Simulation based design of Production and Multi echelon supply chain network for job shop manufacturing environment: A Case Study

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Abstract. Purpose- This study aims to design simulation-based production and multi echelon supply chain network of gear job shop manufacturing. Design/Methodology/approach – Network design and development by ARENA Rockwell automation studio 15.1 version. Findings- Study provide solution to low productivity and improper resources utilization within plant. Research/managerial implications – This study lightened the resources effective utilization and improved productivity without changing any routing, planning and operation timings for the existing network. Helps to curb inefficiencies in multi echelon supply chain network of job shop scenario. Utility of Paper – This paper explores the real job manufacturing environment, their implications and shortcomings. Results of this study shows improvement of key parameters which strengthen supply chain efficiency.

Keywords - Manufacturing, Job Shop manufacturing, Multi echelon supply chain, Modelling, Simulation, ARENA

1. Introduction
Simulation models are enough mature to handle risk associated with design, analysis and handling of complex systems (Heim et. al 1997). Thus, simulation is widely applied to manufacturing systems. (Yu & Popplewell, 1994). Traditional manufacturing systems focused on internal operations and physical transformation of raw material to finished product.

In recent trend manufacturing system not limits themselves to production but also collaborate them selves with supply chain. Supply chain refers to network in which entity flow is within product cycle starting with production and ending at consumer demand fulfillment (Benjamin and Altilok 2007). In supply chain there flow of demand, money, information in both directions. Supply chain are said to be efficient when customer satisfaction is very high, improved predictability, high density of product flow and reduced stock outs. Multi echelon supply chain network has various echelons of working members, this network id required when product density becomes high and to ease management. Various echelons work as a single unit to accomplish goal of supply chain.
In this paper a case study of leading gear manufacturing unit XYZ Pvt. Ltd. is considered, situated in North India and having its own circle of branded customers. Company manufactures gears of three type namely Spur gear (G1), helical gear (G2), Worm Wheel (G3) for automotive and industrial purpose. Spread in the large area of 8000 square meter and working in 3 shifts of 8 hours each per day with 200 employee strengths for various shifts. Because of globalization, strict labor laws, fluctuating government norms and tough competition from competitors of this field company wants to improve its production network and its multi echelon supply chain network for high product flow and improved customer network, leading to generate more revenue and profitability share.

1.1 Inventory Strategies

Proposed company multi echelon supply chain network begins with arrival of consumer demand at network of retailers. Company is having 3 retailers namely R1, R2, R3 for each type of gear G1, G2, G3 being manufactured respectively. Each retailer is fulfilling there demand from distribution center (DC) which collective for three types of products. For procurement of product DC relies on Output buffer of plant (OB). Output buffer is storage of finished manufactured product produced by manufacturing plant (P). Input buffer (IB) supplies raw material to manufacturing unit. Suppliers feeds input buffer of plant as per their demand. In downside direction there is flow of product and upside flow of money. (Refer to figure 3).

Retailers takes up consumer demand and manage inventory as per demand, follows policy of continuous type review (Q\textsubscript{R}, R\textsubscript{R}), exercising retailer control. Whenever in hand inventory recedes level R\textsubscript{a}, a fresh order Q\textsubscript{a} is placed by distribution center (In stock inventory subtracted form backorders, if any). On getting order DC check for the amount ordered by if ordered amount is available, it merely takes in transit delays else additional delays are experienced because of procurement related delays. Demand which could not be satisfied by retailer a the time of order are taken into account of back orders.
In a similar fashion, replenishment at DC is made by placing order at OB at upstream level, following \((Q_{DC}, R_{DC})\) continuous nature based reviewing policy of inventory.

![Diagram of Multi-Echelon Supply Chain Network of Company](image)

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2. Literature of Modelling and Simulation of Multi-Echelon Supply Chain

Literature related to knowledge sharing, its flow and transfer was explored within layers of databases created by researchers. Although some idea may be conflicting, expedited in multi dimensions, overlapping within suggested ideas but main focus ends on common consensus.

