NETWORK-BASED MATERIAL REQUIREMENTS PLANNING (NBMRP) IN PRODUCT DEVELOPMENT PROJECT

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Abstract

Projects are characterized by inefficient time utilization, downtimes and operational delays during the execution stage due to poor material supply programmes. To address the problems, this study evaluated the existing material planning practice, and formulated a NBMRP model out of the variables of the existing MRP and CPM models. Both primary and secondary data were used to test and apply the model to a product development project. The method of CPM was used for data analysis, and a heuristic method based on the logical sequence of critical activities was used for performance evaluation. The result of the analysis indicated that the model performed very well by coordinating the flow and usage rates of materials. Downtimes and operational delays were eliminated giving rise to 100% efficiency when all the research assumptions are taken into consideration. The study recommends in-depth feasibility analysis of materials with respect to availability, sustainability and uninterrupted scheduled flow throughout the project life cycle.

Key Words: Material Requirements Planning, Lead time, Network Analysis, Critical Path, Heuristics.

Introduction

Since after independence in 1960, the economic development effort of the Federal Government of Nigeria (FGN) was directed towards industrialization through manufacturing and product development among others. However, these noble objectives have not been realized when one considers the poor performance in this sector of the economy which is characterized by inefficiency, defective planning and obnoxious fiscal policies of the FGN in this regard. Efficient manufacturing industries are of paramount importance to the economy of any nation, a fact which has been recognized by the UK government, resulting in the development of strategies for the generation of manufacture (Wild 1980). A country with efficient manufacturing industries enjoys a high standard of living with a strong economic base. Because they provide for new or improved products at low production cost, products and services are affordable with increased employment generation. It could be on this premise that Wild (1980) critically observes that the production industries in Great Britain employ 41 percent of the active workforce, of which 80 percent are employed in the manufacturing industries. Instead of relying solely on cost effectiveness and quality management, the development of strategies for efficient time utilization in the manufacturing and product development projects would ensure project success.

The problems and motivation for this study are therefore due to the following:

❖ Inefficient time utilization as a result of downtimes and operational delays in the manufacturing and product development projects in Nigeria.

❖ Lack of coordination and harmonization of rate of materials supply schedules with the usage rate of individual activities in the project schedules; resulting to the following:

i. Late arrival of materials resulting to workers idle time.
ii. Earlier arrival of materials resulting to materials waiting time.
iii. Materials shortages, resulting to low capacity utilization and project failure.
iv. Materials surpluses resulting to high inventory holding cost and congestion at work places.

Also, operational delay could be attributed to inefficient project scheduling, inefficient process planning and design as well as inefficient materials delivery programme to the project site; all due to inefficient material planning practice with respect to materials delivery and project implementation.

For instance, the time utilization analysis of Delta Steel Company Ltd, Aladja Nigeria, 1991 annual production plan shows that: out of the 6288 hours available for production between January and September 1990, only 2436 hours (38.74%) were utilized for production, 3852 hours (61.26%) were the production delays. The delays were caused by: lack of materials (1012 hours), operational delays (1001 hours), equipment breakdown and maintenance (984 hours), lack of auxiliary services (726 hours), power outages (49 hours), other causes (80 hours). Lack of materials includes the following: stock out of direct reduced iron, lack of refractory materials, lack of ferromanganese, stock out of cold tundish board.

Also, the lime plant unit recorded 858 hours of downtimes due to lack of storage space; while operational delays include among others excessive prolonged preparation time. The report continues that the performance of the plan would have improved if production materials and spare parts were made available on time. In view of these problems, this paper is geared towards improving material planning and supply schedules through NBMRP time analysis.

The objective of the study is therefore to design a NBMRP model, which would enhance efficient time utilization in the manufacturing and product development projects by ensuring the following specific objectives.

❖ Schedules the arrival of the required quantity of materials to satisfy the materials needs of individual activities in the project schedule, so as to avoid downtimes and operational delays.

❖ Coordination and harmonization of the rate of materials supply schedules with the usage rate of individual activities in the project schedule, thus minimizing or eliminating the incidence of either materials surpluses or shortages.

❖ Schedules the supply of material requirements of individual activities to arrive at the earliest starting times of each activity so as to minimize delays.

Ubani (2007) has proved theoretically the reasonableness of integration of MRP and Network models in Project Management. This paper therefore is of the view that integration of Material Requirements Planning (MRP) and Network models (Critical Path Method CPM) to formulate an NBMRP model would address the problems of inefficient time utilization in manufacturing and product development projects. Downtimes and operational delays are the major problems in this regard.

