Production Planning and Control in Small Scale Industry; A Computer Aided Engineering Approach

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Abstract

Production planning and control (PPC) is one of the basic managerial decisions in any production industry. This is because of its inherent capacity of improving productivity and customer satisfaction in terms of prompt service delivery. The manual approach to the arrival to this decision has become laborious in recent time due to the growing complexity of production processes particularly in the small scale industry. Hence, this paper presents the CAE (Computer Aided Engineering) approach to arriving at PPC decision in a small scale bottled water industry in Nigeria. The paper shows software development for PPC in small scale bottled water industry using Visual Basic.6.0 2006 environment and Microsoft Office Access 2007 with mathematical models. Simulation of the developed system shows the vantage of software development in handling predominant manual engineering task such PPC in such industry. As a result, software development for handling various engineering tasks (process planning, quality assurance for example) for different small scale industry in Nigeria is highly recommended. This will not only improve productivity, but also create employment and increase the GDP (Gross Domestic Product) of such industry in the country.

Keywords *- Computer Aided Engineering, Product, Production Planning and Control, Simulation Software*

1. Introduction

Production is the process whereby an input (raw material) is transformed into an output (product). The process is value adding and the added value can measured by the difference in the value of the output compared to the input. The main objective of production is to produce a customer demanded goods and services efficiently and economically. One of the managerial responsibilities in any production industry is production planning. The control of the plan is to ensure compliance with the set plan through daily monitoring of the production towards the attainment of the set production quantity.

It is reported that PPC (Production Planning and Control) can be referred to as coordinating system of the production operation. It function is to efficiently utilize the available material resources, people and facility in any enterprise through planning, coordinating and controlling the production activities that transform the raw material into finished products or components in most favourable manner [1].

Planning problem begins with a specification of customer demand that is to be met by the production plan. Control of production plan becomes inevitable due to the fact that production planning is potentially active and always remains in dynamic status as plans may have to be modified in agreement to changes in circumstances [2].

Practically, production planning presents propose daily plan for production activities within a time frame usually referred to as planning horizon. The control is the daily actual performance comparison and calculation of deviation from the proposed plan within the horizon. This deviation from the plan in terms of produced quantity shortfall is ploughed back into the demand for the remaining period of the horizon and a new plan is generated.

PPC requires analytical skills and understanding of production process [1]. The complexity of modern day production industry as therefore made the manual approach mentally difficult. Hence, the introduction of the computer aided engineering approach become appropriate.

1.1. Computer Aided Engineering (CAE)

The Computer is a machine that handles information with amazing speed. CAE is explained as the use of computer technology within engineering in a broader sense than just engineering analysis and also any use of computer software to solve engineering problems or to aid engineering tasks [3].

PPC is a decision making activity; a successful decision-making is strongly dependent upon various capabilities that include the effective acquisition, storage, distribution, and sophisticated use of the knowledge of the human experts in such field [4]. In the context of CAE this would be achieved through the use and development of appropriate software.

It is reported that software engineering (SE) is the application of a systematic, disciplined, quantifiable approach to the development, operation, and maintenance of software, and the study of these approaches; that is, the application of engineering to software. This is because it integrates significant mathematics, computer science and practices whose origins are in engineering. Furthermore, software are developed for three predominant purposes (1) to meet specific needs of a specific client/business (2) to meet a perceived need of some set of potential users (3) for personal use (e.g. a scientist may write software to automate a mundane task) [4].

One of the merits of the use of computer in engineering task is the possibility of simulation of the process. Simulation approach enables decision makers to make a more informed decision about the present task. Simulation is been described as the art and science of creating a representation of a process or system (in this case the production system) for the purpose of experimentation and evaluation [5]. Similarly, simulation is reported to help shorten production process and help to achieve quick improvement and efficiency [6].

PPC provides necessary information to different departments within the industry. For instance, it provides information about available raw material and finished product inventory to the stores department; required machine production hours within the horizon to the operations department.

The present work presents the development of a production planning and control software using Visual Basic.6.0 2006 environment and Microsoft Office Access 2007 for a small scale industry in Nigeria.

2. Methodology

The case study industry is a small scale bottled water industry. There are two main production phases in this industry; bottle production and bottled water production, the developed system plan and control production of both phases. The bottle production phase comprises of preform heating and preform blowing stages. The bottled water production phase comprises of bottle washing, bottle filling, bottle capping, bottle coding, label shrinking and bottled water packing.

