OPTIMIZATION OF PROCESS PLANNING AND CONTROL OF PLASTIC MANUFACTURING INDUSTRY

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Abstract: *A case study of a plastic manufacturing industry was conducted to determine the main factors affecting its production capacity. Major factor affecting production capacity in this industry was realized to be machine downtime, by the process of reducing machine downtime an optimum usage of machine was discovered. It was found that this factor has significant effect on improving the production capacity to optimum in this firm, a comprehensive flow chart for process planning and control was designed, via the development of a decision support system (DSS) for process planning and control of plastic manufacturing industry located in western part of Nigeria. The DSS developed was validated using cycle time, weight of raw material, automatically operated machine from the company. The weight of a unit plastic product of various sample types in the factory was determined, manually produced products in factory were measured and recorded this same data was inputted into the decision support system developed. Results from company and DSS developed were compared using paired t-test comparison, the result showed the 2- tailed significance of 0.045; which shows that there is no major difference between the weight of each plastic product produced by the company machine and the result generated by the DSS developed this confirm the software is reliable according to weight formation of plastic product. The cost estimation t- test result shows 2-tailed significance of 0.035, which showed that there is no much difference between the manual cost estimation result by company and result displayed by DSS.*

Keywords: ***Control,*** *Decision, Manufacturing, Plastic, Process, System*

1. INTRODUCTION

A leading plastic manufacturing company in Nigeria is being considered as the case study of this project. been one of the major manufacturing industries for plastic in Nigeria, it has been on the losing end in recent years, the small and medium scale enterprises are in competition with the high standard plastic manufacturing companies in terms of satisfying consumer needs. Production planning and control aims at providing efficient and effective utilization of production resources, while meeting sales demand for products, and taking into consideration all significant variables that affect the manufacturing environment.

Machine downtime is one of the majorly noticed cause of variation in a manufacturing system, resulting in poor production schedule reliever ability that should be minimized, if not completely eliminated, but this cannot be so therefore the need of optimization is required. The plastic industry is usually characterized by injection moulding machines, with its unique method of taking in raw plastic (granules or pellets) and as an end product it would produce a plastic part according to the shape of the mould. In these machines, the methods of operation can be very complex; plastic moulds can be used on specific machines in ways which add a time constraint to the manufacturing process apart from that due to the operator.

The model available for optimizing decision for production can be in various mathematical, empirical, stochastic and deterministic ways. Most available models cannot handle variety of decisions often made by expertise, before, during or after production process. The DSS is a modeling technique for inputting wide range of knowledge into production planning and control.
The application of DSS is applied in this study.

1.1 Purpose of the study

A decision support system developed for optimization process planning and control of plastic manufacturing industry has been design to enhance production efficiency in a plastic industry, by the process of reduction of machine downtime as the major focus of this research.

2. METHODOLOGY

The study started by studying the current conditions affecting the production downtime. Then each factor expecting to affect the production is modified one by one, and the effect of modifying that factor on the production capacity was studied. First the study is run on investigating the optimum running production capacity process of each machines under study along with the products produced on this machine. Also, an optimization algorithm was formulated considering these items as constraints while product types were used as decision variables for the objective function, to maximize machine uptime or potential availability.
The operational conditions and management decision to produce plastic product were determined from the analysis of the obtained from the plastic production company. The raw materials data includes temperature, weight per product using linear programming based operational constraints. All data where gotten from the establishment over a certain period.
The plastic product weight to quality were transformed to regression model analysis by using cycle time and material weight as process parameters, gotten from the plastic production industry. Flow chart, algorithm, a software coding (using java script) were carried out in conformity to the expert modules generated. The modules utilized were, raw material, temperature conditioning, quality control, manufacturing cost, and finished product.
In the decision support system for process planning and control of plastic manufacturing industry.

DSSOPPCPMI queries and facts were raised based on human expert's advice. These were used to arrive at optimal decision that minimized that overall cost of manufacturing.
The DSSOPPCPMI developed was validated and verification of the software output results from the initial data, latest data, and practical utilization of same in the plastic manufacturing industry use as a case study. The output results were analyzed statistically using paired t - test from which the developed system were compared with human expert working on the plastic product production.

