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Improving Production in Automobile Manufacturing System Using Measurement and Prediction of Man-Machine Performance: A Case Study

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ABSTRACT:

This study aims at the use of man and machine input to improve production in an automobile manufacturing system. The goal of this study is carried out using python and MySQL programs to analyze data extracted for parts used to manufacture two car models; Toyota Avalon and Toyota Yaris. *Parts where modeled and stored in a Structure Query Language using Python to write an app to help track demand of parts. The current process had a total cycle and rate of 66 weeks and 12hrs 30 minutes to set up a car model in the assembly line. After design of the Value stream map (material and information flow chart) diagram using MS-VISIO 2016 for the current process, a key performance factor; reject ratio (rate of parts going out of stock) was identified that affects the lead-time which is caused by equipment failure. During order analysis simulation using excel, parts bearing part numbers 200542,201501,100330 and 200546 fell short within 0, -24, -22, -17 and -16 in the six-sigma chart respectively. A model was built to curb this factor using Material requirement planning (MRP). MRP is used to plan for parts with low inventory in the assembly line. In conclusion it shows that to make one assembly part 200401; four of part 200402 and eleven of part 200403 will be needed having eliminated poor reject ratio. This aids in dropping the initial lead time to 2 hours and 30 minutes to manufacture a car model and decreasing the task time.*

KEYWORDS: lead-time, Material Requirement Planning, reject ratio, task time, value stream map

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1.0 INTRODUCTION

Every manufacturing company is made up of several departments that transmit information in order to facilitate production process. The head of the Company, which is the manager, makes major decision. An error in information transmitted within the various departments will be total loss in control of production that will also affect the economy of the product. These days, manufacturers face several problems such as complicated supply chains and growing product complexity. One of the most important goals of every organization or business or a manufacturing firm is to increase productivity which is measured as the ratio of output to input (Lily *et al*., 2015). Improving productivity means developing an efficient way of manufacturing batches of a product that would be cost and time effective. (Akrani., 2012). This means that an efficient production is known by high ratio experienced with lower input. Therefore, the manager has to select a time favourable way to perform the task hereby improve the production system.

During the manufacturing process, several problems can be encountered when tasks and processes are not properly planned leading to several problems from the managerial level down to the product Production cost can sometimes increase if the production processes are not balanced with the level of demand. Other problems associated with poor optimization are; Maintenance problems, Storage and transportation problems, Product quality problems. The aim of this study is to improve production in automobile manufacturing system using measurement and prediction of man and machine performance and its goal is to use python programming to extract data on assembly parts used in the production of two Toyota car models; Toyota Yaris and Toyota Avalon, to apply Material Requirement Planning (MPR) computation for procurement of parts ordered by customers and to validate the effect of a decent data base structure and material requirement planning in the assembly line of the automobile company.

Most rising companies, face problems of poor management that can cause a lot of time spent doing a task. Adopting the right method of improving a manufacturing system ensures the control of factors like improper inventory, transportation, data management (analysis and mining) and time.
Recently it has been an important task to improving man and machine performances in production due to introduction of advanced technologies making customers needs and demands more unique and complex to achieve and solve, thus making companies to accept and enact changes in their production policies in order to combat uprising problems. According to Lily *et al*. (2015) there has to be a demand for any expected output even if productivity raises the value or gain. Thus, if the manufacturing system is well improved with respect to the demand then problem associated with improper inventory i.e. in the case where the items in stock or in storage will be gross for the available demand leading to a poor economy.

Another crucial problem is the poor transportation or distribution or improper record keeping due to an unorganized assembly line. This problem is predominant in automobile industries well as other manufacturing systems that are involved in the assembling of parts. Boysen *et al*. (2015) states that if an important part is missing then the assembly line has to be stopped. This could lead to the idleness of assembly workers in every 60 to 90 seconds, which is the typical range of cycle times in an automobile assembly. Thus, the profit of one car is lost. Therefore, the conjugal sum of every mistake made or incoherence experienced can cause a significant loss in the company's revenue.
Permin *et al*. (2015) offered another solution to the demand problem, according to them some aspects are important for high productivity. They are integration of knowledge of materials, resources, and processes which in turn can help to forecast or predict the manufacturing system behavior and improvement of production processes.