The individual stages stated above as a dedicated machine that performs the operation of such stage. The mathematical model adopted for the modeling and simulation of the production process at each staged is described below [7]:

i. Un-capacitated Lot-Sizing Model: The purpose is to plan the production over the planning horizon (i.e. fix the lot size in each period) in order to satisfy demand, and to minimize the sum of production and inventory costs.

$$\min \sum_{t=1}^{n} (p_t\, x_t + f_t y_t + h_t s_t) \tag{1}$$

$$s_{t-1} + x_t = d_t + s_t \; for\, all\, t \tag{2}$$

$$s_0 = s_n = 0 \tag{3}$$

$$x_t \le M y_t \; for\, all\, t \tag{4}$$

$$x_t s_t \ge 0, y_t \in \{0,1\} for\, all\, t \tag{5}$$

Where $t = 1, \ldots\ldots n$ represent the discrete time periods, and n is the final period at the end of the planning horizon. The decision variables are x_t , y_t and s_t represent the production lot size in period t, the binary variable indicating whether or not there is a positive production in period t ($y_t = 1\; if\; x_t > 0$) and the inventory at the end of period t respectively.

The data are P_t, f_t, h_t and d_t modeling the unit production cost, the fixed production cost, the unit inventory cost, and the demand to be satisfied respectively for each period t. For simplicity, $d_t \ge 0$ for all periods t. M is a large positive number. Constraint (2) expresses the demand satisfaction during the horizon Constraint (3) says there is no initial and no final inventory of product (Bottles or Bottled water). Constraint (4) forces the setup variable in period t to be

1 when there is positive production $(i.e\ x_t > 0)$ in period t.

ii. Master Production Scheduling Model (MPS): The purpose is to plan the production of a set of items, usually finished products, over a short term horizon corresponding to the total production cycle of these items.

$$\min \sum_i \sum_t \{p_t^i x_t^i + f_t^i y_t^i + h_t^i s_t^i\} \quad (6)$$

$$s_{t-1}^i + x_t^i = d_t^i + s_t^i \ for\ all\ i,t \quad (7)$$

$$x_t^i \leq My_t^i \ for\ all\ i,t \quad (8)$$

$$\sum_i \alpha^{ik} x_t^i \leq L_t^k \ for\ all\ t,k \quad (9)$$

$$x_t^i, s_t^i \geq 0, y_t^i \in \{0,1\} \ for\ all\ i,t \quad (10)$$

Where indices $i = 1,..I$ represent the set of items whose production has to be planned, $k = 1,...K$ represent the set of shared resources with limited capacity, and $t = 1,....n$ to represent the time periods. The variables *x*, *y*, *s*, and the data *p*, *f*, *h*, *d*, have the same meaning for each item i as in equation (1) model above. A superscript i added to represent the item i for which they are specifically defined.

The data L_t^k represents the available capacity of resource *k* at the start of period *t*. The data α^{ik} represent the quantity of capacity of resource *k* consumed respectively per unit of item i produced. Constraint (6) - (8) and (10) are the same as for the (1), (3) and (5). Constraint (9) expresses the capacity restriction on each resource *k* in each period *t*.

iii. Material Requirements Planning Model (MRP): The purpose of this model is to optimize simultaneously the production and purchase of all items –from raw materials to finished products, in order to satisfy for each item the external or independent demand coming from customers and the internal or dependent demand coming from the production of other items, over a short term horizon.

$$\min \sum_i \sum_t \{p_t^i x_t^i + f_t^i y_t^i + h_t^i s_t^i\} \quad (11)$$

$$s_{t-1}^i + x_{t-\gamma^i}^i = [d_t^i + \sum_{j \in s(i)} r^{ij} x_t^j] + s_t^i \ for\ all \quad (12)$$

$$x_t^i \leq My_t^i \ for\ all\ i,t \quad (13)$$

$$\sum_i \alpha^{ik} x_t^i \leq L_t^k \ for\ all\ t,k \quad (14)$$

$$x_t^i, s_t^i \geq 0, y_t^i \in \{0,1\} \ for\ all\ i,t \quad (15)$$

The indices, variables and data are the same as before, except that, for simplicity, index $j = 1,...I$ identifies items. For item i, additional notation $S(i)$ represent the set of materials that are introduced during the production process, i.e. the items that are utilized when product are produced.