Sagerstadt (2002) sees MRP is a basic tool for carrying out the material planning function in the manufacture of component parts and their assemblies into finished products. H_o and Chang (2003) observe that the MRP logic involves taking end item requirements from master production schedule (MPS) and translates them into time - phased requirements for assemblies, parts and raw materials using Bill of Materials (BOM) offset by lead time. The basic output will provide detailed schedules indicating for each parts, when and how much to order. In a similar manner, Waters (1989) describes CPM as a useful way of scheduling and it is time deterministic, while Akpan and Chizea (2002) see scheduling as time-phased planning. Scheduling is carried out in advance of the project commencement time and involves: identifying the tasks that need to be carried out, estimating how long they will take, allocating resources and scheduling when the tasks will occur.

The study is organized as follows: abstract, introduction, conceptual and theoretical framework, literature review, methodology, model formulation, model testing and application, data presentation and analysis, discussion of result, conclusion, recommendation and references.

Theoretical Framework and Literature Review.

Conceptual and Theoretical Frameworks

The MRP is a system that is driven by MPS. As the MPS is updated, the MRP results are also modified. A system such as MRP is characterized by inputs, process and outputs. The inputs are the BOM file, MPS and inventory records/status file. For MRP processing, Dervitsiotis (1981) asserts that, given a feasible MPS for a specific end item, the next step is to translate period-by-period demand into subassemblies, parts and materials needed to make it, using BOM file. Once the total requirements for components and parts are calculated from the MPS and BOM file, the MRP proceeds to determine the net requirements in conjunction with the inventory record file for each period. The MRP could be used to determine the amount needed for each part, exploding the net requirements level by level for all materials by time period into the future by consulting the BOM file.

According to Telsang (2002), the net requirements are calculated by adjusting for existing inventory items already - on order as recorded in inventory file.

$$\text{Net Requirements} = \begin{matrix}\text{Projected gross}\\ \text{Requirement}\end{matrix} - \begin{pmatrix}\text{Inventory on} + \text{Schedule}\\ \text{hand} \qquad\qquad \text{receipts}\end{pmatrix} \ldots\ldots .1$$

The MRP outputs include: actual and planned order releases that go to purchasing and in-house production shop (Telsang 2004), changes in planned orders information on; exception reports, planning reports etc.

Similarly, CPM scheduling technique provides the ability to chart multiple paths that depend on the completion of other tasks while providing the flexibility necessary to successfully manage the project. The time estimate in CPM is deterministic and it could be used where activity durations are known or estimated with certainty. Program Evaluation and Review Technique (PERT) is a network scheduling method similar to CPM; the different being that time estimates in PERT is stochastic or probabilistic.

CPM computation involves furnishing management with some critical indices for proper planning and control of different activities in the form of earliest starting time (E_s), earliest finishing time (E_f), latest starting time (L_s) and latest finishing time (L_f). The E_s of an activity is the sum of the times of all preceding activities on the paths. Where two or more path converges at a node, the longest path governs.

Mathematically, let i = starting node, and j = ending node, t_{ij} = the time duration of any activity following forward pass computation.

$$E_{s(ij)} = E_i \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad .2$$

$$E_{f(ij)} = E_i + t_{ij} \quad \text{i.e.} \quad E_f + t_{ij} \quad - \quad - \quad - \quad - \quad - \quad 3$$

i_1, i_2 are the proceeding events of activities which terminate at node j. The computation for the $Ls_{(ij)}$ and $L_{f(ij)}$ is similar but are from the sink node to the source node (backward pass).

Literature Review.

Making a forecast for manufacturing materials might seem straightforward at the first glance, but this is an inherent problem facing the managers. This is a problem because it takes time to manufacture items. The manufacturers have traditionally circumvented this problem by buying materials in advance, stocking them in the warehouses and building items based on what they think that the customers will buy (forecast). According to BBc, Co UK (2005), suppliers may attempt to solve this problem by buying enough raw material items ahead of time to prevent them from running out. To determine how much raw material that is needed could be a problem because, one could be buying far more materials than required. Consequently, too much of holding cost, tying down of capital, building extra warehouse space and hiring people to look after them. Sometimes, the materials could be scrapped as a result of deterioration and damages. BBC. CO. UK (2005) describes it as a costly way of doing business, but suggested that, it would be much better for suppliers if they only had to buy just enough stock.

