Development of a Competitive Responsive Manufacturing System to Maximize the Energy Efficiency in the Automobile Industry by Process Sequential Optimization

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Abstract-This paper develops a methodology for responsive manufacturing system to work as robust enterprises for automobile products. The manufacturing industrial revolution is nothing but reduction of wastage and losses to save the costly resources. The manufacturing development and improvement aims to reduce manufacturing cost and losses by technical and human consideration. The organization or company can be a private business, or non-private business organization or a government agency, but there ultimate aim is to earn profit, and to satisfied customer by providing timely products and services. The manufacturing scenario is constantly changing. In this changing scenario the industries are willing to retain their customers and provide the products in the right time, with right quality and right quantity. Any delay in process and cycle time result into loss of customer. The company wants to optimize their money, time and space resources. The different improvements tools and software help organization to optimize its processes to achieve more efficient results in minimum time and cost. The roles and responsibilities of the industries are converging towards the customer in order to be a global player in this competition time.

KEYWORDS: Energy efficiency, Responsive Manufacturing System (RMS) Arena simulation, Cycle time reduction.

I. INTRODUCTION

In the manufacturing operation, exceptions may occur dynamically and unpredictably. Their occurrence may lead to the degradation of system performance or, in the worst case scenario, may interrupt the production process [8]. In any batch process industry like automobile sector, where similar products are produced in batches after some intervals, any changes & reduction in cycle time results into direct saving or profit with a multiplying effect.In an automobile sector, to produce waste is a natural process and an energy efficiency maximization program may help to reduce these losses [19]. The energy maximization program needed knowledge of different type processes and energy and their mechanism [9]. The energyefficiency program can be broadly divided into processing techniques, biological conversion methods and chemical conversion products depend on end uses. The object is to maximize the energy efficiency by reduces all type of losses, mainly the set-up-time as each loss is a loss of organization resources [24].

In the context of cyclic manufacture all the items are produced in an optimal cycle time, and the production facility runs at certain cost level [13]. The need to remain competitive in order to survive in the current world, has led the manufacturing sector to consider how, to minimize costs while maximizing quality. At the same time to response faster for customer requirements the production system is analyzed for optimization, so at each stage the loss generated may also optimized.

The total cost consists of the facility setup cost for the basic parts and the total cost is to be optimized in sequences of operations. Numerous models have been developed to overcome manufacturing limitationsuch as determining unnecessary moving, unnecessary inventory and transport but do not identified the stages/ steps of optimum control [6].The losses developed in a manufactured organization are mainly caused by delays occurred during production time [1].Lean manufacturing is a philosophy for structuring, operating, controlling, management, and continuously improving industrial production systems [18].Lean manufacturing is a way of thinking, a culture where all employees continuously look for ways, to improve the process with the philosophy of eliminating all non-value-added activities [3].Lean manufacturing has been increasingly adopted as potential solution for many organizations, particularly within the petrol, automotive and aerospace manufacturing industries.

The technique of simulation has long been used by the designers and analysts in physical science and it promises to become an important tool for taking the complicated problems of managerial decision making and industrial applications [4].Along with simulation techniques and lean techniques the decision making process is become easy. The simulation is a tool to take advantage of fast electronic computer for decision making [2]. The simulation software is deterministic in nature and based on law of probability. The different simulation software is available which helps to implement the lean manufacturing techniques [25]. The simulation application varies from simple queuing models to large integrated systems of production. The economic benefits attributable to lean manufacturing include reduced lead-time and higher throughput and lower work-in-process [26].

II. Responsive Manufacturing System

The globalization and information technology changes the scenario of viewing manufacturing into a different way [5]. The industries, all over the world, whether large or small, are facing challenges on multiple fronts, competition is becoming borderless, new alliances are being formed; internal processes are now being considered for outsourcing. Work-force multiple-utilization and total quality and efficiency are the objective [20].They have to balance with customer and vender both, sometime customer may be a vender also.The capabilities of manufacturing plus expectation of customer lead to increase pressure for fast response and variety. The responsive batch manufacturing system should be capable for sudden and large demand changesand all withminimum losses and with energy efficiency [3]. A responsive manufacturing system is a realistic manufacturing system which has to meet the demands of consumer by aligning themselves with the supplier by flexibility in system and with lean team efforts a satisfaction is developed [2]. The present time required combined efforts of various already developed model of production system, like lean manufacturing, CIM, TQM, Taguchi loss function, etc.

