Design of Production Planning and Control System for A Manufacturing Plant: Case Study

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Abstract

The research study was undertaken to design a computerized system to improve production planning and control strategy for the case study company. The developed computer program was formulated to measure the overall equipment effectiveness, identify losses and bottlenecks, as well as help in achieving maximum output with minimum input. A simulation was also done on the pilot section of the production process for the organization. The proposed system of close monitoring of key variables would enable analysis and tracking of manufacturing processes.

1. Introduction

The manufacturing activity of a plant is said to be “in control” when the actual performance is within the objectives of the planned performance. But if jobs are not being started and completed on schedule, great concern about the meeting of commitments would start to trouble management as poor production planning persist. Optimum operation of the plant is attained only if the original plan has been carefully prepared to utilize the manufacturing facilities fully and effectively. Challenges in job scheduling such as when an operation is to be performed, or when work is to be completed, may greatly affect the flexibility in production operations, full utilization of men and machines as well as the coordination operational coordination. It is against this background that design and implementation of a computerized system was muted to identify losses and measure the effectiveness of an improved production planning and control at the case study organization.

2. Justification

In a manufacturing plant production is the driving force to which other processes react. These include inventory, staffing, customer orders and some other functions which exist because of the need of production. When an organization is not able to meet its objectives such as fulfilling its orders in the right quantizes at the right amount due to the production planning, a red flag is raised and need to improve production planning for the company is put in place to address budget performance and customer satisfaction, in turn will intern improve the good will of a company. Therefore there was a need to develop a system or program such as a production planning and control that helps to predict and plan production so as to avoid the problems mentioned above for consumptive margarine making case study organization.

3. Literature Review

In a processing industry, there are different departments that contribute to the processes that occur from the moment the raw material is purchased until the point a product is delivered to the customer. For a successful operation the various departments are supposed to collaborate and decide together. This mechanism is called Production Planning and Control (PPC), where Production Planning and Control (PPC) is a process that comprises the performance of some critical functions on either side which entail planning as well as control as given in Figure 1 (Kummar 2004). PPC can also be defined as the process that provides management with the ability to strategically direct its business to achieve competitive advantage on a continuous basis by integrating customer focused marketing plans for new and existing products with the management of the supply chain.

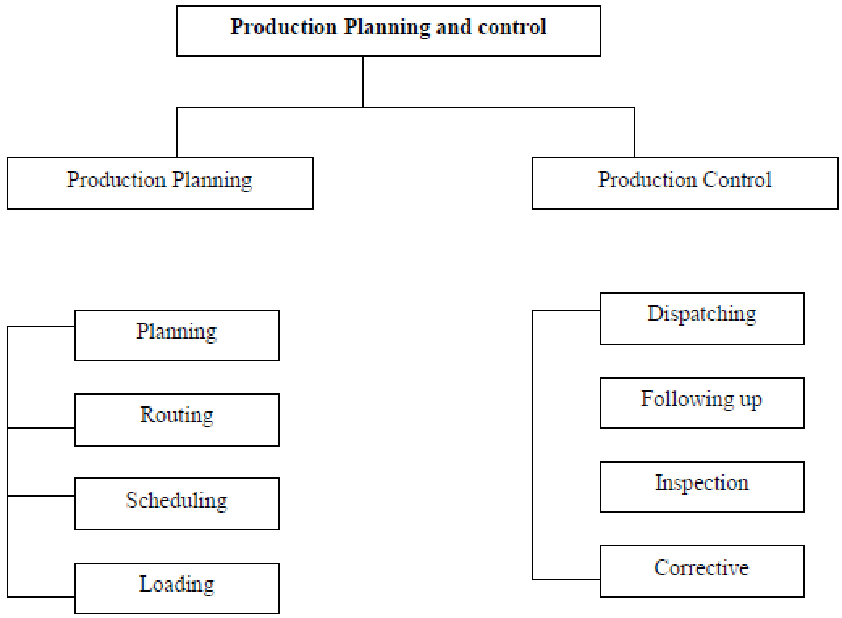

Figure 1.PPC Process (Kummar 2004)