Always $S(i) = \in$ and for $j \in S(i)$, r^{ij} denotes quantity of item i required to make one unit of item j. These r^{ij}, parameter *r* identifies the dependent demand, whereas d_t^i corresponds to the independent demand. For each item i, γ^i denotes the lead time to deliver any lot of i. More precisely, x_t^i represents the size of a production or purchase order for item i required in period *t*, and delivered in period $t + \gamma^i$.

The difference with respect to the previous MPS model is in equation (7) in the form of the flow conservation Constraint (12) For each item i in each period *t*, the amount delivered from production $x_{t-\gamma^i}^i$ ordered in period $t - \gamma^i$, and the demand to be satisfied is the sum of the independent demand d_t^i and the dependent demand $\sum_{j \in s(i)} r^{ij} x_t^j$ implied by the production of immediate successors $j \in s(i)$.

3. Result and Discussion

The combination of Visual Basic.6.0 2006 environment and Microsoft Office Access 2007 were used to develop the production planning and control software for a small scale bottled water industry. Visual Basic.6.0 2006 is the main programming software while Microsoft Office Access 2007 is used to hold and save databases associated with the program.

3.1. Developed system structure

The installation of the developed software on the computer displays a shortcut icon on the desktop. Double clicking the icon opens the user log-in page fig. 1, where username and password are required for further access into the main software interface fig. 2.

Fig. 1 Log-in page

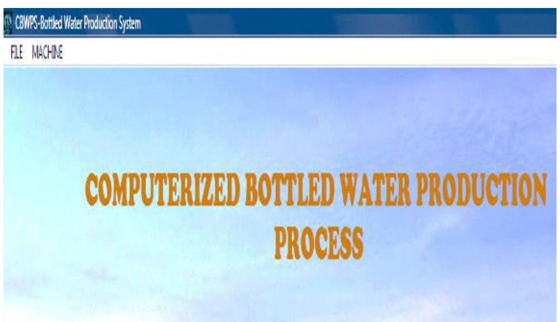


Fig. 2 Main software interface

Fig.2 shows the File and Machine menu. The File menu consists of the customer order processing, daily production, inventory, purchasing and material requirement sub-menus fig. 3. The Machine menu consists of the machine capacity sub-menu fig. 4.

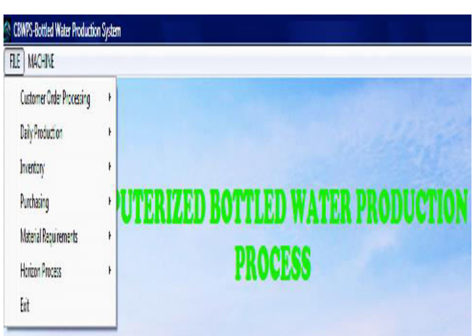


Fig. 3 File menu; sub-menus

Fig. 4 Machine menu; sub-menu

First time use, the system requires the user to enter the vital data necessary for the software to perform optimally in the machine capacity sub-menu fig. 6. This sub-menu is restricted with another password due to its importance to the effectiveness of the software fig. 5.

Fig. 5 Machine capacity log-in

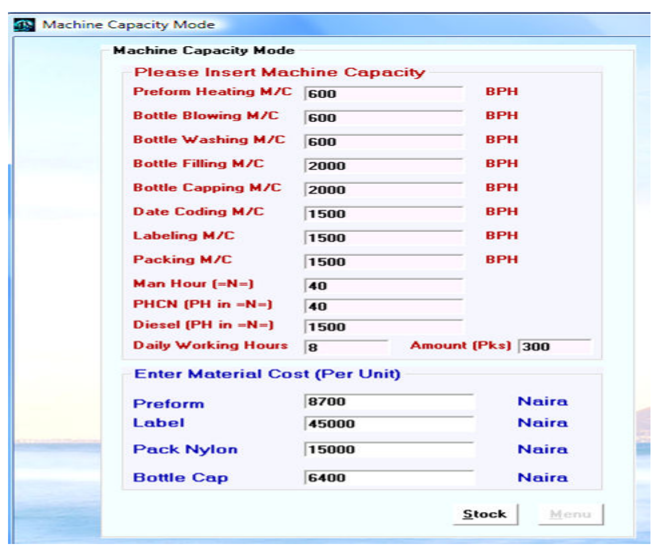


Fig. 6 Machine capacity modes

After the necessary data have been provided in the machine capacity mode, the user is required to stock the inputs and the software returns the user to the main software interface.