The present time is of mass customization e.g. the ability of providing customized product or service through flexible processes and at reasonable cost with high quality [12]. For a successful system an enterprise need a great amount of capital, technology, manpower and time for system development and maintenance. Any system which reduces the costs of life cycle may be useful to minimize time, resources, money and other expenses [9]. The increased presence of global competition has forced manufacturer and service providers for high reliability and capability. The **Fig.1** shows an integrated network of general automobile productsresponsivemanufacturing System.

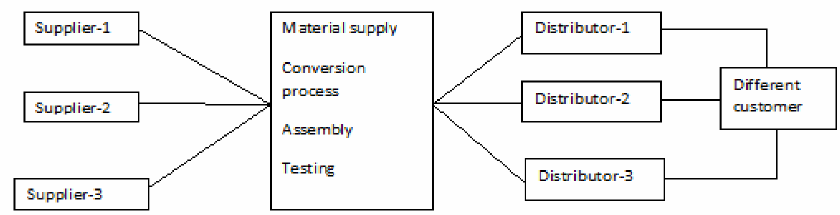


Fig.1.ResponsiveManufacturing System Sequences.

In a batch manufacturing unit generally more than one product are made in certain cycle time, and in order to become competitive, the progressive firms run the production facilities optimally. In multi-product plants, all products follow the same production path as shown in **Fig.2.**

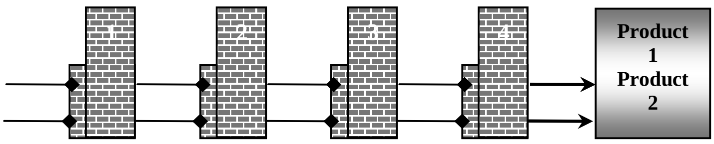


Fig.2Multi-Product Sequences

For each product same work center are used without any rearrangement of equipment. Now ability for companies is to act as the learning type of production system, for changed situation for different product type and their quantity, quality change, cost change and delivery change [5].The customer demand is now just like the requirement of oxygen, food, service and petrol, we cannot store them but we have to supply at right time only. We are following it in our daily life, and now we have to implement in industry [14].

III. ENERGY EFFICIENCY IN AUTOMOBILE INDUSTRY

An automotive batch production unit is more suitable in current requirements to work with energy efficiency. Efficiency can be defined as doing things right, it is achievement of objective with least amount of resources. Productivity implies effectiveness of individuals and efficiency of organization performance [15].Effectiveness is the achievement of objectives and desired result. The increasing cost of energy, environments and resources crises causes to move for maximum energy efficiency [1]. Energy efficiency maximization implies more efficient use of resources with less energy loss. Now energy efficiency is linked with value addition activities.

The automobile sector and its energy efficiency is greatly affected or motivated by Japanese manufacturer. After development of Japanese production system (known as Toyota production system- TPS) the whole process of improvement was led by TPS. The robustness of the Japanese economy is amazing in light of Japan's devastated condition after World War II [11]. An engineer knows that all kinds of functions are energy transformation [19]. The energy is essential for value addition in the product, for obtaining the maximum customer satisfaction [10]. The success of any manufacturing organization depends on its energy consumption, its cost and its total environment losses [5].The energy conservation and maximization strategies are cost effective, which conserve the environment automatically.

The design of a product shall include considerations for manufacturing, parts cost and assembly operations. The cost of any change of resources afterdesign stage will be many time the cost at conceptual stage. This will help to developed new product design with less time.All this development are focused to reduced manufacturing cost, investment holding cost, setup and maintenance cost, warranty cost etc.[22].

The energy efficiency may be improved by proper R & D for developing best energy saving process and energy efficient product [9].The energy efficiency is always associated with production cost, whether it is purchase activity of raw material or fuel, subcontractor bill, machinery bill or rejection bill [17]. The Elena [23] describes energy efficiency maximization is nothing but production cost optimization. For each organization the breakeven point (BEP) for energy efficiency should be known, which guide for actual production.