Production Planning brings all the people together in order to asses future market demand and generate change in the business. Thus PPC plan includes an updated sales plan, production plan, inventory plan, customer lead time (backlog) plan, new product development plan, strategic initiative plan and resulting financial plan. To summarize, the need for PPC is to manage issues like absence of teamwork and shared risk management among internal functions; supply interruption, leading to production delays, on-time delivery issues, lower profits or customer loss; lack of confidence in planning systems; excessive on hand inventories and obsolesce; ineffective utilization of resources and/or lack of resources when needed; poor collaboration among stakeholders – internal or external (finger-pointing); and unacceptable lead times. Production organization is closely related to production type because the production type often significantly affects the structure of the production process. At the same time, flow manufacturing ensures that the production equipment is arranged in accordance with the organizational form of flow manufacturing. The following are important production types: discrete manufacturing, repetitive manufacturing, process manufacturing, Kanban as well as engineer-to-order production.

Repetitive manufacturing is characterized by the interval-based and quantity- based creation and processing of production plans. With repetitive manufacturing, a certain quantity of a stable product is produced over a certain period of time. The product moves through the machines and work centers in a continual flow, and intermediate products are not put into intermediate storage. The work required for production control with repetitive manufacturing is significantly reduced compared to single-lot and order-based production control, and the entry of actual data is simplified. In this case, production has no direct connection to a sales order. The requirements are created in the demand management process, and the sales orders are supplied from stocks. Control of inventory, which typically represents 45% to 90% of all expenses for business, is needed to ensure that the business has the right goods on hand to avoid stock-outs, to prevent shrinkage (spoilage/theft), and to provide proper accounting. Many businesses have too much of their limited resource, capital, tied up in their major asset, inventory. Controlling inventory does not have to be an onerous or complex proposition. It is a process and thoughtful inventory management. There are no hard and fast rules to abide by, but some extremely useful guidelines to help your thinking about the subject. A five step process has been designed that will help any business bring this potential problem under control to think systematically thorough the process and allow the business to make the most efficient use possible of the resources represented. The final decisions, of course, must be the result of good judgment, and not the product of a mechanical set of formulas.

Processes in production planning and production control comprise the following main areas: Sales and operations planning for determining the quantities to be produced; Material requirements planning to calculate net requirements and component requirements, taking into account scrap and lot sizes; Capacity requirements planning for detailed production planning, taking into account available capacities; Production control to control and record the production process (create production documents, record confirmations). These four areas represent the scope of the process only roughly. Figure 2 below shows a detailed overview that explicitly illustrates the process modules that we will deal with in detail, along with their most important input and output values.

