Development of Network Model for Overhaul Maintenance of Meyer 78/18 Bottle Filling Machine

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ABSRACT
To achieve optimal maintenance and scheduling policy for a Bottle Filler, a network model that will describes the maintenance duration and labour cost of this equipment will be of essence. In this study, Network analysis technique was used to ascertain the optimal duration and labour cost of undertaking overhaul maintenance on Meyer 78/18 Filling Machine at 7up Bottling Company Plc, Aba Plant. Also, considered is the implementation of this technique on other critical jobs to forestall unnecessary delays that may be intentional as a result of sharp practices by the personnel or unintentional delays due to wrong scheduling technique. Both critical path method (CPM) and project evaluation and review technique (PERT) were used for the analysis. The project took an optimal duration of 139.45 hours which is approximately 7.43 days (at 24 hours per day for activities A and B; and 8 working hours per day for the remaining activities) to be completed. Also, the sum of sixty-four thousand, four hundred and seventeen Naira and fifty Kobo (₦64417.50) was required as the labour cost in this maintenance project with personnel made up of one (1) engineer, one (1) technician, two (2) craftmen and two (2) unskilled workers.

KEYWORDS: *Critical Path Method; Project Evaluation and Review Technique; Bottle Filling Machine; optimal duration; Breakdown maintenance.*

INTRODUCTION

Recently, we have seen increasing consumption rate of carbonated beverages like soft drinks and beer, marketed in attractive containers and packaging by bottling industries. The combination of product, container and packaging must play their part in safeguarding the beverage, offering appropriateness to the intended outlets and affording maximum convenience to the consumer (Partho and Parameshwaran, 2013). This have been made possible with the introduction of glass bottles, cans, plastic bottles, high speed packaging lines as improvements in the system. A typical bottle filling production line generally includes arranging the bottle, washing the bottles, filling, crowning, date coding, labelling, full bottle sighting, and packing.

Filling machine remains the core of the bottling line equipment. It increases production capacity and reduce labour. Returnable bottles are supplied to the filler through the bottle washer, where they are cleaned with hot detergent to remove all physical and biological contamination then rinsed with fresh water to remove any remaining detergent. Bottles enter the filler through a variable speed feed system consisting of an infeed worm and a star wheel. The infeed worm, made of a tough plastic material, is a large timing screw. The pitch (spacing) of the infeed worm separates the bottles and spaces them correctly for transfer to the infeed star wheel. The star wheel is a circular horizontally placed wheel with a series of pockets around the outside. These pockets correspond with the pitch (spacing) of the filler valves. In passing from the infeed worm the container is fed into a star wheel opening. The star wheel transfers each container onto a platform (lift cylinder) below each filler valve. Each star wheel is surrounded by a guide to keep the bottles in the star wheel pockets. The guide is made to the exact shape of the star wheel, and adjusted to allow only 2-3mm of movement for each bottle between the guide and the star wheel. Each lift cylinder is fitted beneath a filling valve. When the bottle has been placed on the lift cylinder, the cylinder is pushed up under the force of air pressure, which can be adjusted at the filler control panel.

The bottle is now held against the filling valve and filling takes place. Here, the container is first sealed and then pressurized. Simply put, a counter pressure filler pressurizes the container with CO_2 or any other pressurizing gas (counter pressure) to the same pressure as the tank in which the product resides, then fills it with product, then the counter pressure is relieved (allowed to escape back to the bowl / atmosphere in a controlled manner) and then finally the container is closed (capped or crowned). The process flow is briefly shown in figure 1.

Considering the market for the beverage industries, it is instructive that the bottle filling industries in particular, have need for operations improvement (Dewa M. et al, 2013). For a bottle filling machine, it is required that the containers must be filled as quickly as possible with the accurate quantity of product. Also the quality of the product must be maintained during the filling operation and after. It is important to note that when filling a bottle, it is necessary to avoid the introduction of certain elements such as dissolved oxygen in the process, which could invariably affect the accurate fill level of the product and other deficiencies. These abnormalities which are mostly caused by component(s) malfunction at various parts of the filling equipment results in overfills, no crowns, distorted crowns, under fills, flavour change, bottle defects, shut down and incorrect jetting. At a point when these abnormalities becomes more frequent, system overhaul becomes imminent.