IV. OPTIMIZATION ROLE IN THE MANUFACTURING

The best possible performance is called optimum operations. Many models have been developed to search optimal or near optimal solutions. The manufacturing design optimization problem need, reduction of design process, design time and high design quality. The optimum production system is always governed by customer, market, product complexity and technology [6].In engineering, optimization may be applied to solve any problems, from design stage to manufacturing process parameters optimization [10]. For selecting any machining process optimum parameters, the conflicting multiple objective can be convert in to a single composite objective [1].

V. SEQUENTIAL OPTIMIZATION IN PROCESS INDUSTRY

Every manufacturing operation performed in sequences of operations and sometime in stages. It is difficult to optimize the complete process as at each work center different parameters and objective function are needed. In order to reduce complexity the complete manufacturing process is optimized with a common objective of energy optimization. The sequential optimization process determines the main control parameters of each work center. The optimal plant configuration includes quantity and type of main and auxiliary equipment with associated circuits. The design of multi-product plants also considers the uncertainties [29].

VI. LEAN MANUFACTURING AND RMS

A successful production system always provides a better value product to its consumer.The manufacturing philosophy in general are based on central idea that industry can realize some form of competitive advantage, such as improved product quality, timeliness of delivery, reduced costs, new products and services[2]. Rahimifard [20] demonstrate the manufacturing industry challenges to work as responsive manufacturing system (RMS), so responding quickly to the ever changing requirements of customers. A change capable manufacturing system, which can realizes families of similar products in varying quantity and mixes will be developed [8].

Reichelt [28] emphasis for the structure needed for steel plants to work as responsive manufacturing system. The reconfigurable capability support both hardware and software to develop the new products in minimum time [27]. The contemporary manufacturing organization has witnessing a transition of organization to lean manufacturing [26].The responsive manufacturing system offer such features allowing quick adjustment of production capacity and functionality by adjusting or rearrangement or changing the parts [31].

The basic characteristics required for RMS are modularity, integrability, customization, convertibility and diagnosability. The RMS is always responsive to market and customer, society and environments, and with enterprises main and other objectives [5]. The Japanese production system is largely attributed to the development of lean manufacturing. The LM principles steps are start with defining each product for customer requirements, then by value steam mapping and by allowing customer to pull the value and perfection can be achieved and practice for continuous improvements [31].Lean Manufacturing has increasingly been applied by leading manufacturing companies throughout the world. It has proven to have many positive outcomes which include such concepts as reduced cycle time, decreased cost, reduction of defects and waste.

Lean manufacturing aims to achieve the same output with less input; such as less time, less space, less human effort, less machinery, less material and less cost [16].The lean manufacturing [LM] was developed as an alternative to mass production and a step towards RMS.Lean manufacturing is a philosophy for structuring, operating, controlling, management, and continuously improving production systems [21].

A traditional non lean organization is now a functional organization in which disconnected process and product were moving from one functional department to another [9]. The inventory level is high, long delay, large batches sizes and big machines. In LM the functional organization is replaced by flexible cells. The level of inventory is low and single piece of batch size is the target. Goods are produced as per order, nor forecasted and cycle time is also low [11]. The shop floor performance is improved by cellular manufacturing system [13].In order to become lean, an organization must implement an integrated approach from the supplier to the customer [1].The goal of lean manufacturing is to minimize waste in terms of non-value-added activities, such as waiting time, setup time, and WIP inventory, etc. [3].

The Agile manufacturing uses the principles of lean production in broader scale to quickly response to change in product demand and customer needs. The capacity of anagile company is to adapt change depend upon flexibility of production system and they work as virtual enterprise [2]. The tool and techniques applied by two systems are same. For a company to be agile, it must be lean [9].

The Lean Manufacturing, also called Lean Production, is a set of tools and methodologies that aims for the continuous elimination of all waste in the production process. The main benefits of this are lower production costs; increased output and shorter production lead times, for example, more effective use of equipment and space leads to lower depreciation costs per unit produced, more effective use of labor results in lower labor costs per unit produced and lower defects lead to lower cost of goods sold [24]. The lean tools including just in time, cellular manufacturing, total productive maintenance, single-minute exchange of dies, and production smoothing have been widely used in discrete parts manufacturing sectors such as automotive, electronics and appliance manufacturing [18].

VII. SIMULATION

Simulation is an imitation of reality. Children cycling park, with various crossings and signals is a simulations models of the city traffic system.According to one definition “simulation is a represents of reality though the use of a model or other device which will react in the same manner as reality under a given set of conditions ‘’Simulation has also been defined as” the use of a system modal that has designed characteristics of reality in order to produce the essence of actual operation [7].