3. SET UP OF DSSOPPCPMI

The DSSOPPCPMI system set-up is shown in figure 1 which shows six modules working together to support the decision-making task. The material selection module and the process selection module are order independent, thus both a material first and process first selection schemes are supported. These modules evaluate the compatibility between each alternative and product profile requirement and output a partially ordered set of compatible alternatives. Temperature conditioning module are linked together to maintain temperature of the selected raw materials at required temperature between 130°c and 200°c. The quality control module checks the quality of plastic produced in comparison with the standard given for the product in the database of the software. Manufacturing cost module generate immediately the production cost for the entire operation. Finally, the finished product module displays all the category of plastic product produced by the automatically.

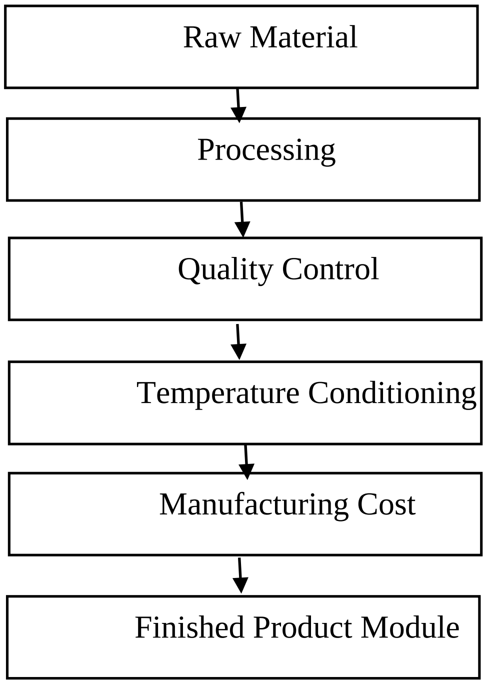

Figure 1: Developed DSSOPPCPMI module

3.2 Model development

The objective of the linear programing is to minimize the total time it takes for production to occur per cost of product. The algebraic formulations are presented below. The objective function represents the production time per cost. The constraints imply the various variation of machine downtime that affect the production efficiency at any given period of time, the downtime being considered cannot exceed these constraints.

Objective function:

Minimize Z = $\sum_{j=1}^{ni} PjXj(Cost\ per\ production\ time)$ (1)

Subject to:

Delay due to barrel blockage

$$\sum_{j=1}^{n1} \beta jXj \leq b1$$

Delay due incomplete product formation

$$\sum_{j=1}^{n1} \partial jXj \leq b2$$

Delay due to personnel

$$\sum_{j=1}^{n1} \gamma j X j \leq b3$$

Delay due to selection for mould

$$\sum_{j=1}^{n1} \alpha j X j \leq b4$$

Delay due to machine selection

$$\sum_{j=1}^{n1} \delta j X j \leq b5$$

Additional constraints

Additional restriction will be required due to company experience or what is currently in operation in the company, it could be noted that not all machines can be used to produce the various molds in the industry. Example market demand for a plastic product limits constraint. These expressions can be given as follows:

Minimum production limit per machine

$Xj \leq Ij$

Maximum production limit per machine

$Xj \geq Ij$

For all Machines

MHR = $\sum_{c=1}^{n} \sum_{j=1}^{M} CkI$

Where, I is counter for machines

I=1 … … …m, k = I… … … n, Counter for raw material associated with each machine.

Production cost pre plastic product j… … …PCj

Where,

PCj = (aj + b1j + cj + fj) + $\sum_{c=1}^{n} \sum_{j=1}^{M} CkI$

Note these parameters:

aj = Direct material cost per unit product j b1j = Direct labour cost per unit product j bi = Denotes the total availability of the its materials

Cj = Direct expenses (rate of electricity, water and oil) per man i= denotes the ith resources j= denotes the jth number of plastic product mi = denotes the number of bags of material in producing the plastic product ni = denotes the number of plastic product produced

Pj = denotes the cost per unit plastic product produced

Xj = denotes the quality of plastic product produced Z = objective function βj = denotes delay due to barrel blockage

γj = denotes delay due to personnel

∂j = denotes delay due incomplete product formation

αj = denotes delay due to selection for mould
j = denotes delay due to machine selection

Table 1 shows the specific proportion of cycle time to weight of product according to the moulds in use as communicated by plastic manufacturing industry used as case study.