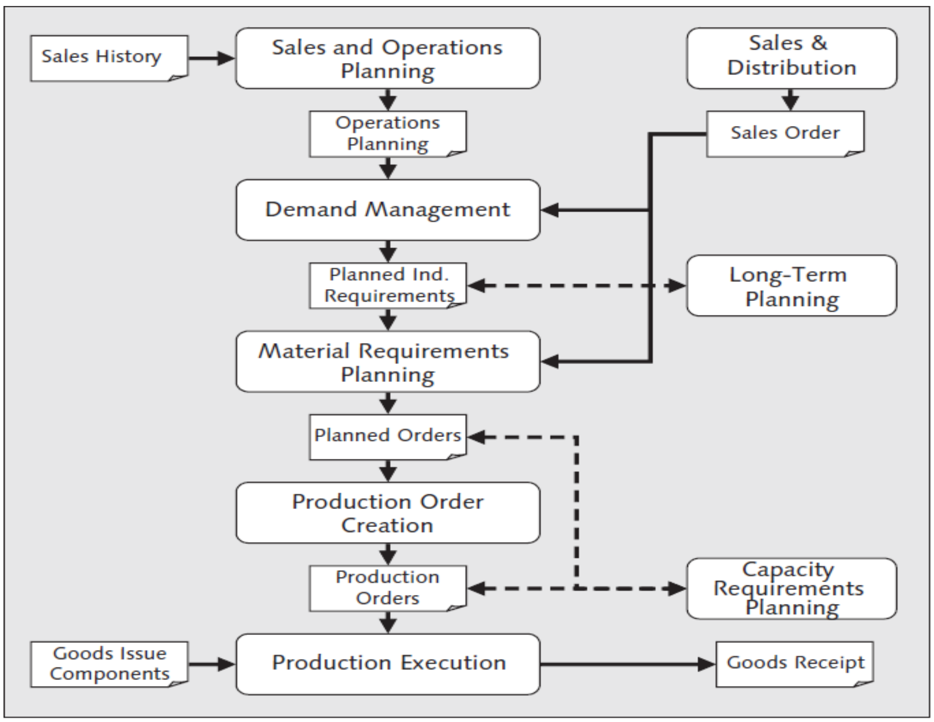

Figure 2. Process Modules (Graves, November 1999)

Sales planning is also referred to as demand planning, covers future requirements without considering stocks and available capacities. The sales history often serves as a basis for sales planning. Operations planning use the results of the sales-planning process to plan the production quantities, and takes initial stocks and capacities into account on a general level. And in turn material requirements planning(MRP) is the central function of production planning. It calculates requirement coverage elements for all MRP levels, based on the demand program, and taking into account lead times, lot sizes, and scrap quantities. In a nutshell, production planning and control is development of a plan by a team of manages from different section of a production, which meets demand at minimum cost or that fills the demand that maximizes profit. It also translates focus demand into a production plan determining the appropriate quantities and timing of inputs and throughput.

4. Production Planning and Control Framework

4.1 Framework formulation

The system developed was based on two principal components which are database and appropriate coded software to access and manipulate the data in the database. While the database used Microsoft Access, the software component would be coded using Microsoft Visual Basic for Access.

*Database***:** Its use in the system will be to keep data and information necessary to a Production Planning and Control system. The data was stored as database tables with relevant fields concerning the particular entities of the system.
Software component: Visual Basic enabled means for data to be written to and accessed from the database as well as extracting helpful and understandable information from the data stored in the database. This was achieved through making the relevant calculations and grouping as well as compiling data to produce readily understandable reports that would aid in the making of management decisions. Thus it would allow data handling, calculations, data compilation and report generation on the Key performance Indicators for case study organization.
Key Performance Indicators: Key performance indicators (KPI) are those factors which were important and critical in terms of measuring the continued success of achieving the objectives of an organization. A time-frame was established for all KPI for aspects like inventory, rejection ratio, overall equipment effectiveness, raw materials, lead times as well as down time. Close monitoring of these KPIs would help the firm focus on achieving set goals in the simulation package.

4.2 Building the Model

Different departments contributed to the process in the selected pilot section for which a model was going to be developed. The place of interest for pilot simulation was the production of margarine as given by a flow chart summary in Figure 3.