Lejtman and Ebrhim (2002) considered the problem related to design of production management. Taken into consideration company experiencing problem in scheduling, procurement of inventory, inventory handling and production facilities. Developed model based upon group technology and designed a Kanban system to assist execution of scheduling based on a pull system. Used SIMUL8 as simulation tool for validating schedule and layout. Clinched that Just in Time, Kanban and group technology (GT) are best to flip the darker side of scheduling and layout associated issues. Moghaddam and Mehr (2005) studied problem of scheduling with in environment of job shop. Considered scheduling problem in job shop scheduling and aimed for reducing make span time. Modelled for 3 Jobs and 4 machine job shop problem, used Visual SLAM as simulation tool for solution to sequencing problem mentioned above. Validated results by application of other software results LINDO and MODSB. Proposed a sequence with reduced make span time for the job shop under consideration. Pierreval and Bruniaux (2007) studied automotive industry supply chain. Considered supply chains associated with automotive product supply chains, in which efforts of various participants sum up for manufacturing a product (say engine of car). To fulfil customer needs, they must be well developed and matured enough to practice the best. Representation Automotive industry which includes various types of production units and of complex products, which are composed of numerous sub-component. Model are dynamic paradigms in lieu with Forrester’s paradigm. Authors expedited in direction of identification of weakness, its capability to tailor itself with disturbances because of fluctuating consumer demands. For modelling of this static nature models were laid out using Modular analysis-based methodology and its associated data flow diagrams depicting product and information flow within network, simulation of same was done by I Think system. Benko et. al (2009) Studied difficult decisions in supply chain management related to Company Oriented and Customer Oriented issues. Application of Simulation was demonstrated on the production-inventory system, whose warehouse deals with single type of product. Simulation outcomes resulted in Optimum value of reorder point at which inventory cost reduce and satisfaction of customer demand, which in turn improved utilization of production facility. Mohan and Gopalkrishan (2011) explored non-
profitable food supply chain which handles food for society section comprising of “Food Insecure”, various operational issues with planning were addressed here. Discussed logistic elements associated with food distribution for insecure. Reclamation center defined here plays a key role in acquisition and collaboration of food products for distribution purpose. Proposed model simulation was done on ARENA Software to analysis and improvement of productivity levels at warehouse. Speed of response is highly relying on the various operational changes made within warehouse helped to expand the output of the reclamation center. Accomplishment rate of demand was enhanced by opting effective strategy of distribution. Results were proved amplified food availability for needy and curtailed food wastage.

Ruiz and Giret (2014) studied application of Simulation process in manufacturing field. Found that most of simulation tools do not consider precise requirements of “New manufacturing Era” such as dispersed associations, interoperability, collaboration and dexterity. Agent based environment for simulation of intelligent manufacturing system and different roles played by these agents of simulation defined considering the specific dynamic features in manufacturing simulation. Used SimISHOP as Simulation tool which start with model formulation, simulation of model and ends with results validation.

Jayant and Garg (2014) studied about Reverse Logistic and growth of sustainability within supply chains. Suggested that position of production amenities, storage and transportation strategies are foremost determinant of closed loop supply chain performance. Reverse Logistic network addressed the rapport of manufacturing and is equivalent Environmental Issues. Presented case study of XYZ Battery industry for collection of End of Life (EOL) Products of Lead Acid Battery. Aim was to Model and simulate the reverse logistic network for assemblage of EOL products proposed industry. Tool used for Modelling & Simulation was Arena Software (11.0) by Rockwell Animation Studio to find solution to problem areas identified and to improve reverse logistic operation.