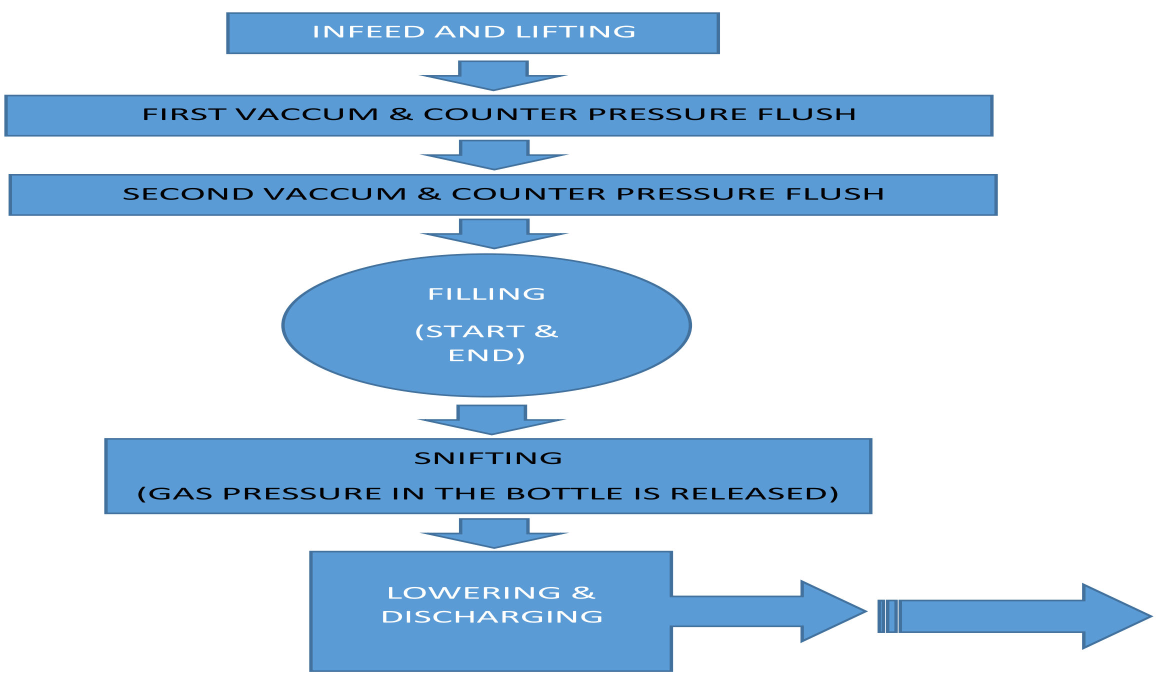

Figure 1: Description of Filling Cycle

To achieve optimal maintenance and scheduling policy, a network model that will describes the maintenance duration and labour cost of this equipment will be necessary. This model will have the ability of evaluating the optimum maintenance duration and the optimum cost of labour required as a function of maintenance and replacement. A common objective of many of these analyses is to find the maintenance and replacement policy where the total costs of repairs, inspections, production losses and other consequences are minimal.

To achieve optimality in this system overhaul, a balance needs to be struck amongst these factors that may militate against smooth operation of the maintenance process. These include: delay in commencement of rehabilitation; abandonment due to insufficient fund budgeted for their execution caused by inadequate fair data on the possible duration during initial planning; unnecessary delay during execution of the rehabilitation project due to corrupt intents by the maintenance and management officials to pave way for cost review on the account of upward deviation of materials and other engineering services costs over the project period and again, unnecessary rushing during the execution of the project especially when commissioning date approaches as a result of some anomalies in job execution, (because the project was not allowed to take normal/optimal durations). It is a fact that most of components and equipment as the case may be, required for this maintenance exercise are imported and the use of expatriates for most of these turn around job. Also, the instability of our currency remains a factor contributing to this costing problem. The establishment of an empirical model on the optimal duration and labour cost required for breakdown maintenance of liquid beverage filling machine will help in checking the excesses in the bottling industries. The application of this optimal filler breakdown maintenance duration and labour cost model will be useful in minimizing resource use in the industry.