MRP reads information on the products, the raw materials and items that comprise it, the customers demand, and the stock of all the items to determine the actual quality needed and when it is required. To develop a basic MRP plan, BBC. CO. UK (2005) lists the following requirements;

i. A forecast of what products needs to be made in the next months (also known as production schedule)
ii. A recipe, which indicates which materials, are to be used, in what quantity to build each (also known as bill of materials)
iii. The time required to obtain or manufacture all products and materials (the lead time)
iv. The maximum amount that can be processed at any one time (batch size)
v. The on-hand stock balance of all products and materials (also known as the inventory balance)

The effect of the MRP is therefore the need to buy raw materials and build products at the possible time. MRP helps to keep stocks low and to recognize quickly that there are problems at the earliest possible times. According to BBC. CO. UK (2005), companies benefiting from MRP typically need low and fewer warehousing facilities to conduct their business. They make better use of their facilities, maintain (or improve) their level of quality and can be more profitable due to lower cost of operations. Based on these principles, the application of MRP at SC Corporation (the world largest producers of evaporation coolers) recorded a tremendous success. Gaither (1990) explains that a team of operation managers initiated MRP at SC Corporation to reduce inventory level. It was also hoped that freeing up factory space through reduction of inventories; another assembly line could be installed without increasing the size of the physical plant. He noted that after two years of installation, the results of the MRP project were spectacular. The total sales increased from $20 million to $40 million, total material value in inventory was reduced from $20 millions to $9.8 million, profit increased fivefold and the factory now has enough capacity to support sales of above $50 million. All these were accomplished with less investment. The machinery needed for the new assembly line required less investment than the reduction in inventory levels attributed to MRP. This type of breakthrough in operations management may have informed the statement by Guide and Srivastava (2002) to the effect, that, "in fact, MRP is still regarded as one of the most commonly used production planning and control system in industries.

In a similar vein, CPM and PERT recorded tremendous successes in their applications in U.K as far back as 1957. According to Akpan and Chizea (2002), in 1958, the E.I. Du Pont de Nemours used CPM to schedule and control very large maintenance and overhaul projects. It was credited with saving one million U.S. dollars in the first year of use, and the planned downtime was reduced by 40 percent within the same period. However, the authors did not review the contributions (if any) of efficient flow of materials resources towards the projects success. Project planning and control dominate all other applications of CPM/PERT, while production planning and control, maintenance planning and control round out 86 percent of the uses of CPM/PERT as shown in table 1 below.

Table 2.1 Application of CPM/PERT

	CPM/PERT Use	**Frequency of CPM/PERT use (%)**
1.	Project planning and control	46
2.	Production planning and control	22
3.	Maintenance planning and control	18
4.	All others	14

Source: Production and Operations Management (Gaither 1990).

Methodology

The methods of research design used are the survey and ex-post facto, with judgmental and area sampling techniques. The firms in the South East geopolitical zone judged to have executed product development projects in recent time was used. Both primary and secondary sources of data were used. The primary data on the order lead times of materials were obtained through personal interview, while the secondary data from production planning and documentation department provided information on the BOM, inventory status, routing list operations etc. The method of CPM was used for project activities scheduling and network analysis to determine Es and other indices of the critical path. A logical table of heuristic based on logical sequence and precedence relationship of the critical path activities are used for the performance evaluation of the model.

Model Formulation, Data Presentation and Analysis

Model Formulation.

Generally, there is no defined existing material planning methods as many organizations rely on rule-of thumb. However, DSC Ltd Aladja uses the method of time utilization analysis to determine the level of downtimes and operational delays resulting from material problems etc. The existing practices are inefficient, characterized by downtimes and operational delay, lack coordination and fail to take cognizance of scheduled supply and usage rates of materials. Therefore, this study is geared towards developing a new NBMRP model to fill these gaps and address the problems of downtimes inefficient rates of scheduled materials supply and utilization during the project execution.

The inputs considered for the NBMRP model are from the existing MRP and network scheduling models, such as Bill of Materials (BOM) and Critical Path Method (CPM) respectively. Similarly, the variables from MRP and CPM formed the inputs variables. The variables from MRP model are the; order lead time L_{mi}, order release time P_{mi} and order receipt time R_{mi} The variables from the CPM network model are the; activity duration, t_i, earliest starting time E_{si} and critical activities.