Linh and Duonga (2015) designed multi-criteria based inventory management system for perishable products. Multi Criterion based metrics, including rate of ordering, ratio of variance, level of average inventory, and procurement rates. It expands theory of inventory for successful management of inventory, service level to customer being provided, finite lead times, along with distinct itemized treatment for each item. The suggested model will empower management to capture real time scenarios, incorporating multiple inventory characteristics that are backing cross-functional continuous upgrading.

Mourtzis and Doukas (2014) studied simulation and its integration with manufacturing systems. Stated with increase in competitiveness in global market, high variation in demand. Processes involved in development of product are getting tangled day by day. Considered Modelling and simulation analysis to get through complex nature systems and key for achievement of new regulating and inventory managing policies. Expeditied current scenario of simulation models starting with their evolution, also examined design of factory, design of flow network of material and information, design of manufacturing systems, and planning and regulating networks, virtual reality in design, development and manufacturing processes (ergonomics, robotics). Khan and Dweiri (2016) considered ware house inventory management role in improving customer service and reducing stock outs. Taken case study of Building of UAE. Developed a model to improve average inventory level, average lost sales, and percentage of customer's dissatisfaction for the main component in the company which is cement. Verified and validated developed model using ARENA simulation software. Finally, some recommendations regarding reorder point, batch size and target stock were given 55 to improve overall warehouse inventory management system for inventory strategy mentioned.

Bechtsis and Tsolakis (2016) studied Automated Guided Vehicles (AGV) and its integration with the Sustainable Supply Chain management. Provided key decisions governing implementation of AGVs into designing and planning phase., as they have strategic importance at various tactical and operational levels of natural hierarchy. Used Sustainable Cube (S2C2) for supply chain as a conceptual tool which collaborates sustainability in SC management along the direction of hierarchical decision-making framework for AGVs. Nyemba and Mbohwa (2017) studied dynamics impacting the material handling within periphery of manufacturing systems, complexity in assembling leading to high level of interdependence among these factors. Presented a case study of a timber processing and furniture making industry having batch production, in which flow levels of production are characterized by
various complex decisions which usually resulted from erratic manner in placing of orders, old and obsolete equipment, backtracking, cross tracking leading to reduced productivity. Tool used for this problem was Modelling and Simulation by ARENA software.

3. Methodology
This study initially focuses on design and development of production improvement network by modelling and simulating it by ARENA 15.1, on the basis of improvement in production network, its effect on whole multi echelon supply chain is taken into account in form of comparison between existing and proposed model. Results for both production and multi echelon supply chain are verified and validated. Results shown in paper are for 30 days run for 8 hours shift only.

Table 1 Research Methodology

3.1 Process of Modelling and Simulation:
Modelling and simulation process start with modelling of real system, model can be mathematical or physical in nature. Developed model is simulated for checking its working behavior and its real time working sense. To validate the results of simulation process, verification and validation of developed model is done. Same is depicted by figure 4.
3.2 Modelling and Simulation of Gear Job shop manufacturing

To respond to low productivity issues and low resource utilization, need of modelling and simulation of manufacturing shop is required. Company produces three types of gear spur gear G1, helical gear G2, Worm gear G3. Existing setup of XYZ has the following layout

- Arrival Area (Docking)
- Milling workstation comprising of 4 machines.
- Drilling workstation comprising of 3 machines.
- Paint shop with single painting both
- Polish workstation
- Shop exit

Assumptions
1. Plant produces 50% of gear G1, 30% of gear G2, 20% of gear G3.
2. Gear entities inter arrival time follow uniform distribution (100,108) minutes in the batch of 8.
3. For internal transportation of gears with inter shops, two fork trucks are deployed
4. On job completion at a location, the gear waits at OB, request for pickup of product is made, and entity wait for arrival of fork truck.
5. on transportation of entity to next location, firstly located in first in first out (FIFO) input buffer.
6. All processes follow a predefined routing and sequence of operations performed on gear being manufactured.

