Modeling and Optimization in a New Machining Production Line by Using Manufacturing System Simulation

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Abstract

Throughput, equipment utilization and costs reduction are critical factors to be considered in a highly competitive environment, especially when the demands of variety of aluminum engine blocks have been increasing rapidly. Flexible Manufacturing System (FMS) is designed to achieve the key of cost effective production because it is a very good combination between variety and productivity. FMS is a system which consists of too many programmable machines that connected by an automated material handling system to produce a very wide variety of products. Correspondingly, the cost for building a new FMS is positively correlated with its flexibility. For that cause, the design of FMS requires an intensive effort on designing, analyzing and optimizing. The aim of this project is to build a simulation model of new manufacturing system for new plant to produce 1200 engine components per day. This system should be flexible, reliable and within maximum scrap rate % 1. Furthermore, the optimization and analysis of production performance measures which are inclusive of cost, machine utilizations, and jobs per hour help the company studying the system and selecting optimal scenario as well as to support upper management to make perfect decision before implementing a new system. The methodology used in this study is simulation modelling which is presented as a powerful technique that can apprehend the complexities of the FMS. Arena software has been used to propose all scenarios. Results show that optimal scenario 3 can increase the throughput by %16 jobs per year.

Keywords
Simulation, Arena, FMS, Aluminum Engine Blocks

1. Introduction

In current day's competitive global market, manufacturers have to enhance their operations to ensure the optimum and quick response to needs of customers. The major goal of any manufacturing corporation is to achieve the highest level of productivity and flexibility which can only be attained in a computer integrated manufacturing environment. Corporations also need to be always innovative themselves to have high quality and reliability, delivery, time, and budgets in their products or services so they can be more compatible to satisfy the customers. In meantime there are serious challenges to manage and optimize the production plan due to the complexity, high number of process, details, and multiple or mix products in addition to uncertainty factors such as demand, utilization or downtime. It will be a serious issues and very hard to make decision among too many options and which one is the best way to achieve the goals. The perfect solutions are when the corporation is able to utilize resources effectively and maximized the profit. Development of validated simulation model and using appropriate tools for each particular scenario in production is always important topic. It became very important for any corporation to use advance techniques and last update methodologies as well as new tools. In order to make manufactures and engineers are very sure that they are using a reliable and advanced system that can lead to keep the corporation on the top among others in innovation and expanding as well as competitive level. Kulkarni et al. [1] mentioned that companies have to deal with too many of changes and challenges in their process and plans of production in fast-changing business environment.

1.1 Flexible Manufacturing System FMS

Flexible Manufacturing System FMS is a production line which consists of many programmable machines that connected by an automated material handling system to produce a very wide variety of products. A FMS is complex, and expensive system in which computers run all the machines that complete the process. Many companies could not afford traditional FMS so they use small versions call flexible manufacturing cells. Nowadays two or more programmable machines CNCs are considered a flexible manufacturing cell, and two cells or more are considered a flexible manufacturing system (FMS). FMS represented an automation of controllable configurations that can be enhanced by optimizing the relationships among machines and material handling components to each other and to the entire system behavior performance.[2] Pisuchpen [3],Wang et al. [4] **,**and Seebacher et al. [5] presented discrete model for flexible manufacturing system . In their study they developed model to evaluate the efficiency of systems. Coefficients of variation and efficiency have been calculated. Results indicated when flexibility increased the system will more complex .Classifications of flexibility are reviewed and discussed. Josephet al. [6] described eight types of flexibility as follows: machine flexibility, process flexibility, product flexibility, routing flexibility, volume flexibility, expansion flexibility, operation flexibility and production flexibility. Presented also a framework to identify the inter dependency of several flexibilities. Groover [7] and Abdulziz [8] stated that FMS should be flexible when be able to produce different types of parts by the system due to quick changeover of operating and physical setup. Different types of flexibility can be evaluated such as product mix, production volume and time. Product mix flexibility which is refers to produce different types of products by using the same machines. Volume flexibility is the changing the production levels. Time flexibility is the capability to have short lead times and to cope with different delivery times. In 2012 [6] defined flexibility as the ability of a system to respond effectively to changes in volume requirements, product-mix requirements, machine status and processing capabilities. The flexibility of an FMS is dependent upon its components, capabilities, interconnections and mode of operation. Wahab and Osman [9] Seebacher et al. [10], and Erdin et al. [11] stated that flexibility is an important feature to deal with changes in the operating environment and is an adaptive response to unpredictable situations. In current days, FMS are preferred in more establishments in daily basis because of their numerous advantages such as quick response to customer demand and high competitiveness. Flexibility considered as a key objective of many manufacturing systems and a key factor in manufacturing organizations.