The following assumptions are made for the NBMRP model:

- Ample capacity and finance exist for the project, though limited.
- Economic order quantity is not considered; rather the model uses aggregate material requirements per activity or activities emerging from a node.
- In-house manufactured components or completed steps of work-in-process are considered as material requirements for the next activity.
- There is no replenishment cycle along the planning horizon because of non-repetitive nature of projects. Activities emerging from a node are treated independently with respect to their materials requirement and next activity.
- For an activity or activities converging to a node, the activity with the longest duration and its material requirements with the longest lead time is used in the analysis, since this governs or determines other activities and their order receipt times of materials.
- The commencement time of an activity E_{si} is the completion time of the preceding activity.

The study evaluated the existing materials planning practice and a new symbolic NBMRP model was developed and formulated out of the variables in the existing MRP and CPM models. The variables were integrated, related mathematically and formulated into the new NBMRP model with a view of reaping the benefit of higher efficiency accruable from them. The model formulation is as follows;

The time for order release P_{mi} which is the time to place order for outside materials or to release job order for in-house components is a function of time for order receipt of materials R_{mi} for an activity and the lead time L_{mi} of the respective materials needed for that activity.

Therefore $$P_{mi} = f\,(R_{mi}, L_{mi}) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad 1$$

$$P_{mi} = R_{mi} - L_{mi} \quad \ldots\ldots 2$$
$$R_{mi} = P_{mi} + L_{mi} \quad \ldots\ldots 3$$

But in NBMRP system, materials are programmed to arrive or be received on the earliest starting time E_{si} of that activity. Therefore, for an activity,

$$R_{mi} = E_{si} \quad \ldots\ldots 4$$
$$R_{mi} = P_{mi} + L_{mi} \quad \ldots\ldots 5$$
$$P_{mi} = E_{si} - L_{mi} \quad \ldots\ldots 6$$

Equations 4.4, 4.5, and 4.6 are hereby referred to as NBMRP general equations. They are use for computing the times for order releases and receipts of material used for scheduling and activity execution in the product development projects. The following downtimes are bound to exist during the execution stage of any manufacturing and project life cycle.

i. Downtime due to workers idle time. This occurs when the scheduled material delivery arrives later than the commencement times of the activity.
ii. Downtime due to materials waiting time. This occurs when the scheduled material delivery arrives earlier than the commencement time of the activity concerned and the preceding activity.

The application of NBMRP general equations 4.4, 4.5 and 4.6 and subsequent scheduling of material orders and activity execution eliminate downtimes arising from workers idle time and material waiting time.

Based on the actual times for P_{mi} and R_{mi}, the analysis of material delivery and activity execution programmes shows that some activities suffered from downtimes due to either workers idle time D_t or materials waiting time W_t. When $R_{mi} = E_s$; the NBMRP model adjusts P_{mi} and R_{mi} with D_t or W_t to new P_{mf} and R_{mf} respectively so that R_{mi} can be equal to E_s. The D_t and W_t were obtained from the initial analysis and they are used in developing an improved final plan for scheduled material supplies and activities execution.
Therefore, the minimum time to supply materials and complete an activity Tsc.

$$Tsc = \begin{cases} R_{mi} + t_i & \text{for } R_{mi} = E_{si} \\ R_{mi} + t_i - D_t & \text{for } R_{mi} > E_{si} \\ R_{mi} + l_i + W_t & \text{for } R_{mi} < E_{si} \end{cases} \quad \text{------} 7$$

Then R_{mf} can be adjusted to the new value with L_{mi} as follows:

$$R_{mf} = P_{mi} + L_{mi} - D_t \quad \text{------} 8$$
and $$P_{mf} = R_{mf} - L_{mi} \quad \text{------} 9$$
or $$R_{mf} = P_{mi} + L_{mi} + W_t \quad \text{------} 10$$

The strength of the NBMRP model lies on the fact that the P_{mi} can be adjusted to achieve an optimum $R_{mi} - E_{s;}$ without violation of logical and precedence relationship on the project activities schedules. Downtimes are therefore eliminated due to the analysis.