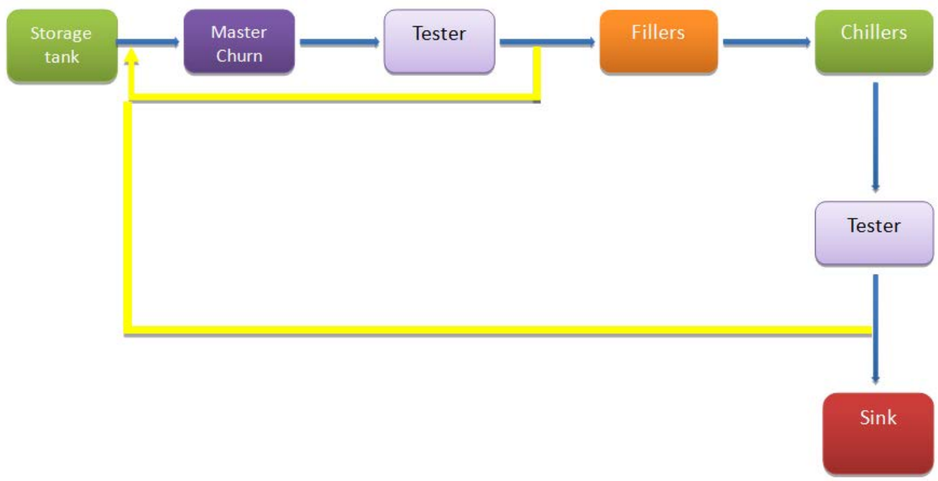

Figure 3.Flow Chart of Margarine Production

An operator would carry boxes of two different types of raw material into the model. These boxes would in turn be converted into two fluids (oil and a mixture of ingredients) which would be transported by pipes to two tanks. From the tanks the material was sent to a single mixer which would mix the two products into a new product. That product was then transferred through a fluid processor, and then converted into flow items (blocks of margarine) which are carried by a conveyor to a sink. The fluid in this model will be measured in gallons, and the time will be in seconds.
A ticker to controls the fluid objects in the model is responsible for calculating how much material was transferred between fluid objects and the rate at which the fluid was processed. In implementing this program an optimum value has to be chosen through a series of test. In this case the ticker was set at 0.75. The screen shoot in Figure 4 shows how the objects are connected the so that there was a processing line from Source 1 to Item To Fluid 1, from Item To Fluid 1 to Fluid Pipe 1, from Fluid Pipe 1 to Fluid Tank 1, from Fluid Tank 1 to Fluid Pipe 3, and from Fluid Pipe 3 to the Fluid Mixer in that order. Also starting at Source 2 the same is done so that there is a parallel processing line with the corresponding objects.