Nowadays, with powerful tools and new techniques, the production technology has been dramatically changing into a more complex automated system. Due to highly competitive market, the companies are always adapting to change in a rapidly changing business environment. Fernandes et al. [12] [13] Stated that the manufacturing companies are facing a turbulent changing environment, with growing complexity and high levels of the diversified demand in products and services .In case of heavy industries such as automotive industry it is very essential the linkage the automation process with human interval and relation between planning and flexible manufacturing to maintain a competitive edge. Goyal et al. [14-16] and Sharma et al.[12] considered that manufacturing system is a complex, discrete and highly dynamic system.Garbie et al. [2] analyzed and evaluated manufacturing systems. The aim of their study is to determine the level of complexity of manufacturing system. Cost has been considered to evaluate the flexibility of the manufacturing systems. Faisal et al. [17] and Sanz-Lobera et al. [18] stated that the complexity and cost considered when the configuration of the system got change to another configuration. Results showed that complexity should be optimized and taken into considerations when designing manufacturing systems. Basically the complexities of the systems came from their flexibility. Analysis of production performance measures, factor of system improvement, experimentations and optimization which include cost analysis are strongly required when the company wants to build a new model for new plant.

1.2 **Cost Analysis**

Manufacturing companies especially automotive face numerous business challenges daily. During that time, companies have few positive cost reducing options that simultaneously enhance operational efficiencies. The ability to identify cost reduction opportunities through enhancing operational performance provides companies' abilities to eliminate costs. Maintaining high quality product and low costs is crucial for manufacturing businesses today. Controlling the total costs of products is often keys to profitability. Giaed et al. [19] and Boysen et al. [20] mentioned that in mass customization environment both suppliers and their customers can get benefit from knowing the sequence in advance to reduce costs. Olio et al. [21] and Carlo et al. [22] proposed that the configuration and reconfiguration approaches were applied to minimize the equipment cost and evaluate the manufacturing system. Results showed that the proposed study reduces the total costs by an average of 25%.

Sancak et al.[23], Goren et al. [24], Mittal et al. [25] , Gyulai et al. [26] and Mak et al [27] explored the impact of lot size and its interaction with operator competence on manufacturing system performance and minimizing costs using simulation technique. Mentioned also when planners split the customer order into lots of different sizes. Their decision based on two concerns to avoid late production plans and to minimize costs. In 2013, Falcone et al. [28] proposed discrete optimization model to address the problem of flexible machines in a manufacturing system in order to minimize handling costs associated to transferring parts between machines. Different scenarios have been proposed to provide the best solution to solve the problems.

2. Case study

The major goal of this study is to build a new manufacturing system to produce aluminum engine block within a new facility for one of the big three automotive companies in North America. The company suggested 3 different machine layouts to select the optimal one to implement.

2.1 Methodology

To carry out comprehensive simulation optimization studies on very detail process and complex manufacturing system. It's very important to select appropriate tool that has a good abilities to deal with a wide range of activities, details, changes, options, variables and levels. Arena software is good tools to use to conduct these kinds of researches to achieve the aim of the research and get optimal results.