In the laboratories a number of experiments are performed on simulated molded to determine the behavior of the real system in true environments.Scale models of machines have been used to simulate the plant layouts and models of aircrafts have been tested in wind tunnels to determine their aerodynamic characteristics [25]. Simulation, which an appropriately be called management laboratory, determines the effect of a number of alternate policies without disturbing the real system. It helps in selecting the best policy with in the prior assurances that its implementation will be beneficial[4]. The operation research other model are not sufficient to tackle all the important managerial problems requiring data analysis. Each technique has its own limitations [30]. In general, the simulation technique is a dependable tool in simulations where mathematical analysis is either too complex or too costly [10].

VIII. ARENA SIMULATION SOFTWARE

The ARENA modeling system from Systems Modeling Corporation is a flexible and powerful tool that allows analysts to create animated simulation models that accurately represent virtually any system. First released in 1993, ARENA employs an object-oriented design for entirely graphical model development. Simulation analysts place graphical objects, called modules, on a layout in order to define system components such as machines, operators, and material handling devices [12]. ARENA is built on the SIMAN simulation language. After creating a simulation model graphically, ARENA automatically generates the underlying SIMAN model used to perform simulation runs [31].
The ARENA product suite is designed for use throughout an enterprise, from strategic business decisions, such as locating capacity in a supply chain planning initiative, down to operational planning improvements, such as establishing production line operating rates.To achieve enterprise wide top-down scalability and ease of use by all levels of an enterprise, ARENA has many unique properties, which are described in brief below. [7]One other advantage of ARENA is that it is open to interaction with many applications such as Microsoft Access and Excel with its built-in spreadsheet data interface. Furthermore, with Visual Basic for Applications (VBA) support there is virtually no limit on creating interfaces and programs.

IX. EXAMPLE

An exampleof automobile unit which is ISO 9001 certified for design, manufacture, sells and supply of construction and road building equipment such as Loader Backhoes and Vibratory Compactors is taken. These products are used primarily for the country's infrastructure development, irrigation, mining.In the automobile unit the assembly shops is used to assemble the vehicle. The assembly shops equipped with state of the heart facilities as shown in **Fig, 3** are:

- Welding Robots.
- Laser Gas-cutting Machines.
- CNC Boring Machines.
- Powder Coating Painting facility

After vehicle assembly they send for cleaning and washing and then testing for performance verification and leakage test etc. For quality assurance sophisticated equipment are used. The plant assembly line controls the whole manufacturing cycle time of the finished products as it shows the output of other functional departments also.

Fig, 3Assembly shops equipped with the modern facilities

X. PROBLEM FORMULATION

In the manufacturing assembly line, cycle time & line equipment utilization is the main problem. As in each assembly line different work center are used and on which different automatic and semi-automatic

machine are usedThe Work cycle is the complete sequence of elements necessary to perform a specified activity or job to yield one unit of production and cycle time is time to perform it. It may also include the elements which do not occur with every cycle.
The CNC machine has added advantages of reduced cycle time by precise tool & fixtures.In this work we use **trial version of Arena 12.0 Simulation software** which have some limitation. The software has full functionality for building & executing training size simulate models. A protection device must be present to use this software with large commercial size model.

XI. METHODOLOGY

In this work the assembly line vehicletesting process is optimize by reducing its cycle time to minimum. The lean tool principals & techniques are used to reduce the cycle time by theARENA simulation.In this work at first the flow process chart of process with cycle time for various element of process is made. The object of problem is to reduce process cycle time & optimized it by lean manufacturing techniques for maximum capacityutilization.
A simulation study starts with efforts on understanding the system in addition with the identification of the goals of the study. The next step is creating the formulation of the model representation usually in terms of mathematical models or flowcharts. Subsequently, the created formulation needs to be transferred into modeling software using programming languages or with specific software tailored into the needs of a simulation study.
ARENA has a natural and consistent modeling methodology due to its flowchart style model building regardless of detail or complexity. Even the flowcharts of systems created by Microsoft Visio can be imported and used directly. It is extendable and customizable, which results in a re-creatable, reusable and templates tailored to applications.