2.0 MATERIALS AND METHODS

The MRP computation is done in a matrix and tabular form. MRP is very well used in Dependent demand (where assembly part depends on several parts), Discrete demand (when demand does not come periodically but occasionally), Job shop production and Assemble-to-order environments.
From the necessary items needed, an MRP computation can be formed to output the Work orders, Purchase Orders and Rescheduling notices.

2.1 Computing MRP Requirements

Let Bij denotes the number of units of item j required to make directly one unit of item i, and let R_{ij} denote the total number of units of item j, direct or indirect, required to produce one unit of item i Clearly $R_{ii} = 1$, while for $j \neq i$ we have;

$$R_{ij}=\sum B_{ik}R_{ij}R_{kj} \quad (1)$$

Where
B_{ik} = quantity of a subassembly part per an assembly part
R_{kj} = total number of assemblies needed
R_{ij} = the total units of item B_{ik} it takes to make an R_{kj} number of assembly item

$$R= 1+BR \quad (2)$$

Where
$I =$ *identity* matrix
$B =$ matrix of parts needs per row

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R= matrix of number of parts need to make particular n number of assemblies on level zero of BOM

So,

$$(1-B)R = 1 \qquad (3)$$

$$R = (1-B) \qquad (4)$$

Therefore, the matrix data can be gotten from the BOM and MPS to give a matrix of the format below:

$$B = \begin{matrix} & t_1 & t_2 & \cdots & \cdots & t_n \\ t_1 & n_{11} & n_{12} & \cdots & \cdots & r \\ t_2 & n_{21} & n_{22} & \cdots & \cdots & r \\ \vdots & \vdots & \vdots & \ddots & & \\ \vdots & \vdots & \vdots & & \ddots & \\ t_n & n_{i1} & n_{i2} & \cdots & \cdots & r \end{matrix} \qquad (5)$$

Where

t_n is the item on the BOM to be made or purchased.

n_{ij} is the number of an item t_n on the same column j, required to make a part t_n on the same row j.

By the matrix;

$t_1, t_2 \ldots t_n$ Are arranged in a hierarchy, thus t_1 cannot be used to make a low-level item t_2. The rows (i) represent the item to be made by an item on the column j. Thus,

Item t_1 requires n_{12} units of item t_2 and n_{1j} unit of item t_n

Item t_1 requires n_{12} units of item t_2 and so on

Based on equation (4)

$$R = \left[\begin{pmatrix} 1 & 0 & \cdots & \cdots & 0 \\ 0 & 1 & \cdots & \cdots & 0 \\ \vdots & \vdots & \ddots & & \vdots \\ \vdots & \vdots & & \ddots & \vdots \\ 0 & 0 & \cdots & \cdots & 1 \end{pmatrix} - \begin{matrix} & t_1 & t_2 & \cdots & \cdots & t_n \\ t_1 & n_{11} & n_{12} & \cdots & \cdots & n_{1j} \\ t_2 & n_{21} & n_{22} & \cdots & \cdots & n_{2j} \\ \vdots & \vdots & \vdots & \ddots & & \vdots \\ \vdots & \vdots & \vdots & & \ddots & \vdots \\ t_n & n_{i1} & n_{i2} & \cdots & \cdots & n_{ij} \end{matrix} \right]^{-1} \qquad \textbf{(6)}$$

$$R = \begin{matrix} & t_1 & t_2 & \cdots & \cdots & t_n \\ t_1 & 1 & b_{12} & \cdots & \cdots & b_{1j} \\ t_2 & 0 & 1 & \cdots & \cdots & b_{2j} \\ \vdots & \vdots & \vdots & \ddots & & \vdots \\ \vdots & \vdots & \vdots & & \ddots & \vdots \\ t_n & 0 & 0 & \cdots & \cdots & 1 \end{matrix} \qquad (7)$$

Where

b_{ij} is the element of the matrix in equation (7) and after performing the mathematical operation in equation (4). Equation (7) can be used to obtain the number of items on the horizontal $t_1, t_2 \ldots t_n$ to make an item $t_1, t_2 \ldots t_n$ on the vertical column.

For example, the number of t_n on the horizontal row needed to make an item t_1 on the vertical column is equal to $b_{1j} \times N_{t1}$. Where N is the specific number of the top-level item t_1 needed.

In order to plan for the order release time for each item the MRP computation is used.