2.2 Modeling approach

According to Figure 1 which shows the flow charts of modeling process that represented all steps to conduct simulation study to attain the objective of this research. In general, modeling approach is to build a traditional model or basic model for the system. Scenario 1 has been selected to be a traditional model. Starting collecting data and the assumption got set up after scenario 1 has been built. Assumption as following:

- Beginning of system does not get starved; end of system does not get blocked.
- Offline buffering is 100% efficient (no delay in buffering)
- Scrap rate is %1
- Leak test and washer set at 76.5s CT
- Gantry load set at 35s CT
- All other non- CNC work station set at 90s CT

2.3 System description

The engine block is the basic support and attaching point for all other engine parts. Engine blocks are made by pouring molten cast iron, steel, or aluminum into molds**.** After the metal cools, the molding sand is washed out and the block is machined to allow other parts to be installed or attached. The major parts installed in or on the block are the pistons, this process called a pre-machining. Figure2 represent process flow charts to produce engine block. In general the major pre-machining process can be described as the following:

- Cylinder set up and installation
- Milling all the faces of engine block
- Locating the holes
- Drilling the holes
- Threading the holes

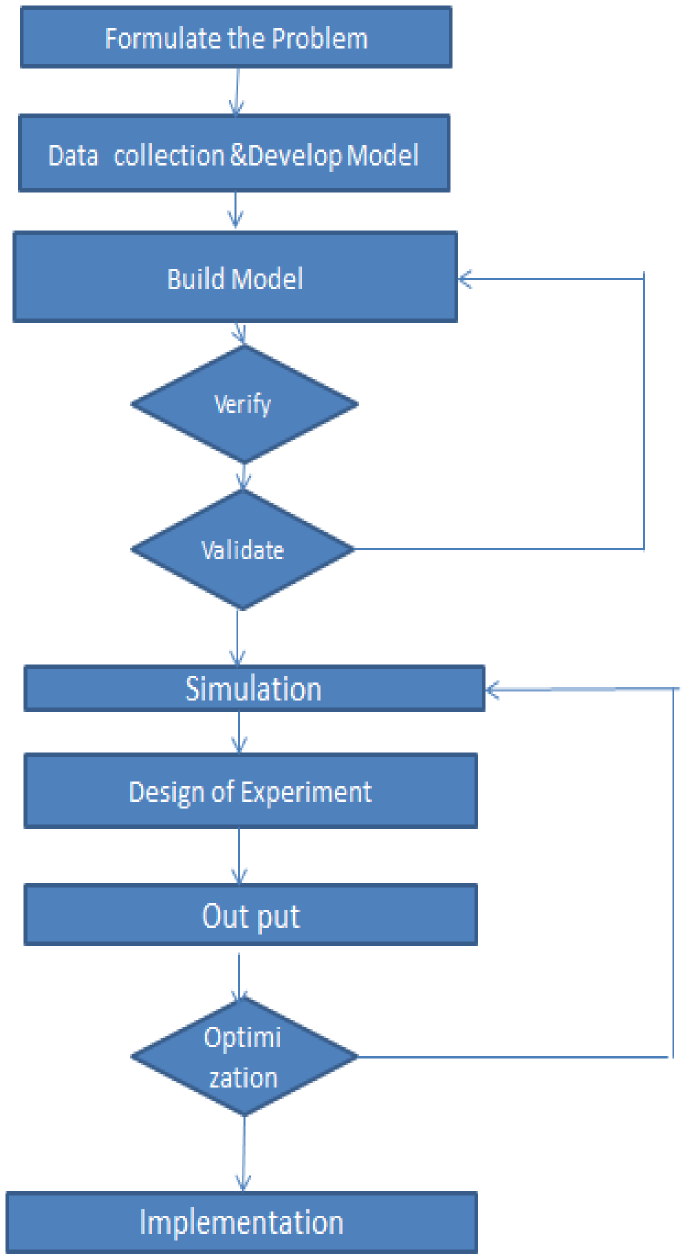

Figure 1. Flow charts of modeling process of simulation study

To produce 1200 engine block per day that will be considered high volume or mass production and that need automated production line to a achieve that. Fig 2 shows the flow charts of simulation modeling for manufacturing system to produce engine block. In general, the production line is fully automated except unloading process .It's manual unloading. For auto load, robot picks up the part and loads it up on the conveyer. From the conveyer robot gantry picks up the part and loads to operation A (OP/A) CNC machines feed points. After OP/A completion, gantry picks up the part load on to OP/B CNC. Upon OP/B completion, gantry loads the part onto OP/C CNCs.Afer that gantry drops the part to the conveyer and then to de burr station to remove sharps edges. After that the part will get washed by washer in order to clean it from the sand. At that time the part will be ready for leak test. Leak test process verifies the part leak and cross cavity leak as well. Traceability process is laser etching. Inspection process will be before the last process which is unloading the part and this only manual process in the entire automated system.