XII. DATA COLLECTION

The data are collected for assembly line field testing line.There are four work centers in the testing line. The trial version of arena simulation software is limited for 150 entities, so field testing line is consider simulating on arena software.The data are collected in flow-chart is actually the graphical representation of all operation, inspection, transportation delay and storage occurring during a process and include information consider necessary for analysis such as time required, quantity and distance moved etc. The various activities in operation performed to test the Vibrating Compactor machine are under as-

- Take machine for testing
- Wash Center
- Field Test Center
- Transport from field to washing area
- Transport to store

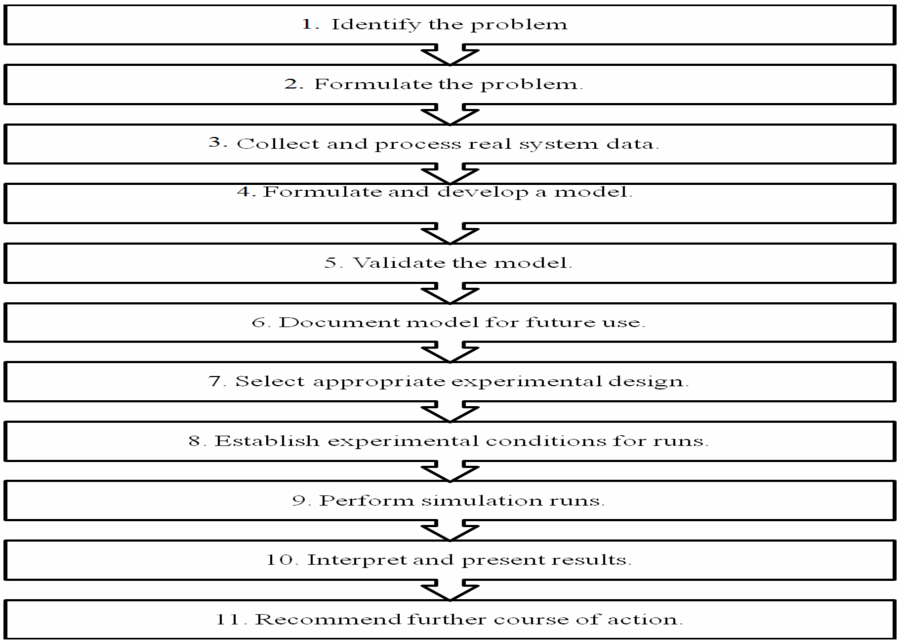


Fig.4 ARENAMethodology [12]

The material type of flow process chart is used this chart is very important for analysis purpose because its gives a complete picture of what is being done and helps to understand the facts and their relationship oneanother all details which must be obtained from direct observations.The data collected are represented in the **table-1** and these data are simulated on the ARENA.

Table-1 Data of exiting assembly line

S.N.	**Criteria**	**Value Min.**
1	Value added	166 min.
2	Wait Time	209 min.
3	Transfer Time	15 min.
4	Total Time	390 min.
5	WIP	5 Mc
6.	Machine Out	6 M/c

Table-2 Data of Improved assembly line

S.N.	**Criteria**	**Value Min.**
1	Value added	103 min.
2	Wait Time	68.9383 min.
3	Transfer Time	10 min.
4	Total Time	186.94 min.
5	WIP	2 MC
6.	Machine Out	10 MC

XIII. SIMULATIONOF EXISTING ASSEMBLY LINE

Arena simulation software is used to simulate the Testing process for Vibrating Compactors, during testing time a huge utilization of resources, delay cycle time for manufacturing process or assembly line in present condition the total time to complete testing is 194 minutes to Model 52. The simulation results are shown by the pie chart in **Fig.5** during this time 4 to 6 machine out per shift or 16 hrs. In a day in every section of assembly line take more consumption of resources Testing Section is another place where resources consumption is more than 80%.

XIV. IMPROVEMENT OF SYSTEM BY LEAN MANUFACTURING TECHNIQUES

To improve the manufacturing line the lean principles are used to reduce the wastage. In the existing model following area are found where improvement can be made to reduce non value added time.

Transportation work center: In transportation of machine from assembly to testing center the time is reduced from 15 minutes to 5 minutes as both are adjutants to each other and more ever it is the planning part to reduce it.