3.0 RESULTS AND DISCUSSION

3.1 Order Simulation and Analysis

To calculate the part going out of stock before the 66th week the following formula was followed:

For part 200542, based on the simulation of the data on python, its initial stock x_0= 1 and several of this part will be needed along a couple of weeks, 2 quantities will be needed in week_57 and 18 quantities will also be needed in the same week, and finally 5 quantities will be needed in week 61.

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To simulate the state of the inventory based on the order the following was do not.

Let

S be the sum of all the order for part 200542 and,

$\mathbf{X_n}$ is the number of part 200542 remaining after a particular order has been fulfilled.

$$S_n = 2, 18, 5$$

$$x_1 = x_o - S_1 = 1 - 2 = -1$$

$$x_2 = x_1 - S_2 = -1 - 18 = -19$$

$$x_5 = x_3 - S_3 = -19 - 5 = -24$$

From the above calculation, before the end of the order all part 200542, there will be no more parts left to fulfill the order for the part. The application does this for every items or part ordered in order to help plan for critical parts that may run out. In the Appendix A shows how the 4 critical parts are to run out before the end of their order. The four critical parts are; parts 200542, 201501, 100330 and 200546. By the graph in the Appendix section part 200542 would be the most used up part. Since it starts out at only 1 item available in the inventory it won't even be available to fulfill the first order of 2 quantities and the later on its quantities will fall to -24 in the inventory by week 61. Also see Figure 1

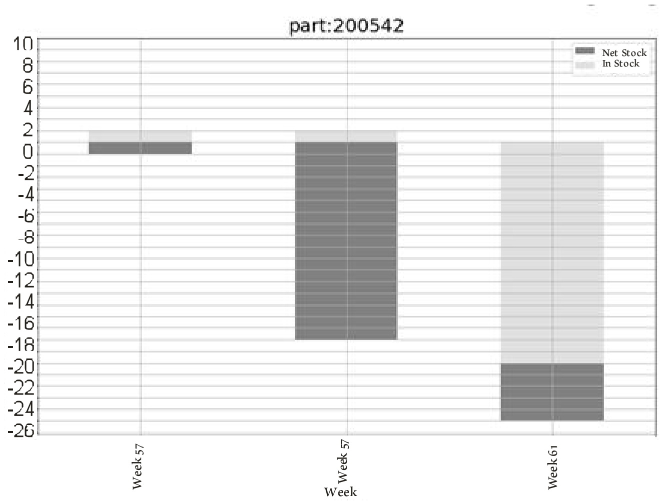

Figure 1 part 200542 Inventory Status

Error! Reference source not found. shows the timeline of part 200542 from week 57 to week 61, the light shade represents how much of 200542 remain after fulfilling the customer's order. The lighter shade represents how much quantity of 200542 will be in stock before the order is taken away. The first two bars occur in week 57. Therefore week 57 starts up with one piece of 200542 in the inventory with a demand for 2 and 18, the value after subtracting this value is carried over to week 61 where the available in inventory starts at -19 and then reduced to -24 due to the 5 pieces order made in week 61.

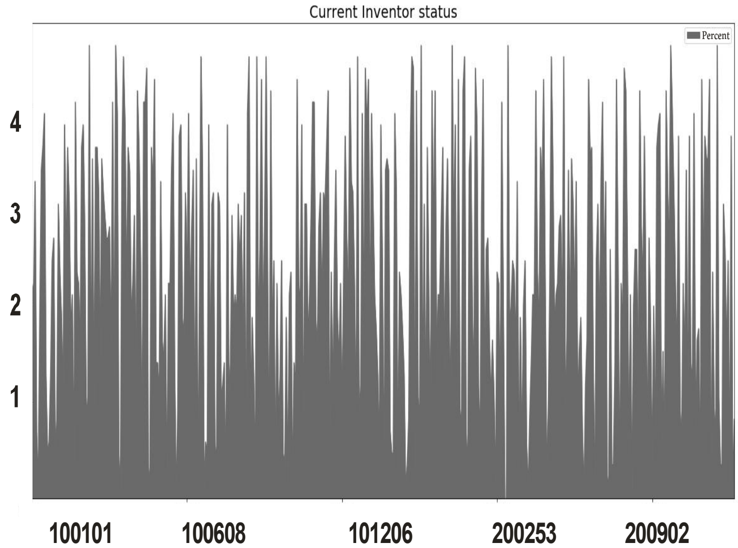

Figure 2 current inventor statuses

Figure 2 this chart illustrates all inputs, orders, part numbers and item no of customers. After knowing the inventory status of a part with time; it is also possible to get who ordered the part and when that part was ordered by running the MYSQL codes below

```
DROP TABLE t5;
CREATE TEMPORARY TABLE t1
SELECT * FROM customer_vehicle_order
```