PPC begins with the need to satisfy all customer order within a specified horizon with a proposed plan. In the system developed, customer order in terms of product quantity, requested delivery date and other necessary data are inputted in the customer order processing sub-menu fig.7. The users can equally view the customer order report to know the demand is spread within the horizon fig. 8.

Fig. 7 Customer order processing

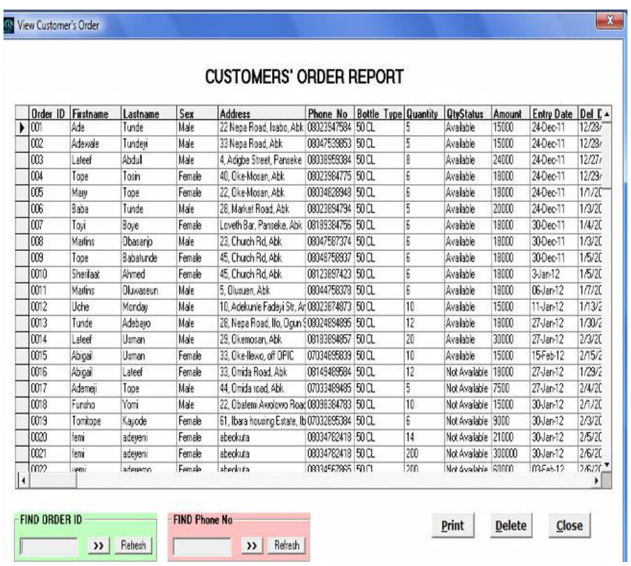


Fig. 8 View customer order report

The production planning for the production of bottle and bottled water to meet the demand of the customers within a selected horizon is done by the system in the Horizon processing sub-menu mode fig. 9. The production plans in this sub-menu can the done within a horizon of 1, 2, 3 and 4 week; as the user selects in this sub-menu.

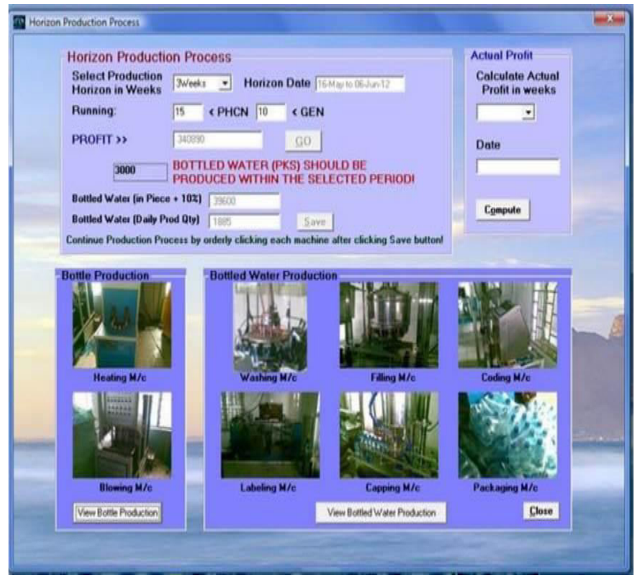


Fig. 9 Horizon process sub-menu

The system plans the production for each machine within the user's selected horizon. The report of this plan is sent to each machine mode linked to the sub-menu. The user can view the production plan for each machine by clicking on the corresponding machine icon on this sub-menu.

Secondly, the user can link the bottle production phase fig. 10 or the bottled water production phase fig. 11. The user in these phases can view the plan of each phase and the corresponding plan (daily quantity to be produced, daily run time, over time etc.) for each machine within the phase.