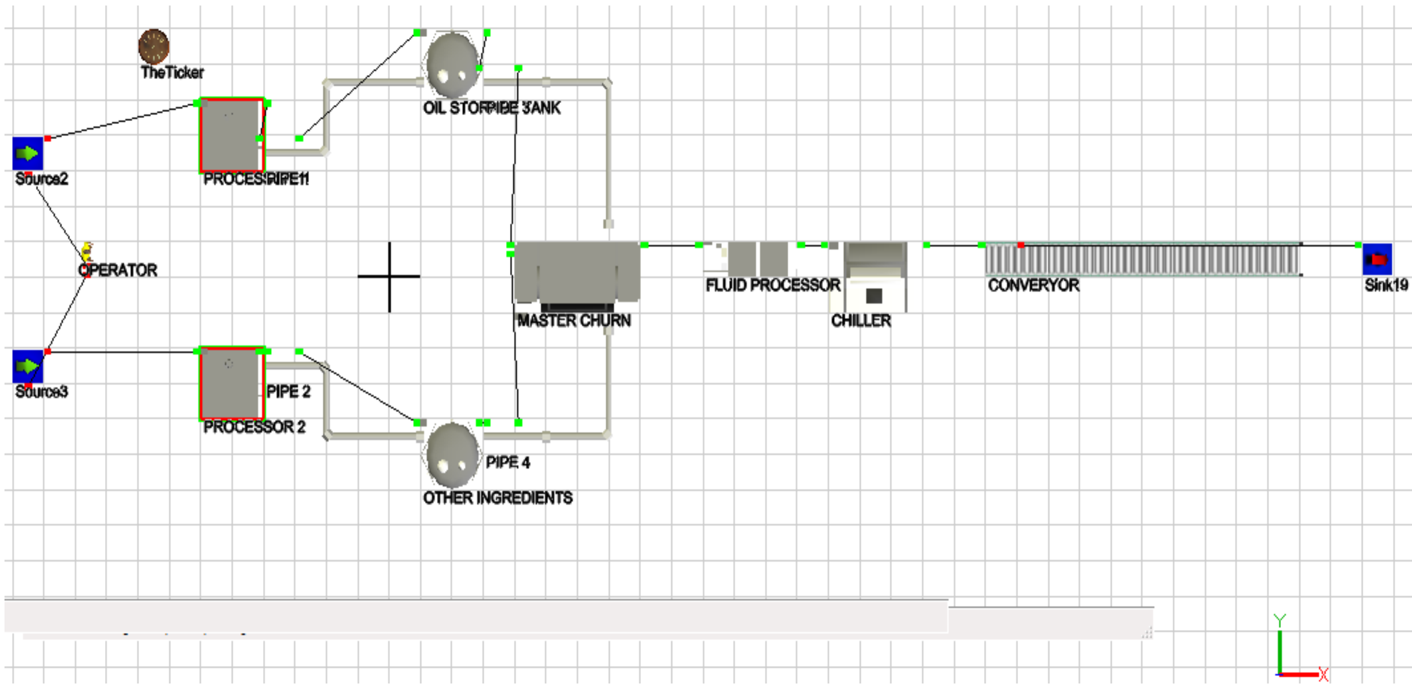

Figure 4.Screenshot 1

The Fluid Pipes now have a maximum output rate of 2, but the default of the Fluid Tanks has a maximum input rate 1. If these values are left as they are, the Fluid Tank's rate will be used during the model run (because it is the lower of two values) and the Fluid Pipe will not be able to send material downstream as fast as you may need it to. For this model, the Tanks should keep their output ports closed until they have received a certain volume of material. They will then open the output ports and leave them open until the Tank becomes empty. They will always keep their input ports open. The Fluid Mixer is configured to receive the two different materials which are oil and other ingredients and combine them into a new material (margarine in liquid form). The Mixer should pull 10 gallons of the first material from input port 1 during step 1. Then it should pull 20 gallons of the second material from input port 2. The delay time for each step is executed after all the material for that step is received, and before the Mixer starts receiving material for the next step. The data would be stored in forms of database tables with relevant fields concerning the particular entities of the system

4.3 Production profile

At the initial stage of the production period, the project may require some years to capture a significant market share. Therefore, production started at about 58% to 64% of its rated capacity in the first and second year of production. But during third year onwards the plant had been working at a range of about 62% and 67% of its rated capacity. This definitely indicates that they was room for improvement in the operation with the help of a production planning and control system, which finds way in which to maximize profits with minimum inputs. The annual requirements for raw and auxiliary materials for production in the manufacturing process are given in the Table 1 and Table 2 below.

Table 1.Raw material requirement inputs

Sr No.	Raw Material	Unit	Qty	Cost (‘000 dollars)
1	Hydrogenated oil & fat	kg	220500	562.5
2	Milk (skimmed)	kg	40250	17
3	Salt	kg	1552	0.56
4	Additives	kg	1125	27
5	Packing materials	LS	LS	180
	Total	-	-	787.06

Table 2.Annual utility production requirements

Sr No.	Utility	Unit	Qty	Cost (‘000 $)
1	Electricity	kWh	24,000	14.22
2	Furnace oil	kg	3,520	19.04
3	Water	m^3	5,000	50
	Total			83.26

From the two tables the total value of the inputs is $870320, the main raw material being hydrogenated oil, packing material and water. These values could be further compared with the throughput values so as to identify the areas where major loses are incurred and the areas where most bottle necks occur.

4.4 Production cost

The annual production cost at full operation capacity is estimated at about 1.69 million USD. The material and utility cost accounts for 51.21%, while repair and maintenance take 15.13% of the production cost.

Table 3.Annual production cost at full capacity (‘000$)

Items	Cost	%
Raw Material and Inputs	787.06	46.31
Utilities	83.26	4.90
Maintenance and repair	257.1	15.13
Factory overheads	44.63	2.63
Administration costs	71.4	4.20
Total Operating costs	1,243.45	73.17
Depreciation	292.28	17.20
Cost of finance	163.66	9.63
Total Production cost	1,699.39	100

Taking note of the highlighted cells a value of 15.13% maintenance can be reduced by excising proper maintenance thus by selecting the most suitable maintenance systems such as preventive maintenance or reliability centered maintenance. Now looking at the 2.63% for the factory overheads which are those cost that are unplanned. These maybe due to the losses incurred during production and other unplanned costs in maintenance. A depreciation of 17.20 could be due to the holding cost of either the raw material or even the end product. Inventory that sits on a shelf is subject to damage, depreciation, and even obsolescence.