Washing work Center: Time is reduced 26 minutes to 20 minutes the idle time is also reduce 5 minutes to 0 minutes as washing process may be continued to other machine which is to be tested. This also reduces the unnecessary process of starting and stopping of water pump when vehicle are in cue for testing.

XV. TIME REDUCED IN FIELD TESTING WORK CENTER:

This time is reduced from 108 minutes to 50 minutes by the following suggestion

- Two inspector are used in place of one is the exiting testing system to increase working in the shift.
- In lunch time the second shift operator can inspected the machine.
- The inspection of leakage is done by shop floor people; this will also help to remove the possibility of defects developing in assembly.
- At the washing timeat work center the driver of vibrating compactor are present at place to reduce the worker idle time up to 9 minute.

The improved model is again simulated on arena software with the data as shown in the**Table-2**by the lean techniques and the flow process chart for the improved assembly line to optimize the testing process and to maximizes the individual efficiency and plant energy efficiency.The pie chart used for the analysis work.The implementation of improved model is a team decision, which required decision to be taken in presence of assembly people, testing people and inspection department, so minimizes the resistance to improvement.

XVI. RESULT AND DISCUSSION

The results of the simulation on the ARENA are shown in the **Fig.6**the software automatically calculates the value-added, non-value-added, wait time, WIP, etc.in the form of pie chart**.** The **table-3,**indicate the improvement possibility in the modern automatic plant.Theuse of simulation software required a lot of practice to conversant to use them. Also for developing a completely improved model various series of experiment of simulation are required andthe model is deterministic in nature

Table-3 Comparison of results of model 52

S.N.	Criteria	Existing System	Improved System	% Improvement
1	Value added	166 min.	103 min.	40%
2	Wait Time	209 min.	68 min.	68%
3	Transfer Time	15 min.	10 min.	33%
4`	Total Time	390 min.	186 min.	50%
5	WIP	5 Mc	2 MC	60%
6`	Machine Out	6 Mc	10 MC	80%

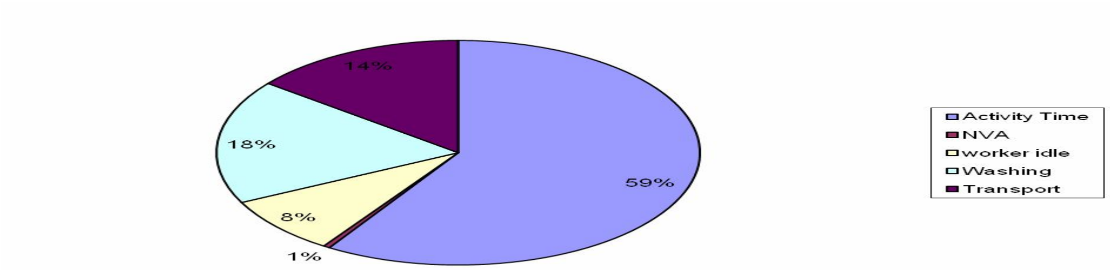
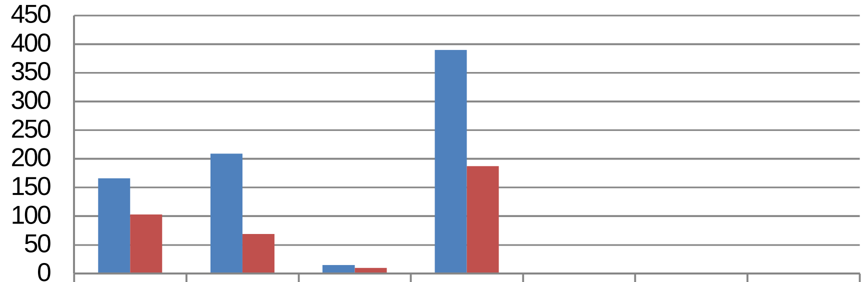


Fig. 5 Pie Chart for Existing testing line for Vibrating Compactor Machine Model- 52

XVII. CONCLUSION

The current manufacturing is not complete without applications of advanced manufacturing techniques and software like lean manufacturing, agile manufacturing, CIM, etc. The development of a Competitive Responsive Manufacturing System to maximize the Energy efficiencyneeds the continuous efforts from organization all elements and sequential process optimization.There are different simulation software and their application The ARENA and other simulation software have advantage of fast and precious decision making and for set-up-time sequential process optimization. The methodology reduces the waiting and idle time.