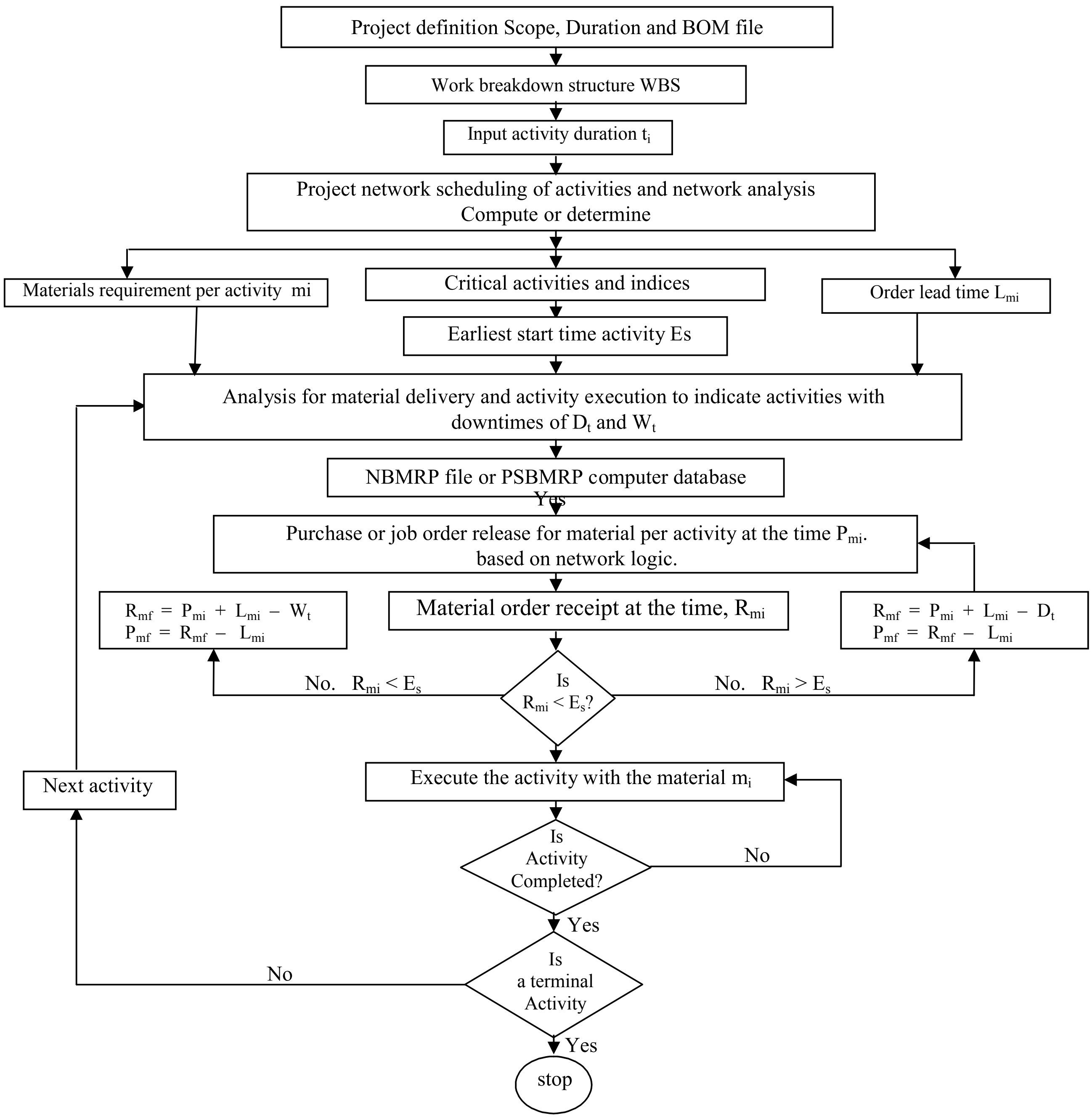

Figure 4.1 Flow algorithm/chart of NBMRP model.

Model Testing and Application

The model was tested on the critical activities as applied to the recently executed product development project at ANAMMCO Ltd Enugu Nigeria. One of the objectives of the Government of Nigeria in incorporating Mercedes Benz – ANAMMCO, among others is to produce Mercedes Benz vehicles at a lower cost in Nigeria. The project involved development of the existing MBO 1414 model to an improved model of MBO 1418 model for enhanced capacity and engine performance with 14 metric ton and 1800 horse power of engine capacity. ANAMMCO Ltd Enugu operates eight working hours a day. The description of routing list – operations showing the standard labours and standard machine hours formed the basis for the determination of activity duration for the manufacturing of approximately six units of MBO 1418 model. Also, BOM file provided information on material requirements, and their L_{mi}. The existing materials planning practice are characterized by high inventory holding cost, and material supply delays. The manufacturing plans do not take cognizance of materials usage rate, supply rate and schedules with respect to individual activities of the project schedules.