Table 1: Specific Proportion of Cycle Time to Weight of Product

S/N	MOULD TYPE	CYCLE TIME(Seconds)	MATERIAL WEIGHT (kg)
1	Ice Cream Cup	25	0.20
2	Chair (Power)	145	4.10
3	Wheel Cover	80	1.86
4	Custard Bowl	43	1.90
5	Table	155	4.54
6	Knob	39	0.45
7	Car Mud	62	2.10
8	Bike Tail Light	28	0.30

4. RESULTS AND DISCUSSION

The developed DSSOPPCPMI software takes the user through a phase of questions and based on the values entered by the user, it triggers the inference engine where series of calculation would be made before it brings about the results automatically. It analyzed the production process of plastic products by giving advice to the user on the best decision to take, the production possibilities, the appropriate quantity and quality needed for the product in other to achieve optimality.

The DSSOPPCPMI is well designed to a way it advices user on each production possibility according to the choice of product chosen by the user on whether production can take place or not.

The following questions are asked by the user using the system:
Select your mould type for production of product.
IF:
Ice cream cup, Chair (Power), Wheel Cover, Custard Bowl, Table, Knob, Car Mud, Bike Tail Light.
Input your total value of unit you needed for production.
Select your machine type according to mould selected.
IF:
Machine 10, Machine 7, Machine 30, Machine 28, Machine 26, Machine 29.
Select your choice of raw material according to mould selected.
IF:
Polypropylene, Granules, Polycarbonate.
THEN:
The Inference Engine report to the user if production can occur or not from data inputted by user.

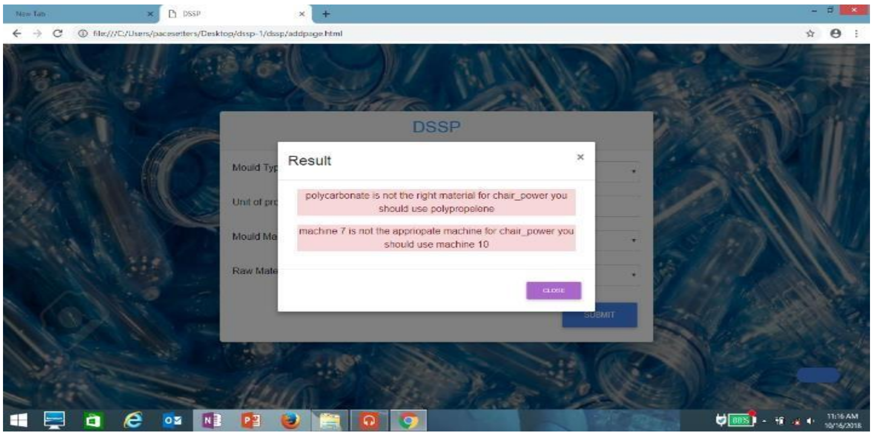

Figure 2. Production possibility Alert that production cannot occur.

The figure 2 shows an error statement telling the user about the wrong selection of machine and material and telling the right combination that is needed for the production. Figure 3 reviews the right selection that is needed to be inputted by the user for production to occur without an error statement, the user has been guided by the system towards making the right selection for production possibility.

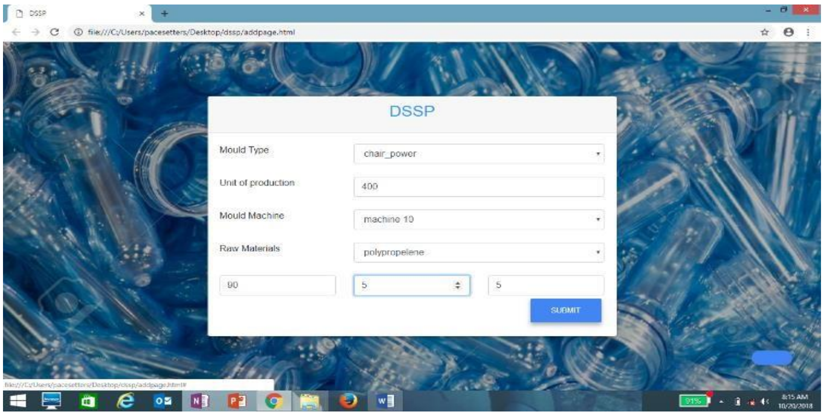

Figure 3. Production possibility Selection after Following Correction from Error Statement.