	Value Added	Wait Time	Transfer Time	Total Time			
EXISTING SYSTEM	166	209	15	390			0
IMPROVED SYSTEM	103	68.9383	10	186.94			

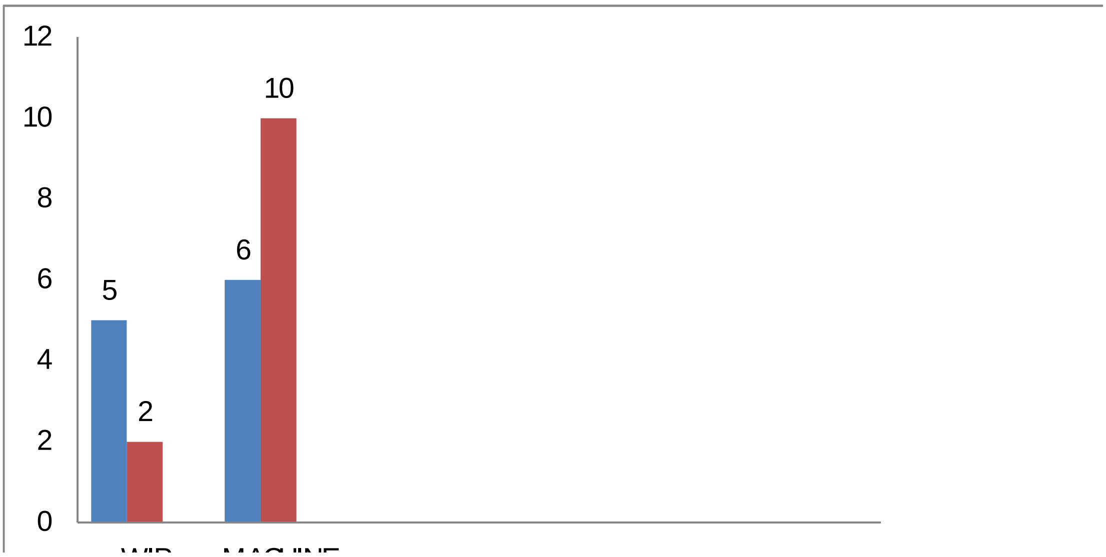


Fig.6 Result of the simulation on the ARENA to compare existing and improved model

REFERENCES

[1] Askin R.G., Goldberg J.B., "Design and Analysis of Lean Production system," Chapter 7-10, John Wiley & Sons [ASIA] Pvt. Ltd. (2003), Singapore.

[2] Bachlaus M., Pandey M.K.,Mahajan C., Shanker R., Tiwari M.K., "Designing an integrated multi- echelon agile supply chain network: a hybrid Taguchi-particle swarm optimization approach," Journal of Advance Manufacturing Technology (2008), DOI 10.1007/s00845-008-0125-1.

[3] Burcher P., Dupernex S. "The Road to Lean Repetitive Batch Manufacturing," International Journal of Operations and Production Management(2008), 16 (2), 210-220.

[4] Carlson J.G., Yao A.C., "Mixed Modal Assembly Simulation," International Journal of Production Economics (1992), 26, 161-167.

[5] Chary S.N., "Production and Operation Management," Chapter 10 & 11, Tata McGraw- Hill Publishing Company Ltd. (2005), New Delhi

[6] Chi C., "Optimal Ordering Policy of Periodic Review Systems with Replenishment Cycles," European Journal of Operational Research (2006), 170, 44-56.

[7] Fowler, J.W., Rose O.," Grand Challenges in Modeling and Simulation of complex Manufacturing Systems."Simulation, Vol.80, Issue 9, September (2004): 469-476.

[8] Guan Z., Peng Y., Ma L., Zhang C., Peigen L.I., "Operation and Control of Flow Manufacturing based on Constraints Management for High-Mix/Low-Volume Production," Front. Mech. Eng., China, 3(4) (2008), 454-461.

[9] Grover M.P., "Automation, Production Systems, and Computer- Integrated Manufacturing," Chapter 2, 13 & 20, Pearson Education (Singapore) Pvt. Ltd. (2004), India, Second Edition.

[10] Jeffwu C.F., Hamada M., "Experiments Planning, Analysis and Parameter Design Optimization," capter 10-12, John Wiley & Sons [ASIA] Pvt. Ltd. (2002), Singapore.