| Gear Type | Operations Sequence | Processing Time (Minutes) |
|-----------|---------------------|--------------------------|
| G1        | Milling Operation   | 35                       |
|           | Drilling Operation  | 20                       |
|           | Painting Operation  | 55                       |
|           | Polishing Operation | 15                       |
| G2        | Milling Operation   | 25                       |
|           | Painting Operation  | 35                       |
|           | Polishing Operation | 15                       |

Table 3 Distances among various shops

| From Location | To Location       | Distance (feet) |
|---------------|-------------------|-----------------|
| Arrival Area  | Milling Workstation| 100             |
|               | Drilling Workstation| 100             |
| Milling Station| Drilling Workstation| 300             |
|               | Paint Shop         | 400             |
| Paint Shop    | Polishing Area     | 150             |
|               | Polishing Area     | 300             |
|               | Arrival Dock       | 250             |
| Drilling Workstation| Paint Shop     | 150             |
|               | Polishing Area     | 400             |
| Polish Workstation| Arrival Dock  | 250             |
|               | Shop Exit          | 200             |
Modelling and Simulation on ARENA

Arena Simulation package by Rockwell Inc., enables it users to develop model and simulate it for various modular designs. Figure 4 illustrates the structure as well as simulation model logic in ARENA simulation environment. Simulations begin with “Create Jobs” where gears to be manufactured enter the manufacturing system in the given lot size and after that as per the company requirement the job type (G1, G2, G3) is assigned. After that as per table 1, operation plan is executed for the time limits defined for each job type assigned earlier. To facilitate the necessary movement of in process/processed gears for distances as per table 2 fork trucks are utilized and also being model in simulation envelope. At last counter tally, records for total number out, processing time and resource utilization and flow time for each type of job. Finally, job makes “Shop Exit”, making all engaged resources free and quits the system of simulation under consideration.
3.3 Modelling and Simulation of Multi Echelon Supply chain of XYZ Pvt. Ltd.

Architecture of multi echelon supply chain of XYZ is shown in figure 3 and details of it were discussed in section 1.1. for modelling and simulating it on ARENA software following assumptions and variables were used.

3.3.1 Assumptions

1. Poison distribution followed by demand arrival pattern. Demand arrives within batch of 8 product unit and portion of unsatisfied demand is said to be lost.
2. Keeping in view modelling generalization and adaptability, manufacturing time distributions belong to Erlang distribution. All delays in transportation are as Erl (k=2, \( \lambda=1 \)), whereas for manufacturing process time distribution it follows Erl (k=3, \( \lambda=5 \)).
3. At each tier orders are taken following the sequence of their placement. Order containing shipments are generated once, previous replenishment is received and acknowledged.
4. In scenario of stock-out at plant or DC, it is accounted as unsatisfied portion of demand, order fulfilment (shipment) is deferred till its clearance.
5. Distance between output buffer and distributor is 45km and 4 trucks are employed.
6. Distance between distributor and retailer 1 is 50 km and for that 3 trucks are employed.
7. Distance between distributor and retailer 2 is 43 km and for transportation 2 truck is employed.
8. Distance between distributor and retailer 3 is 45 km and for transportation 1 truck is employed.
9. For the transportation to distribution centre cost of busy/hour is 14, idle/hour is ₹4, per use is ₹8.

Figure 6 ARENA Model of gear job shop manufacturing
10. For the transportation to retailer 1 from distribution centre cost of busy/hour is ₹11, idle/hour is ₹2, per use is ₹11.
11. For the transportation to retailer 2 from distribution centre cost of busy/hour is ₹12, idle/hour is ₹1, per use is ₹12.
12. For the transportation to retailer 3 from distribution centre cost of busy/hour is ₹13, idle/hour is ₹2, per use is ₹13.
13. For the gear entity holding cost/hour is 0.30, initial wait cost is 0.12, initial other cost is 0.40.
14. All assumptions are made for 8 hours working shift and for 30 days run length.