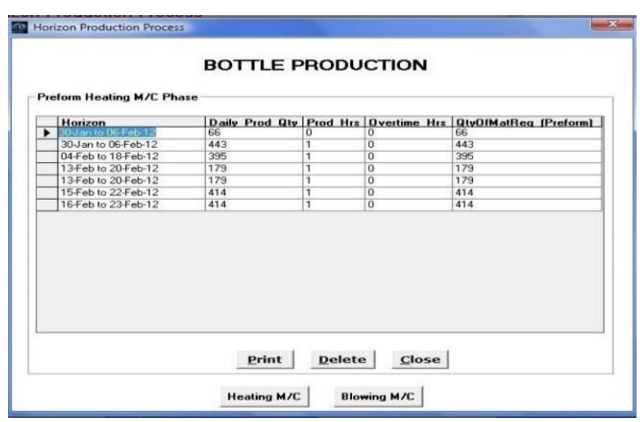


Fig. 10 Bottle production plan phase

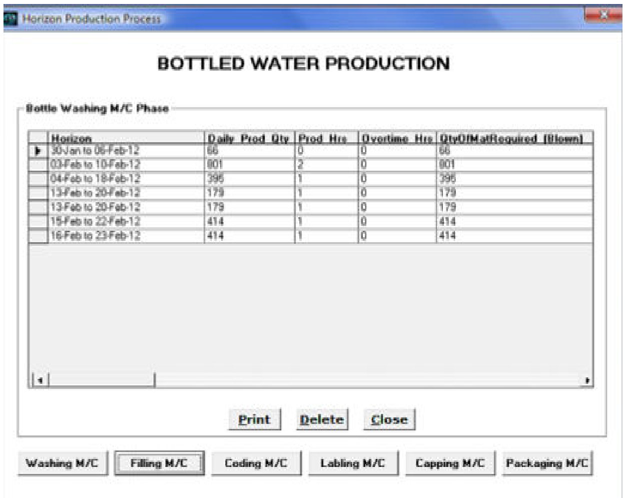


Fig. 11 Bottled water production phase

The system checks the inventory sub-menu fig. 12 of any shortfall in the available raw material (preform, label, bottle cap and transparent plastic films) to that which is necessary to meet the production plan of the selected horizon. This shortfall is reported in the material requirement sub-menu fig. 13 where the user can view them and make necessary order before the start of production.

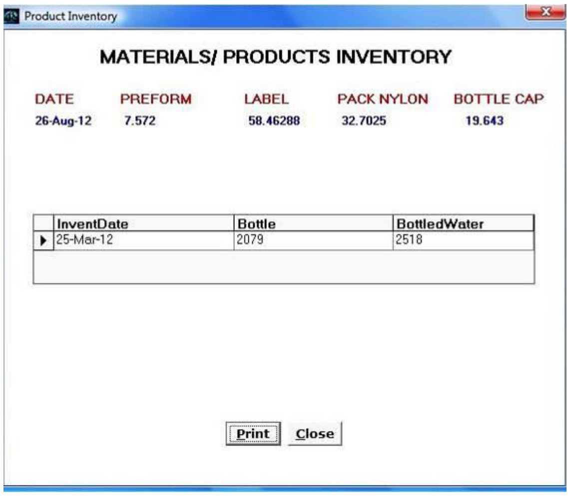


Fig. 12 Inventory sub-menu

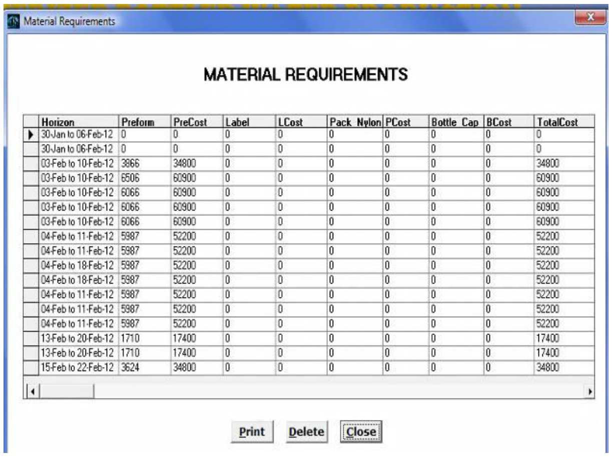


Fig. 13 Material requirement sub-menus

Control in production planning is the analysis of variance in the propose production plan to the actual produced within the horizon. The developed system achieves this for both the bottle and the bottled water production phases.

The user of the system makes daily production entry in the daily production sub-menu fig. 14 for both production phases. The system then reports the entry in the daily production report mode fig. 15. In this mode the user can view the daily produced bottle and bottled water and there variance against the proposed plan within the horizon.

Negative variance indicates a shortfall while a zero variance indicates plan conformance and a positive variance indicates the excess produced quantity.

