0.0396



```
        Distribution Summary

Distribution:   Poisson
Expression:     POIS(4.85)
Square Error:   0.004024

Chi Square Test
  Number of intervals   = 3
  Degrees of freedom    = 1
  Test Statistic        = 0.227
  Corresponding p-value = 0.661

        Data Summary

Number of Data Points   = 20
Min Data Value          = 2
Max Data Value          = 9
Sample Mean             = 4.85
Sample Std Dev          = 1.98

        Histogram Summary

Histogram Range         = 1.5 to 9.5
Number of Intervals     = 8
```

2. Inventory Check

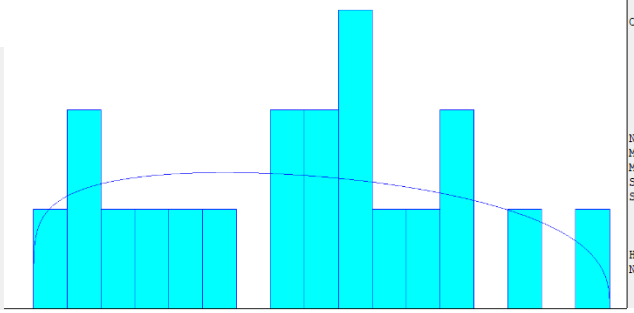
Function	Sq Error
Lognormal	0.0133
Gamma	0.0142
Weibull	0.016
Erlang	0.0165
Exponential	0.0256
Beta	0.0288
Poisson	0.0305
Triangular	0.0345
Normal	0.0382
Uniform	0.0662



```
        Distribution Summary

Distribution:   Lognormal
Expression:     3.5 + LOGN(4.7, 5.28)
Square Error:   0.015952

Chi Square Test
  Number of intervals   = 3
  Degrees of freedom    = 0
  Test Statistic        = 0.0285
  Corresponding p-value < 0.005

        Data Summary

Number of Data Points   = 20
Min Data Value          = 4
Max Data Value          = 20
Sample Mean             = 8
Sample Std Dev          = 3.99

        Histogram Summary

Histogram Range         = 3.5 to 20.5
Number of Intervals     = 17
```

3. Quality Check

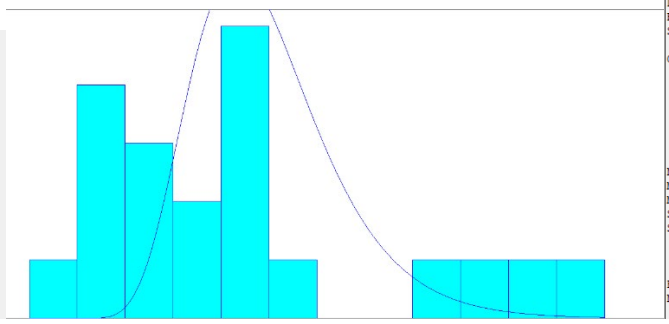
Function	Sq Error
Beta	0.0239
Normal	0.0254
Uniform	0.0262
Triangular	0.0275
Weibull	0.0299
Poisson	0.0319
Erlang	0.033
Gamma	0.0331
Exponential	0.0387
Lognormal	0.0407



```
        Distribution Summary

Distribution:   Beta
Expression:     5.5 + 17 * BETA(1.18, 1.37)
Square Error:   0.023913

Chi Square Test
  Number of intervals   = 3
  Degrees of freedom    = 0
  Test Statistic        = 0.331
  Corresponding p-value < 0.005

        Data Summary

Number of Data Points   = 20
Min Data Value          = 6
Max Data Value          = 22
Sample Mean             = 13.4
Sample Std Dev          = 4.54

        Histogram Summary

Histogram Range         = 5.5 to 22.5
Number of Intervals     = 17
```

4. Bat oil

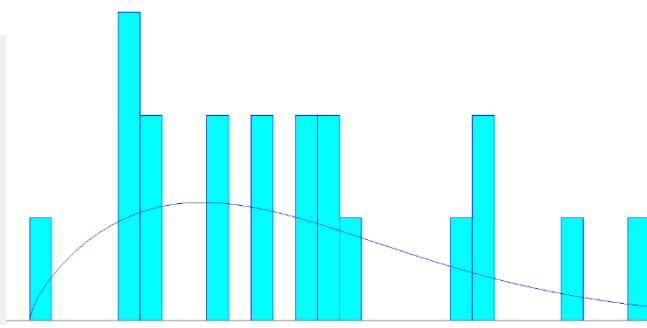
Function	Sq Error
Lognormal	0.0333
Erlang	0.0348
Gamma	0.0349
Weibull	0.0376
Beta	0.0507
Poisson	0.052
Normal	0.0562
Exponential	0.0606
Uniform	0.0667
Triangular	0.0707



```
Distribution Summary

Distribution:   Lognormal
Expression:     3.5 + LOGN(4.61, 4.16)
Square Error:   0.037605

Chi Square Test
  Number of intervals   = 3
  Degrees of freedom    = 0
  Test Statistic        = 3.35
  Corresponding p-value < 0.005

Data Summary

Number of Data Points   = 20
Min Data Value          = 4
Max Data Value          = 15
Sample Mean             = 7.95
Sample Std Dev          = 3.19

Histogram Summary

Histogram Range         = 3.5 to 15.5
Number of Intervals     = 12
```