Table 4 Details of variables used in Modelling and Simulation of Multi echelon supply chain

| Sr. No | Symbol | Meaning | Initial Value for Runs |
|--------|--------|---------|------------------------|
|        |        |         | 30 Days    | 300 Days    |
| 1      | InventoryPosition _DC | In stock inventory available with Distribution centre | 150         | 1700        |
| 2      | Order_Output | Order placed by output buffer | 0           | 0           |
| 3      | Inventory_DC | Inventory capacity of distribution centre | 225         | 2300        |
| 4      | Backorder_DC | Backorder available at distribution centre | 0           | 0           |
| 5      | AvailableforBackorder_DC | Current status of backorders at Distribution centre | 0           | 0           |
| 6      | Inventory_Retailer _Retailer | Inventory capacity of Retailer | $0 \leq \text{Inventory\_Retailer} \leq R_R + \text{QR}$ | $R_R \leq \text{Inventory\_Retailer} \leq R_R + \text{QR}$ |
| 7      | InventoryPosition _Retailer | Current inventory status of retailer | $R_R \leq \text{Inventory\_Retailer} \leq R_R + \text{QR}$ | $R_R \leq \text{Inventory\_Retailer} \leq R_R + \text{QR}$ |
| 8      | Order_DC | Order placed by distribution centre | 0           | 0           |
| 9      | Q_R | Quantity ordered by retailer | 150         | 1550        |
| 10     | R_DC | Target level inventory of distribution centre | 150         | 1600        |
| 11     | Inventory_Output | Inventory available at output buffer | 300         | 3100        |
| 12     | Production_Plant | Production produced by plant | 0           | 0           |
| 13     | InventoryPosition _Input | Current inventory status of input buffer | $R_R \leq \text{Inventory\_Input} \leq R_R + \text{Qi}$ | $R_R \leq \text{Inventory\_Input} \leq R_R + \text{Qi}$ |
| 14     | Inventory_Input | Inventory available at input buffer | $R_R \leq \text{Inventory\_Input} \leq R_R + \text{Qi}$ | $R_R \leq \text{Inventory\_Input} \leq R_R + \text{Qi}$ |
| 15     | Q_DC | Quantity ordered by distribution centre | 300         | 3300        |
| 16     | Order_Supplier | Order placed by input buffer to supplier | 0           | 0           |
| 17     | R_I | Target value input buffer | 200         | 2100        |
| 18     | Q_I | Quantity ordered by input buffer | 190         | 1900        |
| 19     | BigR_Plant | Target level of Plant | 500         | 5500        |
| 20     | r_Plant | Reorder level plant | 250         | 2500        |
|   | Demand Description                           | Status          | Value 1 | Value 2 |
|---|---------------------------------------------|-----------------|---------|---------|
| 21 | Backorder_DC                                | Backorder of distribution centre | 0       | 0       |
| 22 | AvailableForBackorder_Output                | Current status of backorders at output buffer | 0       | 0       |
| 23 | FullySatDemand_Retailer                    | Demands full filled by retailer | 0       | 0       |
| 24 | FullySatDemand_Output                      | Demand full filled by output buffer | 0       | 0       |
| 25 | FullySatDemand_DC                          | Demand fully satisfied by distribution centre | 0       | 0       |
| 26 | FullyDemand_Input                          | Demand received by input buffer | 0       | 0       |
| 27 | FullySatDemand_Input                       | Fully satisfied demand received by input buffer | 0       | 0       |
| 28 | r_Input                                     | Reorder level of IB | 0       | 0       |
| 29 | r_Output                                   | Reorder level of output buffer | 150     | 1800    |
| 30 | Supplier Demand                            | Demand received by supplier | 0       | 0       |
| 31 | Production Units                           | Production units produced | 0       | 0       |
| 32 | Output Buffer_Demand                       | Demand generated by output buffer | 0       | 0       |
| 33 | R1 Demand                                  | Demand generated by R1 | 0       | 0       |
| 34 | R2 Demand                                  | Demand generated by R2 | 0       | 0       |
| 35 | R3 Demand                                  | Demand generated by R3 | 0       | 0       |
| 36 | DC_Demand                                  | Demand generated by distribution Centre | 0       | 0       |
3.3.2 Modelling Logic used in Multi echelon supply chain modelling