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```
JOIN assembly list ON
customer_vehicle_order.vehicle_id=assembl
y_list.vehicle_no;
ALTER TABLE t1 DROP currency;
CREATE TEMPORARY TABLE t2
SELECT
order_no,customer_name,part_no,quantity,da
te FROM t1
JOIN part_list ON
t1.assembly_id=part_list.assembly_no
WHERE part_no=200542;

CREATE TEMPORARY TABLE t3
SELECT
order_no,customer_name,part_no,quantity,da
te FROM customer_assembly_order
JOIN part_list ON
customer_assembly_order.assembly_id=part
_list.assembly_no
WHERE part_no=200542;

CREATE TEMPORARY TABLE t4
SELECT * FROM t2
UNION SELECT * FROM t3
UNION SELECT
order_no,customer_name,part_no AS part_id
,quantity,date
FROM customer_part_order
WHERE part_no=200542;

ALTER TABLE t4 CHANGE part_no
part_id VARCHAR (6) NOT NULL;

CREATE TABLE t5
SELECT order no,
customer_name,part_name,part_id,quantity,d
ate FROM t4
JOIN part list
ON t4.part_id=part_list.part_no;
SELECT * FROM t5
```

When the code above runs on MySQL

This makes it easier to trace an order by applying the above code to a button so that when pushed the command runs and brings out the necessary data based on the query.

3.2 Demand Analysis

Data for the first 10 most demanded items are shown on the table 1. it shows total quantity and amount of parts ordered by customer systematically.

Table 1 A Demand Table

part no	Frequency	Total quantity
101306	2	35
200517	3	27
200542	3	25
200212	2	24
201403	2	24
201209	2	23
100631	1	23
101501	1	23
101502	1	23
101503	1	23

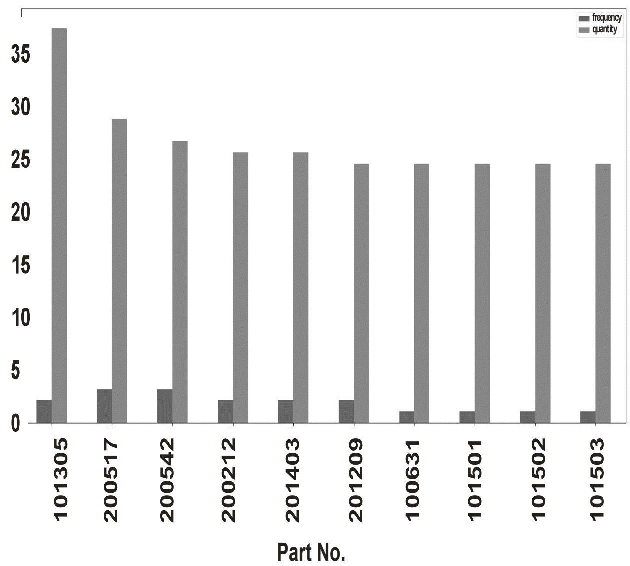

Figure 3 Demand Plot

From the graph illustrated in Figure 3, the most demanded product can be easily worked out and further simulations can be done to predict and ensure more sales since the inventory will be kept in check there will be fewer problems associated to the status of the inventory. Also based on this forecast another relationship can be noticed in the Appendix section where the number of items available at week one will not be able to serve the order within the following weeks. The amount demanded is 35 while the amount available is 29.

Let

Lead time = L => (the time it takes to make or order the item)

Gross Requirement = $d(t)$ => (quantity of item needed before subtracting the on-hand inventory

Scheduled Receipt = $e(t)$ => (quantity of an item already ordered before the start of week one (1)

Projected on-hand = $h(t)$ => (quantity of the item already in the inventory)

Net requirement = $n(t)$ => (quantity of the item needed after the inventory have been subtracted)

Planned order receipt = $x(t)$ => (quantity of an item that is planned to be procured in a certain week)

Planned order release = $y(t)$ => (quantity and time that the item procured in x(t) will be received)

i. **Part 200401:**

$d(t) = 9, e(t) = 0, h(t) = 5$

Therefore, net requirement $n(t) = d(t) - h(t)$

$$n(t) = 9 - 5$$
$$n(t) = 4$$

The planned order release is dependent on the lead time L, L=2.

Therefore, the planned time to receive 4 quantities of part 200401 is T + L,

Where T = current time, T = 1

Thus, the planned time is $T + L = 1 + 2 = 3$