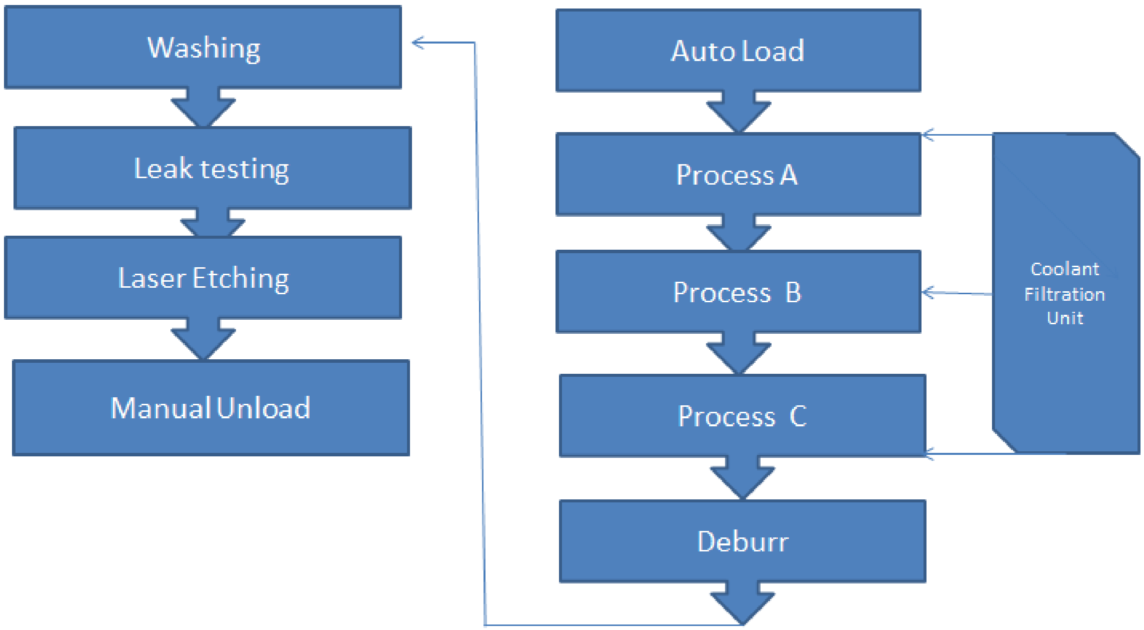

Figure 2. Process flow charts to produce engine block

The proposed design of the new automated manufacturing system to produce aluminum engine block is consist of following equipment: 16 CNCs ,6 robots , 5 gantries , 2 washers , cooling unit , laser unit ,4 leak test, 2 de burr , 2 manual inspect station ,2 manual unload station , 2 CMMs, gage bench , filtration system and conveyers. Figure (3, 4 and 5) show three different machine lay out to study.