Data Presentation and Analysis

The existing method of time utilization analysis for DSC Ltd was revisited and adopted for preliminary time analysis; and is presented as follows: Out of the 6288 hours available for production between January and September 1990, only 2436 hours (38.74%) were utilized for production, 3852 (61.26%) were the production delay as follows:

Table 4.1 Time Utilization Analysis

Causal Factors	Downtimes (hours)	Percentage Downtimes
1. Lack of materials	1012	26.27
2. Operational delays	1001	25.98
3. Equipment breakdown and maintenance	884	25.55
4. Lack of auxiliary services	726	18.85
5. Power outages	49	1.27
6. Other causes	80	2.08
Total	**3852**	**100.00**

The method suffered a total downtime of 3852 hours (61.26%), where lack of materials accounted for 26.27% of the total downtimes. Also uncoordinated scheduled supply and usage rates of materials by individual activities resulted to inventory holding problems. However empirical data pertaining to parameters and variables in CPM and MRP models were not available at DSC Ltd for the application of NBMRP. It was for this reasons that ANAMMCO Enugu, having satisfied the data requirements was used for the analysis and application of NBMRP.

Table 4.2: Work breakdown structure, activity with material requirements and estimated activity duration, precedence relationship and order lead times for MBO 1418 prototype from ANAMMCO Ltd Enugu.

		Standard hours			Estimated activity Duration		Materials lead Time (days)	Preceding Activity
	Activity (and material requirement)	**Labour**	**Machine**	**Total**	**Hours**	**Days**		
G	Order material for activities H and I	-	-	-	-	30	-	-
H	Manufacture of body skeleton (Mild Steel Sheets)	289.75	72.14	316.89	2171.35	271	30	G
I	Manufacture of semi luxury seat (Seat upholstery materials)	26.30	6.45	32.75	196.50	25	30	G
J	Body paneling (body skeleton)	174.75	43.69	218.44	1310.64	164	271	H
K	Frame extension (Steel plates, CKD)	10.30	2.54	12.84	77.04	10	120	H
L	Trim the body (Electrical fitting, CKD)	135.12	33.78	168.90	1013.40	127	120	J
M	Assemble the frame (Wheel and rim, CKD)	11.50	1.76	13.26	79.56	10	120	K
N	Paint the chassis (Nova gray paint)	1.70	0.43	2.13	12.78	2	30	L
O	Paint the body (Paneled body)	181.33	45.41	266.74	1360.44	170	164	M, N
P	Assemble tyres and accessories (Michelin tyre, wheel and rim, CKD)	3.00	0.50	3.50	21.00	3	120	I, O
Q	Assemble chassis/frame (Fuel tank bracket, CKD)	21.45	5.35	26.80	160.80	20	120	P
R	Assemble chassis/engine (Assembled Chassis/frame).	22.70	5.77	28.47	170.82	21	20	Q
S	Final Assembly (Trimmed body)	21.00	5.25	26.25	157.50	20	30	R
T	Rectification and	21.93	5.49	27.42	164.52	21	20	S

	quality test (Final assembled MBO 1418).							

Source: Extract and analytical estimates from routing list – operations and BOM file of MBO 1418, ANAMMCO (2003)

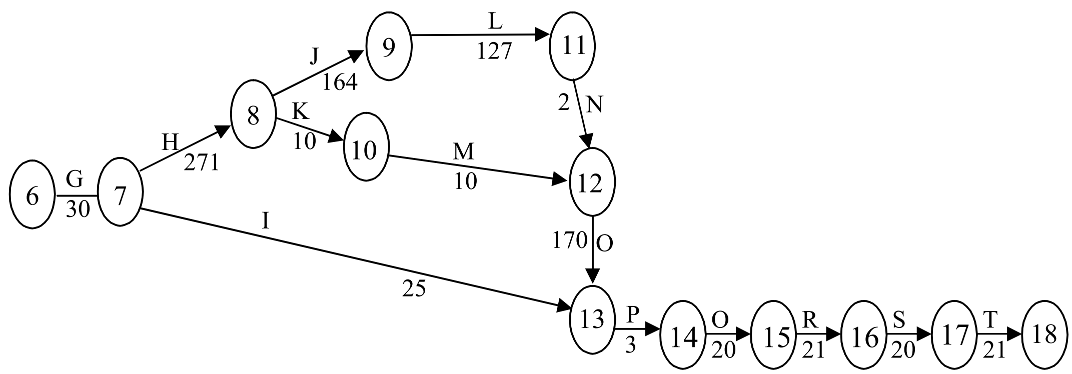

Figure 4.2: Network scheduling diagram of the execution/manufacturing stage of product development project activities for MBO 1418 model prototype.
The critical path is G,H,J,L,N,O,P,Q,S,T, with a duration of 849 days.