![Flowchart of the modelling logic]

- **START**
  - 1. Demand by Customer at Retailers
    - Product Available?
      - YES: Demand filled & Inventory Updated
      - NO: 2. Order Placed at Distribution Centre
  - 2. Order Placed at Distribution Centre
    - Quantity available at DC?
      - YES: Demand filled & Inventory Updated
      - NO: 3. Order Placed at Output
  - 3. Order Placed at Output
    - Quantity available at Output Buffer?
      - YES: Demand filled & Inventory Updated
      - NO: 4. Order Placed at Manufacturing Plant
  - 4. Order Placed at Manufacturing Plant
    - Finished Product available at Plant?
      - YES: Demand filled & Inventory Updated
      - NO: 5. Raw material ordered from input buffer
  - 5. Raw material ordered from input buffer
    - Raw material Available?
      - YES: Demand filled & Inventory Updated
      - NO: 6. Order Placed at Supplier
  - 6. Order Placed at Supplier
    - Demand filled & Inventory Updated
  - 7. Order full-filled by Supplier

**END**
• Modelling and Simulation of Retailer Segment -

- There are three Retailer in Multi echelon Supply chain network of company.
- Separate Retailers for three distinct products and they interact with customer demand and demand arrival follows Poison distribution with mean value of 8.
- Retailer gets its demand fulfilled from Distribution centre.
- Each time when demand arrives, customer demand is tallied, inventory status is checked whether it is available or not then proceeded by decide module.
- If inventory is available, it taken away and inventory status is updated else it counts for demand lost.
- If inventory level down crosses Reorder level order is placed at Distribution centre as target inventory value.

• Modelling and Simulation of Distribution Centre Segment

- Distribution centre feed retailers and gets its product supply from Output buffer of plant.
- For three distinct products common distribution centre is there.
- Whenever demand form retailer arrives at Distribution Centre, it is tallied and its checked for its availability.
- If demanded quantity count is available then its is transported to retailer else it counts for backorders. And order is placed by Distribution centre at Output buffer for fulfilment of backorders (if any).
- **Modelling and Simulation of Output Buffer**
  - There is single output buffer which feeds from manufacturing plant.
  - At output buffer, whenever an order arrives firstly it is tallied with available status of inventory at buffer, if it is sufficient then order is released and buffer inventory is updated.
  - If output buffer inventory is lower than demand then production is restarted in plant and ordered quantity is delivered at buffer, to reduce backorders and increase inventory level of Output buffer.

- **Modelling and Simulation of Input Buffer**
  - Input buffer feeds manufacturing plant and get raw material from supplier.
Whenever plant places an order of raw material at input buffer, its demand is tallied with available inventory, if sufficient inventory is available at buffer, it proceeds to plant.

If sufficient inventory is not available at buffer order is placed at supplier and seized manufacturing unit is released to produce, with availability of raw material.

When output buffer inventory reaches its target value, production is suspended and demand is disposed at input buffer.

- **Modelling and Simulation of Supplier**
  - This model segment generates input buffer orders, send raw material to input buffer.
  - As per assumption supplier is having sufficient inventory on hand always and arrives at Uniform distribution of [100, 140] hours.
  - Whenever demand arrives at supplier, it is tallied and order status is changed to release plant order and plants starts working and input buffer inventory status gets updated.
• **Modelling and Simulation of Overall Multi echelon Supply Chain**
  This consist of sub models at various echelons level it is shown in figure 12

![Figure 12 ARENA model of Multi echelon Supply Chain Network of XYZ Pvt. Ltd.](image)

### 3.4 Verification and Validation

**Gear Manufacturing Unit** –

Verification is done at operationality end of of model. It is done to ensure that –
- Programming errors within modelling.
- Scope of model is not affected by any errors, oversights, or bugs.