The planned order release $y(t) = 4$ on week 3

ii. **Part 200402**

$d(t) = 9, e(t) = 0, h(t) = 1$

Therefore, net requirement $n(t) = d(t) - h(t)$

$$n(t) = 9 - 1$$
$$n(t) = 8$$

The planned order release is dependent on the lead-time L, L=1.

Therefore, the planned time to receive 4 quantities of part 200401 is T + L,

Where T = current time, T = 1

Thus, the planned time is $T + L = 1 + 1 = 2$

The planned order release $y(t) = 8$ on week 2

iii. **Part 200403**

$d(t) = 9, e(t) = 0, h(t) = 7$

Therefore, net requirement $n(t) = d(t) - h(t)$

$$n(t) = 9 - 7$$
$$n(t) = 2$$

The planned order release is dependent on the lead-time L, L=2.

Therefore, the planned time to receive 4 quantities of part 200401 is T + L,

Where T = current time, T = 1

Thus, the planned time is $T + L = 1 + 2 = 3$

The planned order release $y(t) = 2$ on week 3

Summary: By getting the appropriate data from different departments in a production firm, the right information can be extracted and visualize properly to view the most critical points. By employing the use of a computerized production, everything can be monitored accordingly. The Figure 4 below summarizes the interaction of man and machine to improve production.

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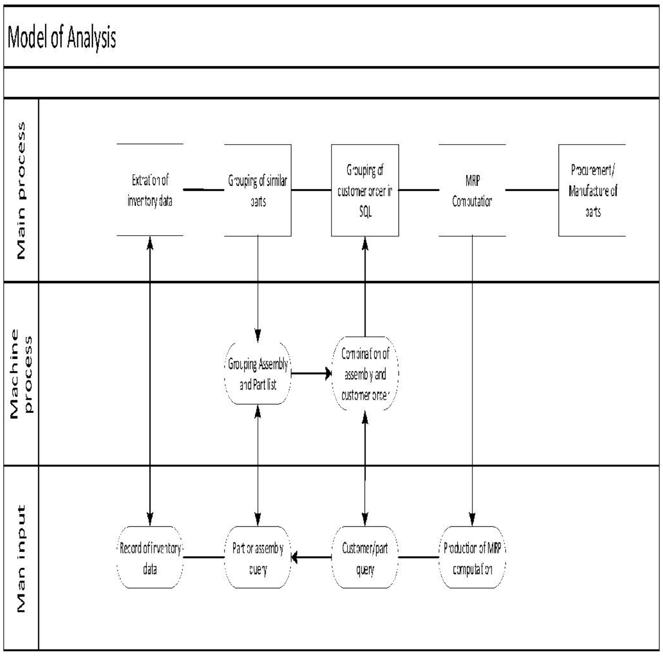

Figure 4 Model of Analysis

4.0 CONCLUSION

In the course of achieving an improved production in the automobile manufacturing company within 66 weeks of production of car model, PYTHON programming was used to extract data for parts, customer's orders and assembly list needed for analysis and simulations. The arrangement of data carried out using MYSQL which is a Structure Queried Language. It helped in orderly arranging the data gotten in a tabular form for easy accessibility and comprehension of vehicle, assembly and parts data. The ordered data helped to track the lead times of parts and the order customers have made.

A key performance indicator which is reject ratio was identified. Furthermore, simulation was carried out to generate a forecast of demand and schedules by performing Material Requirement Planning computation to set up a new model analysis to curb the problem. To improve a manufacturing system, human error was minimized using automations of processes usually carried out by an operator; this helps to plan for production and procurement on a longer time frame.

The analysis shows that to in order to make one part 200401 in the inventory, four parts (200402) and eleven parts (200403) will be needed, hence eliminating poor reject ratio in the inventory. This aids in reducing initial lead rime to setup a car model from 12hours 30minutes to 2hours 30 minutes within 66 weeks of production.

This study aids in enabling developing automobile companies switch over to digital methods of handling affairs like the use of engineering programmes like the MySQL and MRP. There is also need to eliminate record keeping in hard copy since it can cause loss of space and confusion in a working environment.

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