Table 4.3: **Critical path analysis showing critical path activities, duration, earliest starting times of activities, longest lead time of material requirement per activity, order release time and order receipt time.**

	Critical Activity	**Duration (Days)**	**Material lead time (days)**	**Earliest starting time (days)**	**Time for order Release (days)**	**Time for order Receipt days**
G	Order material for H and I	30	-	30	-	30
H	Manufacture of body skeleton	271	30	301	0	30
J	Body paneling	164	271	465	30	301
L	Trim the body	127	120	592	345	465
N	Paint the chassis	2	30	592	562	592
O	Paint the body	170	164	594	430	594
P	Assemble tyres and accessories	3	120	764	644	764
Q	Assemble chassis/frame	20	120	767	647	767

R	Assemble chassis/engine	21	20	787	767	787
S	Final Assemble	20	30	808	778	808
T	Rectification and quality test	21	20	828	808	828

The performance of the system was evaluated in two steps. The first step was based on the actual ordering times for material. In this case, the order release time of material of an activity is equal to the order receipt time of materials for the preceding activity. The second step was based on NBMRP equations that adjusted the orders release and receipts times for materials by satisfying the condition, $E_s = R_{mi}$. Activity G is removed from the performance evaluation since no activity was executed with respect to material supply.

Table 4.4: Critical path analysis and performance evaluation based on the actual times for order release and receipts as well as on the longest lead time of materials per activity (in days) for MBO 1418 prototype.

Critical path activities	Duration	Earliest starting time (days)	Lead time of material	Order release time	Order receipt time	Execution starting time	Execution completion time	Workers idle time	Material waiting time
H	271	30	30	0	30	30	301	-	-
J	164	301	271	30	301	301	465	-	-
L	127	465	120	301	421	465	592	-	44
N	2	592	30	421	451	592	594	-	141
O	170	594	164	451	735	615	764	21	-
P	3	764	120	615	764	764	767	-	29
Q	20	767	120	735	855	855	875	88	-
R	21	787	20	855	875	875	896	-	-
S	20	808	30	875	905	905	828	9	-
T	21	828	20	905	925	925	946	97	-

Table 4.4 shows performance evaluation with respect to materials order and project execution. The execution started on the 30th day. Total time for materials order deliveries = 925 days,

Materials waiting time = 214 days.

Workers idle time = 215 days.

Efficiency with respect to material deliveries 76.86%

Similarly, total time for activity execution = 946 – 30 = 916 days.

Efficiency of the overall system = 53.17%.

Table 4.5: Critical path analysis and performance evaluation of the system based on the NBMRP model (in all units in days) for MBO 1418.

Critical path activities	**Duration**	**Earliest starting time (days)**	**Lead time of material**	**Order release time**	**Order receipt time**	**Execution starting time**	**Execution completion time**	**Workers idle time**	**Material waiting time**
H	271	30	30	0	30	30	301	0	0
J	164	301	271	30	301	301	465	0	0
L	127	465	120	345	465	465	592	0	0
N	2	592	30	562	592	592	594	0	0
O	170	594	164	430	594	594	764	0	0
P	3	764	120	644	764	764	767	0	0
Q	20	767	120	647	767	767	787	0	0
R	21	787	20	767	787	787	808	0	0
S	20	808	30	778	808	808	828	0	0
T	21	828	20	808	828	828	849	0	0

Discussion of the Result

From the analysis in table 4.4, activities O, Q, S and T recorded downtimes of 21, 88, 9 and 97 days respectively due to workers idle time D_t. Similarly, activities L, N and P recorded downtimes of 44, 141 and 29 days respectively due to materials waiting time W_t.

For illustrative purposes, activities O and L were used for the application of NBMRP equations 4.4, 4.5 and 4.6 on the model for the adjustment of downtimes in order to satisfy the NBMRP conditions.