In Gear manufacturing process, verification of model is spontaneous process for number of replications it makes. Here acceptable level of error is assumed to be less than 5%.

To make assurance that modeled data portraits best the actual working and to enhance ts relevance a confidence interval analysis was executed. At confidence interval of 95%, and the necessary number of replications of simulation were calculated by the following: (Kelton et al., 1991)

\[
n = \frac{(z_{\frac{\alpha}{2}})^2 \sigma^2}{d^2}
\]

where \(n\) = replications required, \(d\) refers to sensitivity level, \(\sigma\) = standard deviation, \(z\) refers to critical value from the standard normal table at the assumed confidence level. For our model to achieve 95 % confidence level, 60 replications are required.
It can be seen from figure 13 that mean square value is as low as 0.000166 and corresponding p value greater than 0.15 which proves arrival time distribution is having best fit.

Multi Echelon Supply Chain Network –

| Name                              | Distribution | Expression |
|-----------------------------------|--------------|------------|
| Demand arrival at each Retailer   | Poisson      | Mean (8)   |
| Manufacturing time delay          | Erlang       | (k=3, λ=5) |
| Transportation delay              | Erlang       | (k=2, λ=1) |

Figure 13 Distribution fit for inter arrival time of gear manufacturing

Figure 14 Distribution of demand arrival at retailer
Poisson distribution is being followed by demand arrival pattern having mean value of 8 its correctness is checked by input analyser of ARENA. It can be seen from figure 14 that for chosen distribution square error value is very less as 0.000192 and p value is >0.15 which proves goodness of fit of distribution.

Manufacturing time delays are assumed to follow Erlang distribution. It can be seen from figure 15 that for chosen distribution square error value is very less as 0.000254 and p value>0.15 which proves goodness of fit of distribution.

Transportation delays are assumed to follow Erlang distribution. It can be seen from figure 16 that for chosen distribution square error value is very less as 0.000094 and p value>0.15 which proves goodness of fit of distribution.

4. Results

All the results produced here are validated and verified for their correctness in section 3.3.3. ARENA 15.1 version is used, on computer having intel i7 processor, 8 GB RAM, Windows 10.1 pro version. Results shown here are for 60 replications and run length of 30 days at rate of 8 hours per day.

4.1 Gear production network

After analysis of existing model it was found that waiting time was very high for Painting spray booth as 55 minutes. As per discussion of results of existing model with company executives, main bottleneck was single spray booth, any technical glitch hampered the production line. All other operations were working to their optimized value and sequence. To cope up with prevailing issues of low productivity, availability of ample land space with company and company own interest of generating more revenue and profitability share, idea of new spray booth was suggested. In proposed model for painting spray booth were 2 in number. Because of which production improved and resources utilization also shown improvement it can be seen from tables below

| Table 6: Number IN/OUT for gear manufacturing unit |
| --- |
| **Number In/Out** | **Number of gear in/out for 60 replications run length 30 days** |
| **Existing Model** | **Proposed Model** | **Improvement (%)** |
| | | | |
Table 7 Resources Scheduled utilization for gear manufacturing unit

| RESOURCES        | Scheduled resource utilization (average) for 60 replications run length 30 days |
|------------------|---------------------------------------------------------------------------------|
|                  | Existing Model | Proposed Model | Improvement (%) |
| Drilling Machine | 0.2012         | 0.2534         | 25.94            |
| Milling Machine  | 0.5903         | 0.7423         | 25.74            |
| Polish Gear      | 0.2492         | 0.3121         | 25.24            |
| Spray Both       | 0.3298         | 0.4850         | 47.05            |

Hence improvement shown in manufacturing unit satisfies, the need of proposed model of multi echelon supply chain in compliance with proposed model of gear manufacturing unit.