[11] Jones C., Medlen N., Merio C., Robertson M., Shepherdson J., "The Lean Enterprise," B.T. Technology Journal, 17(4) (1999), 15-22.

[12] Kelton, W.D.,. Sadowski R.P., Sturrock D.T., Simulation with Arena. McGraw-Hill, New York, NY.2 Kleijnen, J. P. C. 1987. Statistical Tools for Simulation Practitioners (2004), Marcel Dekker, New York.
[13] Lingaraju D., Rao A.B.K., Ramji K., Pramiladevi M., “Cell Formation and the Machine Selection in the Design of Cellular Manufacturing System,” Proceedings of International Conference on Recent Trends in Mechanical Engineering, Ujjain (2007), IP94-98.
[14] Martinich J.S., “Production and Operations Management: An Applied Modern Approach,” Chapter 1 & 5, John Wiley & Sons [ASIA] Pvt. Ltd. (2002), Singapore.
[15] Montgomery D.C., “Experiments Planning and Analysis,” Chapter 6-10, John Wiley & Sons [ASIA] Pvt. Ltd. (2007), Singapore.
[16] Moreno C. W., “Optimization in Production Operations: Optimal Lean Operations in Manufacturing,” Ultramax Corporation (2006), U.S.A.
[17] Naishuler I.B., “Identification and Management of Risks at Introduction of New Products into Manufacture,” Russian Aeronautics, 51(4) (2008), 461-465.
[18] Pattanaik L.N., Sharma B.P., “Implementing Lean Manufacturing with Cellular Layout: A Case Study,” International Journal of Manufacturing Technology (2008), DOI10. 1007/s 00170-008-1629-8.
[19] Phadke M.S., “Quality Engineering by Robust Design,” Prentice Hall (1989), Englewood Cliff’s
[20] Rahimifard A., Weston R.H., “A Resource-based Modeling Approach to Support Responsive Manufacturing System,” International Journal of Advanced Manufacturing Technology (2009), DOI 10.1007/s00170-009-2025-8.
[21] Rajput R.K., “Manufacturing Technology [Manufacturing Processes],” Chapter 1, Laxmi Publications Ltd. (2007), New Delhi.
[22] Sharma D.D., “Total Quality Management Principles, Practice and Cases,” Chapter 4,8, Sultan Chand & Sons (2007), New Delhi.
[23] Sharma S., “A Method to Exchange the Demand of Products for Cost Improvement,” International Journal of Advanced Manufacturing Technology (2008), DOI 10.1007/s00170-009-1959-1.
[24] Sahoo A.K., Singh N.K., Shanker R., Tiwari M.K., “Lean Philosophy: Implementation in a Forging Company,” International Journal of Advanced Manufacturing Technology, 36 (2008), 451-462.
[25] Schroer, B.J., “Simulation as a Tool in Understanding the concepts of Lean Manufacturing” Simulation, Vol.80, issue 3, March (2004): 171-175.
[26] Su. Y., Liao W., Guo Y., Ding Q., Ding Q., “Key technologies for ASP-based product customization Service for SMEs : a case study,” International Journal of Advanced Manufacturing Technology, 42 (2009), 381-397
[27] Su L.H., Chen Y.H., “Scheduling multi-operation jobs on a single flexible machine,” International Journal of Advanced Manufacturing Technology, 42 (2009), 1165-1174.
[28] Tahmasebipour Gh., Hojjat Y., Abdullah A.A., “Optimization of STM/FIM nanotip aspect ratio based on the Taguchi method,” International Journal of Advanced Manufacturing Technology, 44 (2009), 80-90.
[29] Wang Z., Jia X.P., Shi L., “Optimization of Multi-Product Batch Plant Designs under Uncertainty with Environmental Considerations,” Clean Technology Environment Policy (2009), DOI.10.1007/s10098-009-0207-6.
[30] Ulgen, O., Gunal A., Grajo E., TheRole of Simulation in Design and Operation of Body and Paint Shops in Vehicle Assembly Plants, Proceedings of the European Simulation Symposium, Society for Computer Simulation International (1994), 124-128.
[31] Zeid I., “Mastering CAD/CAM,” Chapter 20, Tata McGraw Hill Publishing Company Ltd. (2007), New Delhi.