The evaluation and control of most industrial and scientific project, often require the use of techniques such as simple bar chart, milestone chart, Gant chart, Assembly Line Balancing and Network Analysis (Benjamin, 2008 and Wayne and Munirpallam, 2003). However, most modern project scheduling, planning, monitoring, co-ordination and control problems are best suited using network modeling (network analysis). This is because it is an outstanding tool for predicting all activities required for successful projects completion with minimum resources and time (John, 2009 and Cheema, 2006). Fortunately, two closely related techniques in Network Analysis, PERT (program evaluation and review technique) and CPM (critical path method), are available to assist in carrying out these responsibilities of management of a project that requires coordinating numerous activities. Here, a myriad of details must be considered in planning how to coordinate all these activities, in developing a realistic schedule, and then in monitoring the progress of the project. These techniques make most use of networks to help plan and display the coordination of all the activities.

Both approaches help managers to address questions such as: What is the total time required to complete the project? What are the start and the completion times for individual activities? Which critical activities must be completed as scheduled to meet the estimated project completion time? How much delay can be tolerated for non-critical activities without incurring a delay in the estimated project completion time? What is the least expensive way to speed up a project to meet a targeted completion time? Other answerable questions include: What is the probability of completing a project within a given time frame? What is the variability in the project completion time?

PERT is generally used for those projects where time required to complete various activities are not previously known. It is probabilistic model and is primarily concerned for evaluation of time.

It is event oriented while CPM provides a most efficient approach for project scheduling when the duration of activities are known with certainty (Rogelio, 2010 and Nwankwojike, 2012). The approach consists of finding the earliest and the latest schedules to avoid delays in project completion. It is a deterministic model and places emphasis on time and cost for activities of a project. The CPM approach assumes that the duration of activities are known with certainty and the actual duration will turn out to be exactly as estimated. However, in practice this is not always possible and many projects involve variability in activity times due to factors such as lack of prior experience, equipment breakdown, unpredictable weather conditions, late delivery of supplies, and others. PERT analysis is used when the duration of activities are not known with certainty. Both techniques are usually applied together to improve time and cost efficiency in project execution (Cheema, 2006). PERT and CPM have been applied for variety of projects, which include: construction of new plants, research and development of a new product, NASA space exploration projects, movie productions, building a ship, government-sponsored projects for developing a new weapons system, relocation of a major facility, maintenance of a nuclear reactor, installation of a management information system, conducting an advertising campaign (Wayne and Munirpallam, 2003 and Imaga, 2003).

To apply CPM and PERT, we need a list of activities that make up the project, their precedence relationships and the time estimates for each activity. The project is considered to be completed when all activities have been completed. For each activity there is a set of activities (called the predecessors of the activity) that must be completed before the activity begins. A project network is used to represent the precedence relationships between activities. The two common approaches of a project network representation are activity on node (AON) or activity on arc (AOA). In the first approach, the nodes of the network represent the project activities and the arcs show their precedence relationships. In the second approach, the project activities are reported on arcs and nodes represent the starting or the completion of activities. The immediate predecessors of an activity refer to those activities that must be completed prior to the starting time of a given activity. Similarly, immediate successors of an activity refer to those that follow the completion of a given activity.

Considering AON, it is common in this approach to add one dummy source activity node (referred to as Start) and connect it to all activities nodes with no immediate predecessors as well as one dummy destination activity node (referred to as Finish) and connect it to the project network with arcs from activities with no immediate successors. This ensures that there is one starting point and one finish point in the project network. For a project network, one convenient way to determine its duration and critical activities is through the identification of all the different paths in the network. A path is a sequence of connected nodes in the network from the start node to the finish node. The length of the path is given by the sum of the durations of the activities on the path. In any project network, the path with the longest duration is called a critical path and the corresponding activities are called critical activities in that they must be completed as scheduled so as to meet the scheduled project completion time. The estimated duration of the project is therefore given by the length of the critical path. It is possible to find more than one critical path in a network project, but all critical paths will have the same length (Hillier and Lieberman, 2001).