4.2 Multi Echelon Supply Chain

Here results for the existing and proposed multi echelon supply chain network are shown. Improved multi echelon network corresponds to improvement in production network and existing model of supply chain corresponds to existing production network. Here all results are generated by ARENA and key parameter strengthening supply chain are chosen and compared.

Table 8 Idle Cost for multi echelon supply chain network

| Resources                  | Idle cost improvement for 60 replications 30 Days Run Length |
|----------------------------|---------------------------------------------------------------|
|                            | Existing | Proposed | IMPROVEMENT (%) |
| Gear Manufacturing Unit    | 1980     | 1933     | 2.37%            |
| Transport to Retailer 1    | 3358     | 3126     | 6.90%            |
| Transport to Retailer 2    | 959      | 843      | 12.09%           |
| Transport to Retailer 3    | 478      | 246      | 48.53%           |
Table 9 Number in at DC and gear supplied to retailer for multi echelon supply chain network

| Entity                  | Number in DC and gear supplied to retailer improvement for 60 replications | 30 Days Run Length |
|-------------------------|--------------------------------------------------------------------------------|---------------------|
|                         | EXISTING | PROPOSED | Improvement (%) |
| Number in DC            | 240      | 300      | 25%               |
| Gear supplied to Retailers | 240 | 300 | 25%               |

Table 10 Resources scheduled utilization for Multi echelon supply chain network

| Resources                | Resource scheduled utilisation improvement for 60 replications For 30 Days Run Length |  |
|--------------------------|----------------------------------------------------------------------------------------|---|
|                          | EXISTING | PROPOSED | Improvement (%) |
| Gear Manufacturing Unit  | 0.0833   | 0.1047   | 25.93%          |
| Transport to Retailer 1  | 0.2227   | 0.2763   | 24.69%          |
| Transport to Retailer 2  | 0.3340   | 0.4144   | 24.73%          |
| Transport to Retailer 3  | 0.6680   | 0.8288   | 24.73%          |
| Transport of Shipment to DC | 0.0671 | 0.0832   | 23.99%          |

Table 11 Various counts for multi echelon supply chain network

| COUNTS | 60 Replications 30 Days Run Length |  |
|--------|-------------------------------------|---|
|        | EXISTING | PROPOSED | Improvement (%) |
| Transport of Shipment to DC | 2686 | 2640 | 1.71% |
### 5 Conclusions

Work presented here is real case study of gear manufacturing job shop production unit. In this study no changes are made in operation sequence, operation timings and existing routing of flow only by modelling and simulating the production network of company, need of 2 spray booths was suggested and accepted by company as well. By this number in shown improvement of 26% and number out showed improvement of 25.52%. Based on this improvement its effect on company supply chain was simulated, demand generation at output buffer showed improvement of 25%, demand generation at input buffer showed improvement of 25%, count for number of gear G1 delivered improved by 24.16%, count for gear G2 delivered improved by 25% and count for gear G3 delivered improved by 25.53%. moreover, resources utilization also shown improvement in range of 24-25% which enough to resolve the pertaining issues with plant as discussed in section 1 of this paper. Company on the basis of suggested improvements can accelerate their economy, revenue generation and market position with increased customer satisfaction. As supply chain is a dynamic process and always adapts itself corresponding to changes in working environment, to suit the market trends and challenges, simulation review can be taken for emerging trends.

Future work can be extended in the direction of verification of results of this work by other modelling and simulation software like SimiShop, SIMUL LINK, FlexiSim, Petrinet etc. Current can also be expedited by using numerical optimization and statistical techniques for justification of work. Work can also be extended by changing the number of suppliers, retailer distribution centre for more advance level inventory management of segments.

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