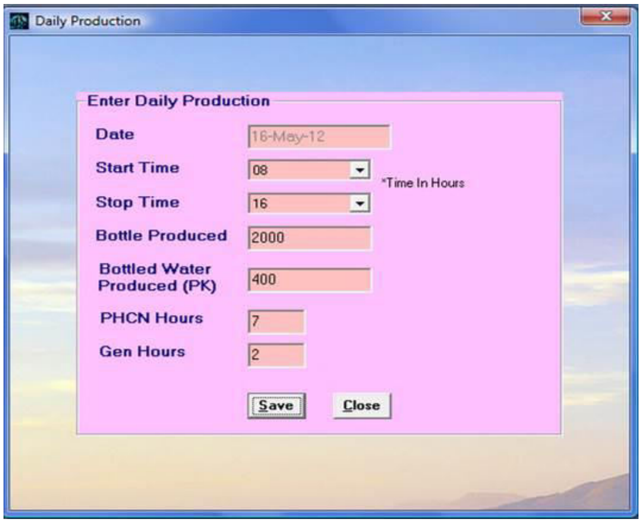
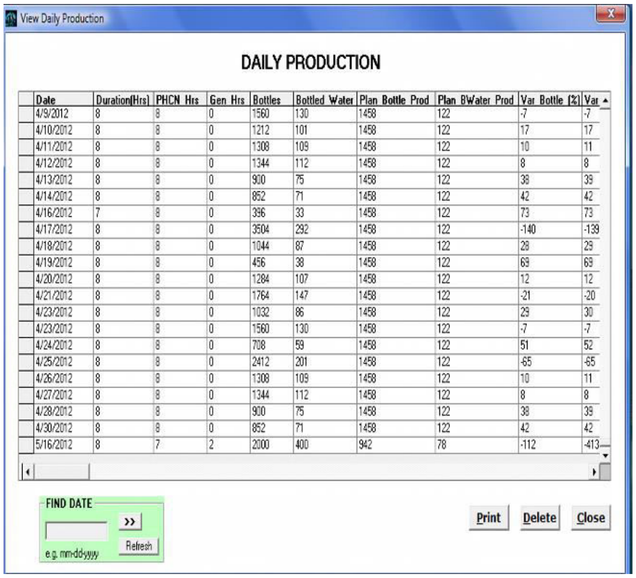


Fig. 14 Daily production sub-menu



Date	Duration(Hrs)	PHCN Hrs	Gen Hrs	Bottles	Bottled Water	Plan Bottle Prod	Plan BWater Prod	Var Bottle (%)	Var
4/9/2012	8	8	0	1560	130	1458	122	-7	-7
4/10/2012	8	8	0	1212	101	1458	122	17	17
4/11/2012	8	8	0	1308	109	1458	122	10	11
4/12/2012	8	8	0	1344	112	1458	122	8	8
4/13/2012	8	8	0	900	75	1458	122	38	39
4/14/2012	8	8	0	852	71	1458	122	42	42
4/16/2012	7	8	0	396	33	1458	122	73	73
4/17/2012	8	8	0	3504	292	1458	122	-140	-139
4/18/2012	8	8	0	1044	87	1458	122	28	29
4/19/2012	8	8	0	456	38	1458	122	69	69
4/20/2012	8	8	0	1284	107	1458	122	12	12
4/21/2012	8	8	0	1764	147	1458	122	-21	-20
4/23/2012	8	8	0	1032	86	1458	122	29	30
4/23/2012	8	8	0	1560	130	1458	122	-7	-7
4/24/2012	8	8	0	708	59	1458	122	51	52
4/25/2012	8	8	0	2412	201	1458	122	-65	-65
4/26/2012	8	8	0	1308	109	1458	122	10	11
4/27/2012	8	8	0	1344	112	1458	122	8	8
4/28/2012	8	8	0	900	75	1458	122	38	39
4/30/2012	8	8	0	852	71	1458	122	42	42
5/16/2012	8	7	2	2000	400	942	78	-112	-413

Fig. 15 Daily production report mode

Finally, since a plan is potentially active and always in dynamic status the developed system automatically update the proposed plan for the time left within the horizon with an upward review in the case of shortfall or downward review in the case of positive variance.

4. CONCLUSION

The development of PPC software using Visual Basic.6.0 2006 environment and Microsoft Office Access 2007 for a small scale bottled water industry in Nigeria has been presented with necessary details. Simulation of the system has also been use to showcase the inherent vantage of appropriate software development in handling predominant manual engineering task such PPC in such industry.

One of the basic requirements in any production industry is appropriate PPC decision. This is important for it potential capacity of improving productivity and customer satisfaction in terms of prompt delivery; the developed system has shown how the computer with appropriate software and mathematical model can be used to achieve this requirement.

However, customer feedback in terms of delivered product is not captured in this work and is recommended for future work.

Therefore, software development for handling various engineering tasks (process planning, quality assurance for example) for different small scale industry in Nigeria is highly recommended. This will not only improve productivity, but also create employment and increase the GDP (Gross Domestic Product) of such industry in the country.

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