4.5 Demand trending

The demand of production of margarine has shown a general increasing trend although there is fluctuation in some years. The demand level in 2014 was about 170 tons but has increased in 2015 and sudden decrease in production in the 2016, 2017 which might have been due to economic hardships during that period. During these two years not only did the demand affect the production of margarine, it cloud also have been due to poor production. The demand of the product would grow as a result of continuously improving of the production planning and control. By continuously revising their production planning and taking into note their KPIs great improvements can be observed.

4.6 Key performance indicators

Change in key performance indicators over time is mostly based on threshold alerts, and this should initiate valuable action. Table 4 gives the KPIs for the case study organization in 2017.

Table 4.Current Key Performance Indicators (2017)

Key Performance Indicator	**Target**	**Actual**
Inventory (tons)	344	294
Lead time	0	3
Down time %	10	15.13
Customer Satisfaction %	100	88
Rejection ratio %	12	18.8

From the above able it clearly shows that during the period 2017 they were not able to reach their target. A small % value of the lead time shows that a greater part of the production has been able to provide the required amount of the throughputs at the required time. A 15.13% down is a reasonable value compared the 10% standard value for such a production company.

5. Testing and analysis

The system was tested to ensure that it gives the right outcomes as those that are expected of it at design stage. For calculations, particular calculations were done manually then the results were fed into the simulation that then analysis the outcome in the form of bar charts, pie charts and line graph. Any discrepancies that arise were taken to imply that the system was not performing as expected of it and a review of the code design was considered to ensure the system was meeting the specifications. An analysis of the KPIs of the plant was also carried out so as to identify the stumbling blocks to achieving the best production.The snapshot in Figure 5 below represents the relationship of the time at which the master churn and chiller are collecting material and the time spent when they are empty. According to this graph the rate at which the chiller is converting the liquid margarine into solid is faster than the rate at which it is collecting the liquid media of the margarine.