5. Machine Knock

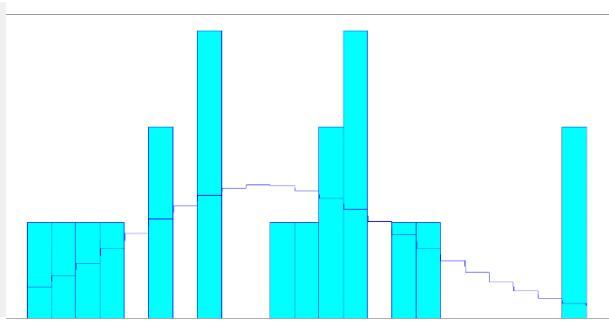
Function	Sq Error
Weibull	0.0549
Gamma	0.0555
Erlang	0.0557
Beta	0.0567
Poisson	0.057
Normal	0.0571
Triangular	0.0577
Lognormal	0.059
Uniform	0.0593
Exponential	0.0648



```
Distribution Summary

Distribution:   Weibull
Expression:     59.5 + WEIB(13.5, 1.67)
Square Error:   0.054945

Chi Square Test
  Number of intervals   = 3
  Degrees of freedom    = 0
  Test Statistic        = 0.919
  Corresponding p-value < 0.005

Data Summary

Number of Data Points   = 20
Min Data Value          = 60
Max Data Value          = 87
Sample Mean             = 71.6
Sample Std Dev          = 7.34

Histogram Summary

Histogram Range         = 59.5 to 87.5
Number of Intervals     = 28
```

6. Hand Knock

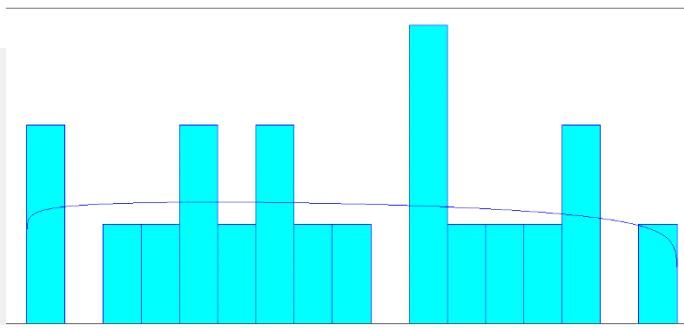
Function	Sq Error
Poisson	0.0501
Normal	0.0504
Beta	0.0508
Uniform	0.0515
Weibull	0.0519
Gamma	0.0539
Erlang	0.054
Triangular	0.0557
Exponential	0.0587
Lognormal	0.0602



```
Distribution Summary

Distribution:   Poisson
Expression:     POIS(32.8)
Square Error:   0.050102

Chi Square Test
  Number of intervals   = 3
  Degrees of freedom    = 1
  Test Statistic        = 1
  Corresponding p-value = 0.342

Data Summary

Number of Data Points   = 20
Min Data Value          = 23
Max Data Value          = 45
Sample Mean             = 32.8
Sample Std Dev          = 6.3

Histogram Summary

Histogram Range         = 22.5 to 45.5
Number of Intervals     = 23
```

7. Bat Polish

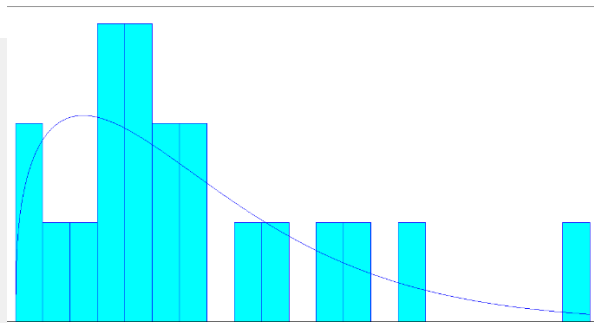
Function	Sq Error
Beta	0.0258
Uniform	0.0262
Normal	0.0304
Poisson	0.0309
Weibull	0.0323
Erlang	0.0352
Gamma	0.0354
Triangular	0.038
Exponential	0.0402
Lognormal	0.0465



```
Distribution Summary

Distribution:   Beta
Expression:     9.5 + 17 * BETA(1.04, 1.11)
Square Error:   0.025809

Chi Square Test
  Number of intervals   = 3
  Degrees of freedom    = 0
  Test Statistic        = 1.36
  Corresponding p-value < 0.005

Data Summary

Number of Data Points   = 20
Min Data Value          = 10
Max Data Value          = 26
Sample Mean             = 17.8
Sample Std Dev          = 4.79

Histogram Summary

Histogram Range         = 9.5 to 26.5
Number of Intervals     = 17
```