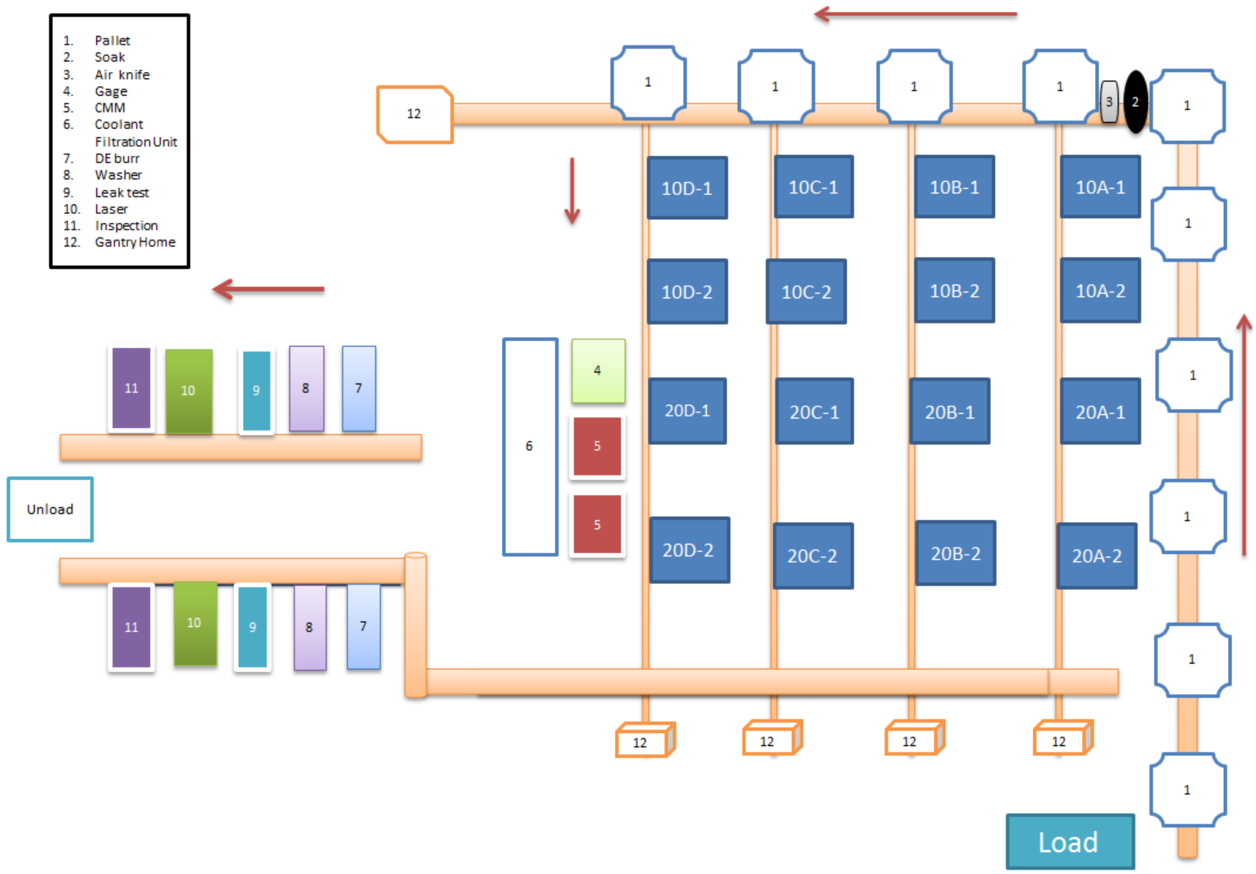

Figure 3. machine layout scenarios 1

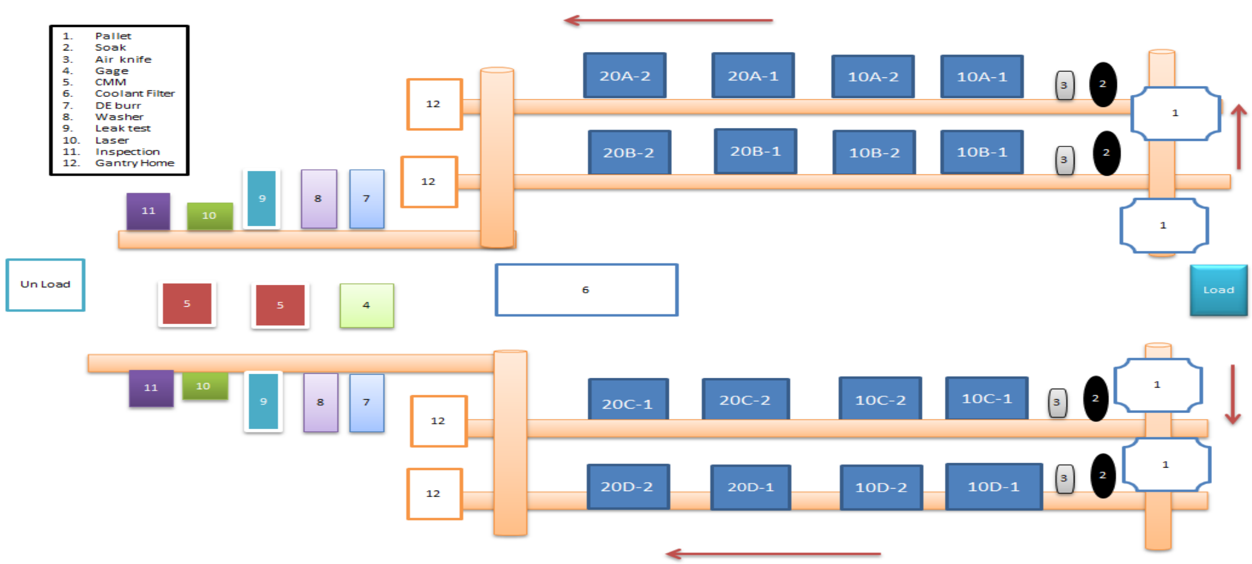

Figure 4. machine layout scenarios 2

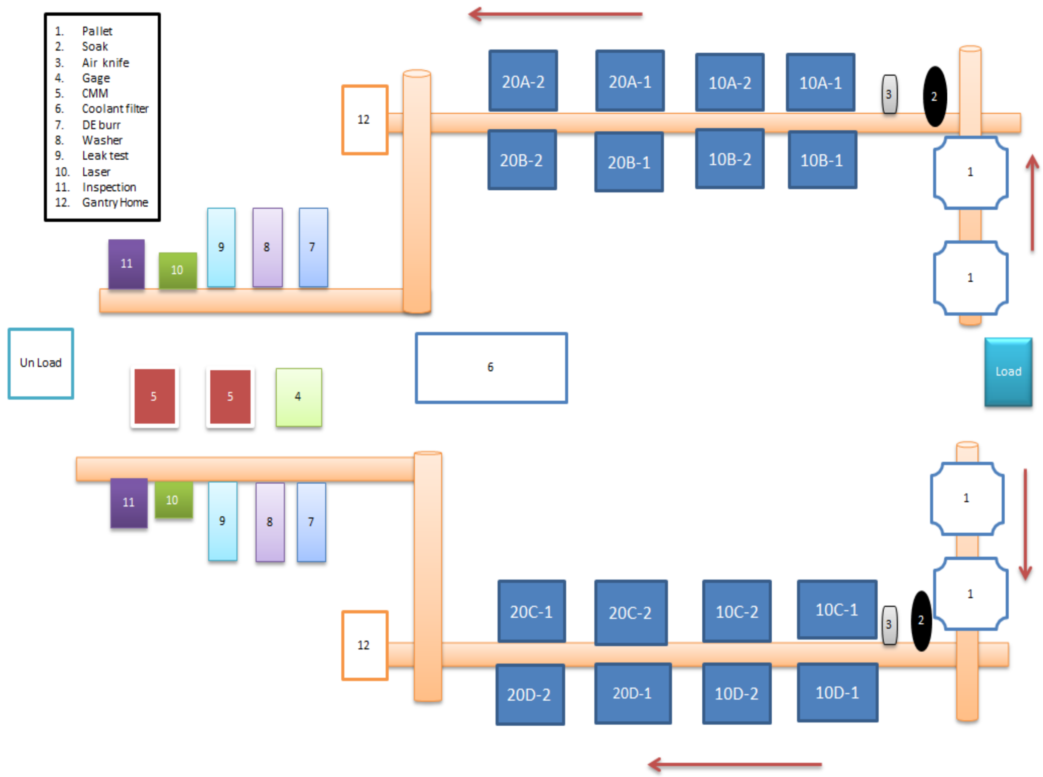

Figure 5. Machine layout scenarios 3

2.4 Arena Software

Arena software will be used to carry out this research. Arena from systems modeling corporation is considered a powerful tool to model a production line with unreliable machines and discrete variable to identify the line performance. Considered also very advance technique that allows modelers to create animated simulation models. Arena software considered a powerful tool to analyze and evaluate manufacturing system. [31- 37]