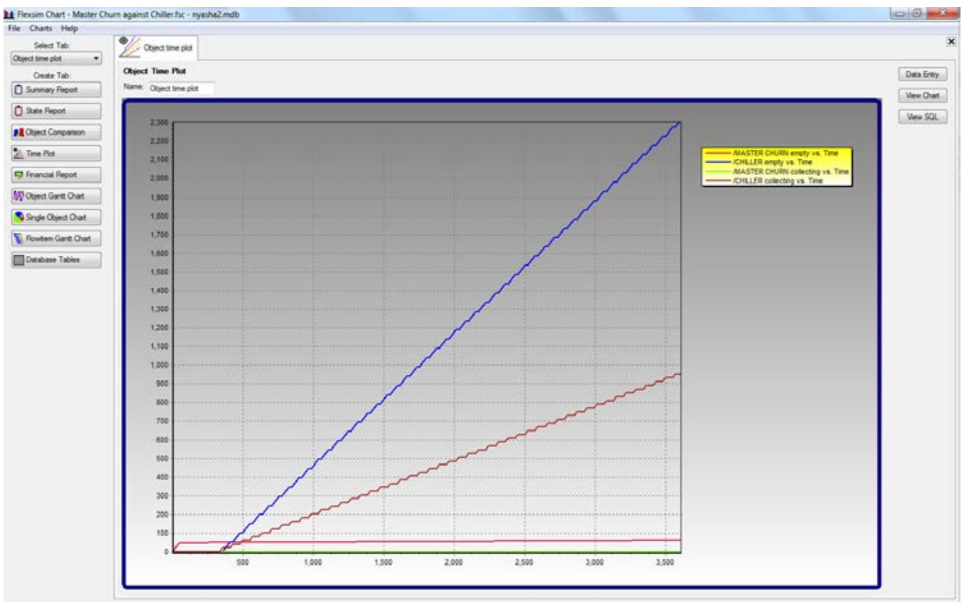

Figure 5. Master churn and chiller material collecting times

This in return shows us that there is a bottleneck between the chiller and the master churn (mixer). It could either be the master churn, that's the rate at which it is mixing the ingredients is very slow or that the chiller is very fast to such an extent that it can even affect the quality of our end product (margarine). Thus there is need to have a look at processes being done by the two and maybe try to adjust rate of operation of the machines. Master churn is one of the main machines for the production of margarine, there is need to analysis the activities occurring during the process. The function of the master churn is to cook and mix the different types of ingredients used to produce margarine. During the process they are also some loses incurred, such as energy loses.

As part of the reports, the overall equipment effectiveness was calculated and comparison of the past OEE and the one expected when the system is used. OEE before use is 43% and after the systems this improves to 50%. From these numbers it can be noted that working on production planning without a computerized system that help in planning production and job scheduling the effective use of the machine or equipment is 43%. This is within the lowest benchmark and requires 17% for it to reach the typical OEE for discrete manufacturers. On the other 50% for the simulation indicates that they is still room for improvement when actual planning is done, although it hasn't reached the 60% due to the use of estimated values. With a proper planning of the production it would insure a higher OEE and also improves the production and quality of the throughputs.

The most appropriate performance indicators to the case study company in the production of margarine are: quality of the product, customer satisfaction is very important, lead time, rejection ratio and the level of the inventory. These are adequate performance indicators as they provide ad sufficient basis to assess the performance. After setting the KPI they is need to monitor those KPIs, thus to say control them watch the activities going on around them, if its inventory is it rising depreciating or is it moving out quickly. On the other hand, operating costs must also be carefully considered. The necessity for tracking KPI other than just Equipment Reliability and Budget Performance is to pinpoint areas responsible for negative trends (leading indicators). By observing and tracking planned/schedule compliance and planned work as a percentage of total labor should be able to detect " non-improving" or even negative performance early enough to identify and correct the training problem. The tracking of positive leading KPI (for production planning) also provides significant motivational stimuli maintenance department personnel. KPIs such as Lead time, customer satisfaction are the leading indicators that measure and track performance before a problem arises.

6. Conclusion

The costs incurred during the implementation of this system entail the purchasing the full package of the Flexsim simulation and Microsoft office and training the stuff (training and licensing). Having set the actual values of the inputs of the plant in the simulation model, it is observed that the value of the throughput is almost the same. That's the inventory level can be determined over a period of a week, month or year depending on how a decision is made to control inventory. Using other graphs such as the time plot bottlenecks can be located thus pinpointing a problem which allows provision of a better way to solve the problem identified. If enough time is allowed for the programing, the system can be further defined to give more accurate results. Such that more details such as the setup time, utilizing time can be stated and can allow the calculation of the overall equipment effectiveness. VBA was used to help the simulation system store and analysis data into meaningful information as indicated by the provided Microsoft access and the Microsoft excel which contains some macros.

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Biography

Ignatio Madanhire graduated with a PhD in Engineering Management at the University of Johannesburg, South Africa, where is also a Senior Research Associate. He is also a Senior Lecturer with the Department of Mechanical Engineering at the University of Zimbabwe. He is a professional member of Zimbabwe Institution of Engineers (ZIE) and he is also registered with Engineering Council of Zimbabwe (ECZ). He has research interests in engineering management and has published works on cleaner production in renowned journals.

Charles Mbohwa is a Professor of Sustainability Engineering and currently Vice Dean Postgraduate Studies, Research and Innovation with the University of Johannesburg, SA. He is a keen researcher with interest in logistics, supply chain management, life cycle assessment and sustainability, operations management, project management and engineering/manufacturing systems management. He is a professional member of Zimbabwe Institution of Engineers(ZIE) and a fellow of American Society of Mechanical Engineers(ASME).