8. Individual Gear Packing

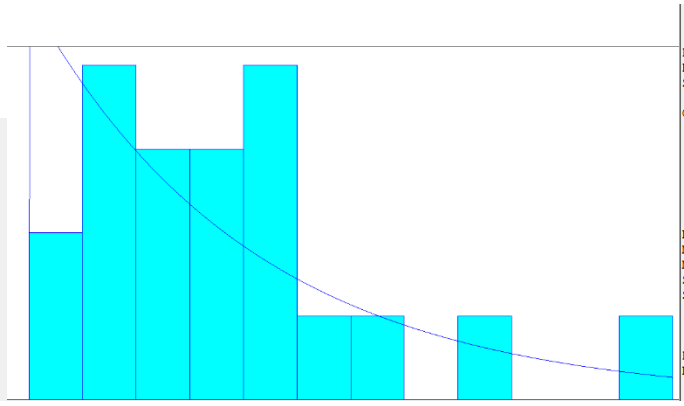
Function	Sq Error
Weibull	0.0233
Erlang	0.024
Gamma	0.024
Beta	0.0283
Exponential	0.0309
Triangular	0.031
Normal	0.0323
Poisson	0.0329
Lognormal	0.0329
Uniform	0.0474



```
Distribution Summary

Distribution:   Weibull
Expression:     4.5 + WEIB(7.07, 1.33)
Square Error:   0.023318

Chi Square Test
  Number of intervals   = 3
  Degrees of freedom    = 0
  Test Statistic        = 1.99
  Corresponding p-value < 0.005

Data Summary

Number of Data Points   = 20
Min Data Value          = 5
Max Data Value          = 25
Sample Mean             = 11
Sample Std Dev          = 5.07

Histogram Summary

Histogram Range         = 4.5 to 25.5
Number of Intervals     = 21
```

9. Invoicing

Function	Sq Error
Erlang	0.014
Gamma	0.0141
Weibull	0.0144
Lognormal	0.0186
Poisson	0.0233
Beta	0.0241
Triangular	0.0244
Normal	0.0258
Exponential	0.0389
Uniform	0.0617



```
Distribution Summary

Distribution:   Erlang
Expression:     3.5 + ERLA(1.88, 2)
Square Error:   0.014382

Chi Square Test
  Number of intervals   = 3
  Degrees of freedom    = 0
  Test Statistic        = 0.116
  Corresponding p-value < 0.005

Data Summary

Number of Data Points   = 20
Min Data Value          = 4
Max Data Value          = 15
Sample Mean             = 7.25
Sample Std Dev          = 2.73

Histogram Summary

Histogram Range         = 3.5 to 15.5
Number of Intervals     = 12
```

Report of Existing Model

Time

VA Time	Average	Half Width	Minimum Value	Maximum Value
Order	50.0805	(Insufficient)	5.9709	182.15

NVA Time	Average	Half Width	Minimum Value	Maximum Value
Order	0.00	(Insufficient)	0.00	0.00

Wait Time	Average	Half Width	Minimum Value	Maximum Value
Order	228.28	(Insufficient)	0.9338	675.46

Transfer Time	Average	Half Width	Minimum Value	Maximum Value
Order	3.1045	(Insufficient)	1.0000	5.5000

Other Time	Average	Half Width	Minimum Value	Maximum Value
Order	0.00	(Insufficient)	0.00	0.00

Total Time	Average	Half Width	Minimum Value	Maximum Value
Order	281.47	(Insufficient)	10.0000	859.38

Other

Number In	Value
Order	210.00

Number Out	Value
Order	67.0000

WIP	Average	Half Width	Minimum Value	Maximum Value
Order	77.7853	(Insufficient)	0.00	143.00

Report for Improved Model

Time

VA Time	Average	Half Width	Minimum Value	Maximum Value
Order	46.3363	(Insufficient)	5.8653	243.16

NVA Time	Average	Half Width	Minimum Value	Maximum Value
Order	0.00	(Insufficient)	0.00	0.00

Wait Time	Average	Half Width	Minimum Value	Maximum Value
Order	149.84	(Insufficient)	0.7215	660.79

Transfer Time	Average	Half Width	Minimum Value	Maximum Value
Order	3.5714	(Insufficient)	1.0000	5.5000

Other Time	Average	Half Width	Minimum Value	Maximum Value
Order	0.00	(Insufficient)	0.00	0.00

Total Time	Average	Half Width	Minimum Value	Maximum Value
Order	199.75	(Insufficient)	8.5000	775.32

Other

Number In	Value
Order	199.00

Number Out	Value
Order	98.0000

WIP	Average	Half Width	Minimum Value	Maximum Value
Order	53.7707	(Insufficient)	0.00	101.00