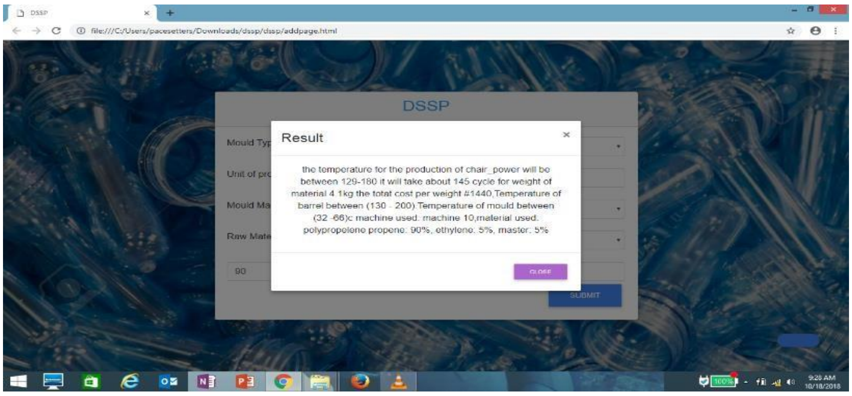

Figure 4 Quality production control module

Figure 4 reviews the that production process can being with all the right selected input, of number of units needed and the cost for producing that total amount of units, it also reviews the temperature at which the machine barrel and mould need to be.

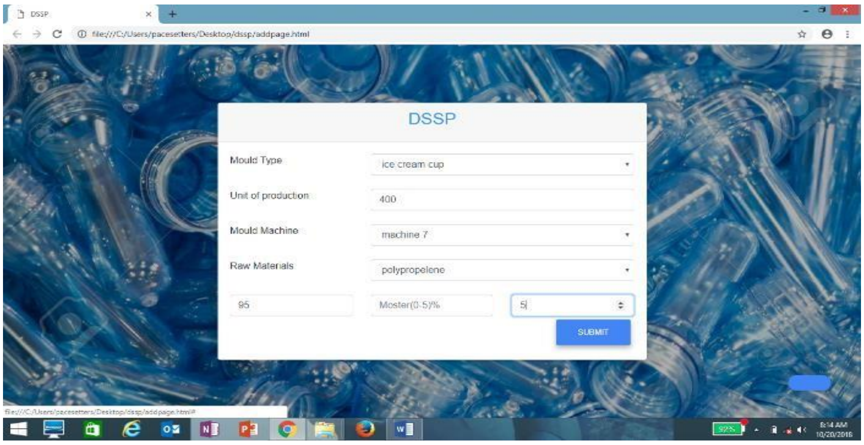

Figure 5. All Options Available for Selection for a Production Process.

According to figure 5, it shows all the available options that has to be filled up before a production can take place.

4.1 Validation of DSSOPPCPMI Developed

The validation of the DSSOPPCPMI developed was done with a single unit of plastic of each plastic product weight. Table 2 weight using factory value and DSSOPPCPMI developed with % difference in weight for a unit product.

Table 2. Weight of unit plastic product formulation by the company and DSSOPPCPMI

Product Type	The Company weight (kg)	DSSOPPCPMI weight (kg)	% Difference
Ice Cream Cup	0.20	0.20	0.00
Power (Chair)	4.20	4.10	0.1
Table	4.56	4.54	0.02
Wheel Cover	1.88	1.86	0.02
Bike Back Light	0.31	0.30	0.01
Custard Bowl	1.90	1.90	0.00
Knob	0.46	0.45	0.08
Car Mud	2.30	2.10	0.20
Total			0.36

Table 3. Paired Sample Statistics

Cost Method	Mean	Standard Deviation	Standard Mean Error
Manual	895.05	384.89	136.08
Decision Support	895.02	384.89	136.08

Table 4. Paired Sample Test for Cost

Paired Difference						
Cost Method	Mean	Standard Deviation	Standard Error Mean	t	Df	Sig (2-tailed)
Pair (Manual)						
And Decision Support	0.0275	0.0211	0.0075	3.6667	7	0.035

Table 4 shows the results gotten from t-test by the comparison between the company cost estimation for a week production and cost estimation using DSSOPPCPMI developed for each unit product production. The result show 2- tailed significant of 0.035 in Table 4, this implies that there is some difference between the manual method of costing and DSSOPPCPMI developed, hence the DSSOPPCPMI developed is reliable reducing cost of production of a unit plastic product and it also faster than the model costing method of approach by the company.

5. CONCLUSION

The optimization of process plaining and control of manufacturing industry was achieved by the usage of a DSSOPPCPMI system. From the DSS model, has maximize effectiveness of planning yielding to better quality and low cost. The use of DSSOPPCPMI developed shows uptime was maximized thereby reducing downtime, showing that this system can be applied in any production firm facing similar situation in production process and control in a manufacturing firm.

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