For activity O, $P_{mi} = 45$, $R_{mi} = 615$, $E_{si} = 594$, $L_{mi} = 164$, $D_t = 21$

But $R_{mi} \neq E_{si}$, $R_{mi} > E_{si}$, Recalling that $P_{mi} = R_{mi} - L_{mi}$, $R_{mi} = P_{mi} + L_{mi}$.

The adjusted final values of R_{mi} and P_{mi} to R_{mf} and P_{mf}, for the final plan are as follow:-

$R_{mf} = P_{mi} + L_{mi} - D_t = 451 + 164 - 21 = 594$. Hence; $R_{mi} = E_{si}$

$P_{mf} = R_{mi} - L_{mi} = 594 + 164 = 430$.

Similar treatments were applied to activities Q, S and T.

Also for activity L, $R_{mi} = 421$, $P_{mi} = 301$, $E_{si} = 465$, $L_{mi} = 120$, $W_t = 44$, $L_{mi} = 120$.

120 $W_t = 44$, But $R_{mi} \neq E_{si}$, $R_{mi} < E_{si}$, Recalling that $P_{mi} = R_{mi} - L_{mi}$, $R_{mi} = P_{mi} + L_{mi}$, and to satisfy the condition of $R_{mi} = E_{si}$. The R_{mi} and P_{mi} are adjusted to new final values of R_{mf} and P_{mf} as follow:- $R_{mf} = P_{mi} + L_{mi} + W_t = 301 + 120 + 44 = 465$ days, Therefore, $R_{mi} = E_{si}$, $P_{mf} = R_{mf} - L_{mi} = 465 - 120 = 345$ days. Similar treatments were applied to activities L, N and P. Unlike the existing materials planning method in which time utilization analysis indicated a downtime of 61.26%, NBMRP recorded a downtime of 0%. The NBMRP model is capable of adjusting both P_{mi} and R_{mi} to new values of R_{mf} and P_{mf} with either D_t or W_t to satisfy the condition of $R_{mi} = E_{si}$. This enhances the efficiency of the system to 100 percent when all the research assumptions are taken into consideration. Table 4.5 provided the final plan for the material supplies and projects execution indicating how downtime could be

completely eliminated. NBMRP model has therefore fill the existing gaps in respect of coordinated scheduled materials delivery and utilization rates as well as elimination of downtimes and inventory holding problems.

Conclusion and Recommendation

Conclusion:

In conclusion, the analysis has shown that NBMRP performed very well when applied to the execution stage of manufacturing and product development projects, and therefore capable of achieving the intended objectives. A trend towards relying increasingly on judgment and rule-of-thumb in dealing with materials planning and project scheduling would be a major set back to project success. However, strict time discipline, compliance with both activity and material delivery schedules are very importance to ensure project success. Existing method was characterized by excessive downtimes, while with the new NBMRP model, downtimes were eliminated with efficient coordination of supply and usage rates of materials resulting to zero level inventory and enhanced project performance.

Recommendations:

The study therefore recommends that feasibility assessment on the sustainable materials availability throughout the projects life cycle should be carried out before embarking on such projects. Many projects have started well and failed later due to: bottleneck and impediment to materials supplies, materials scarcity, shortages and inefficient inventory management. Also, manufacturing and product development projects organizations should as a matter of corporate policy, employ effective materials planning method such as NBMRP method. This will be an indispensable strategy for enhance performance instead of relying on rule-of-thumb.

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20th May, 2008
OUR REF: 70-003-012-28

TO WHOM IT MAY CONCERN

PAYE TAX DEDUCTION CONFIRMATION

This is to certify that the bearer, Ezurike Kenneth M.I. is a Staff of Imo Broadcasting Corporation, Owerri – Imo State and has paid his **PAY AS YOU EARN (PAYE)** Tax through the usual deductions at source by the Finance Department of the Corporation.

DETAILS OF INCOME AND TAX AS FOLLOWS

YEAR	**INCOME**	**TAX**
Year 2005	254,312.00	35,109.27
Year 206	346,854.00	46,416.00
Year 2007	411,988.00	47,940.00
TOTAL	**₦1013,154.00**	**₦129,465.27**

He is therefore, not indebted and should be exempted from further taxation for the 2005, 2006 and 2007 fiscal year to avoid double taxation.

R. A. NKWOPARA
DIRECTOR OF FINANCE.