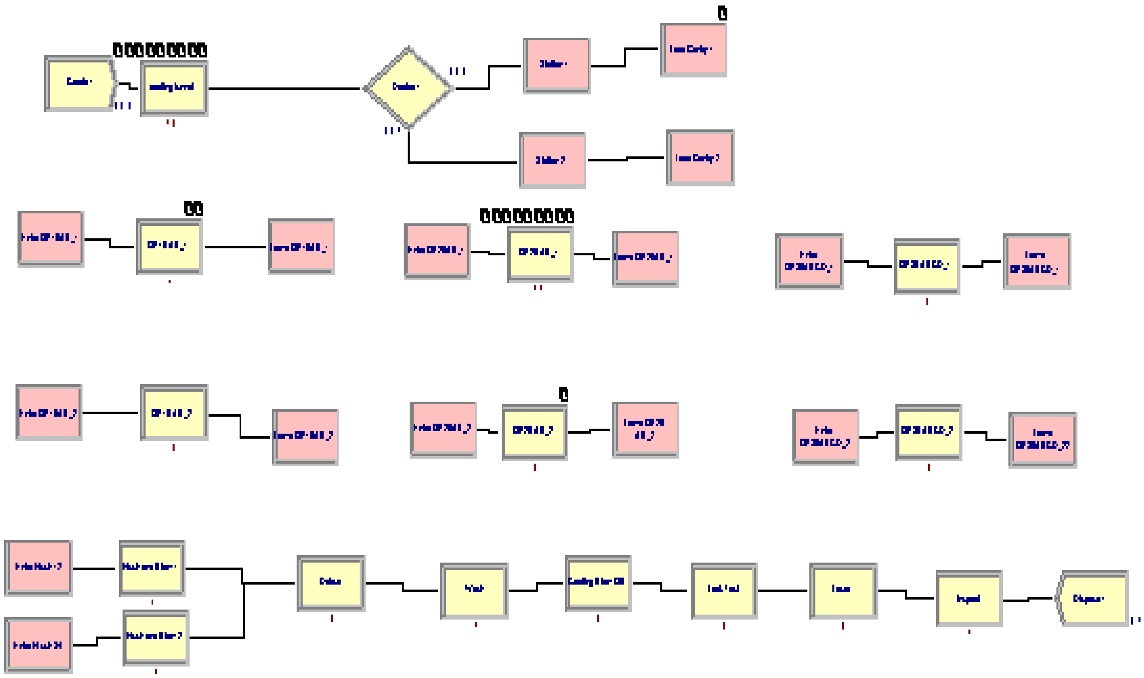

Figure 6. Process diagram of Arena simulation Scenario 3

3. Results and discussion

After running 3 simulation models for 3 scenarios, table1 show the result of throughput analysis such as average, minimum and maximum for product in and product out.

Table 2 shows the average of number of product out, net product per day, increasing in number of product and decrease in cost for all scenarios. We got the net number of product for each scenario as the following:

Net number of product = Number of product out (% scrap + downtime+ validation target)……1

Where:

Scrap percentage is 0.1

Downtime = %15

Validation percentage = %5

For example the net number of product per day for scenario 3

According to equation no.1

Net number of product per day= 1764 (0.01+0.15+0.05) =1393 job per day

Again Table 2 shows that scenario 1 just meet the target which can produce 1200 job /per day. Scenario 2 achieved 101 jobs per day more than the target. Also the results show the scenario 3 attained 193 jobs per day more than the target. So scenario 3 will be our recommendation to the upper management because we can maximize the profit by increase the number of product as the following:

No. of increase per year= No of working days x number of increase per day
= 250 x 193
= 48250 job/ year
Or the throughput increased up to %16

Table 1. Throughput analysis

	# Average in job/day	# Average out job/day	# Min. in job/day	# Min. out job/day	# Max. in job/day	# Max. out job/day
Scenario 1	1560	1521	1539	1502	1593	1550
Scenario 2	1682	1647	1661	1625	1712	1666
Scenario 3	1801	1764	1982	1743	1829	1785

Table 2. Throughput analysis with % of job increase

	Scenarios	Job/day Average	Net job /day	% Job increase
Number of product out	1	1521	1200	%0
Number of product out	2	1647	1301	% 8
Number of product out	3	1764	1393	%16

Conclusion

Three different machine layouts have been modeled by using ARENA simulation software. Throughput and profit considered a critical factor in this study. Model of scenario 1 was used as traditional model to collect data and set up the assumptions to build the other models. Results show that scenario 3 was the optimal choice to implement a new production for new plant. With this scenario can increase the throughput by %16 engine components /year. For future work there is good opportunity to save a lot of money by eliminating some CNCs and other equipment.

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