For all activities in the network the following information are computed (Nwankwojike, 2012 and Wallace, 2015): The earliest start time (EST) which is the earliest time at which an activity can start if no delays occur in the project; the earliest finish time (EFT), which is the earliest time at which an activity can finish if no delays occur in the project; the latest start time (LST), which is the latest time at which an activity can start without delaying the completion of the project; the latest finish time (LFT), which is the latest time at which an activity can finish without delaying the completion of the project. A forward pass (from the starting node to the finish node) is used to compute the EST and EFT, whereas a backward pass (from the finish node to the starting node) is used for the LST and LFT.

To determine the critical path and the project schedule, the approach consists of calculating, respectively, the starting time and the completion time for each activity as well as identifying the corresponding slack. The slack time for an activity refers to the length of time that can be tolerated without incurring a delay in the scheduled project completion time. The slack time per activity needs to be calculated first to identify the critical path(s), by considering either the start times or the finish times.

In PERT analysis where the duration of activities are not known with certainty. It involves three types of estimates of the duration of an activity instead of one single value as in the case of CPM (Hillier and Lieberman, 2001):

1. The optimistic duration *a* = estimate of the duration under the most favorable conditions,

2. The pessimistic duration *b* = the time an activity will take under the most unfavourable conditions.

3. The most likely duration *m* = the most realistic time an activity will require to be completed under normal conditions.

It is obvious from these descriptions that prediction of these parameters at the initial planning, budgeting and awarding of contract for the overhauling of the filler machine will check the excesses often seen in such projects. Prediction of these parameters with respect to the system overhauling is also of economic sense to know the exact time the project will last in order to reduce logistic costs such as exorbitant hotel bill/daily allowance among others associated with hosting of maintenance personnel. The saving resulting from this prediction will make more funds available for other developmental projects.

This study is therefore aimed at exploring the optimal duration and labour cost of various activities involved in the Meyer 78/18 Filling Machine breakdown maintenance at 7up Bottling Company Plc, Aba Plant using CPM and PERT techniques (network analysis) to serve as a model/guide for planning and budgeting of such project in other bottling companies.

METHODS

This study involved direct practical participation in the breakdown maintenance of a Meyer 78/18 Filling Machine breakdown maintenance at 7up Bottling Company Plc, Aba Plant, Abia State of Nigeria, during which distinct jobs of the project were identified with the man hours (duration) and labour cost involved per activity. The bottle filling machine is designed to feed glass bottles into the machine, supply them to the filling and capping process, and subsequently discharge filled and capped bottles from the machine. The bottle filler consists of components such as the Conveyor which conveys the glass bottles directly to the feed screw. In addition is the Machine carousel, which carries the lift cylinder table and the tubular ring bowl, linear drive, outer control cams and stop segments (control ring with height adjustment motor, angle gears, universal joint shafts and lifting columns). Also, bottle lifting elements, height-adjustable scissor joints equipped with aseptic sealing systems. There are in addition, torque motors and gearbox system. Filling system also make up the design and it consist of filling level probe, evacuation mechanism and other components. Performing double CO_2 rinsing, fast filling phase, precise fill level measurement, low-foam pressure-controlled pressure relief, speed-independent filling process. Other components that make up the machine include: Valve manifolds, Vacuum pump, Crown capper, Exterior cladding, Electrical elements (such as cables, or pneumatic supply hoses). Lastly the Diagnostic system such as pressure sensors that continuously record the pressure curve during a filling process and send it to the display screen. This has the advantage that the process sequence can be monitored permanently even inside the bottle. The vacuum actually achieved in the bottles and the correct CO_2 purging process can be read, among other things. Also is the operator panel.

The overhauling activity begins with activity A and ends with activity S as outlined in table 1 and shows the distribution of the project activities relative to the actual number of hours to complete individual activity (Figure 2) and their respective cost implication in Naira. The costs are basically labour costs based on the assumption that materials are supplied and already available for use.

Applying the critical path method (CPM), the starting and finishing times of each activity if no delays occur in course of the project are the earliest start time (EST) and the earliest finish time (EFT) of the activity. Considering that EST_b is the earliest time activity b can start, and EFT_b is the earliest time activity b can finish. From this, the earliest an activity can finish is the earliest time it can start plus its duration. In general, if d_b is the duration of activity b, we have that

$$EFT_b = EST_b + d_b \quad (1)$$

If activity a is an immediate predecessor of activity b, then activity b cannot start until activity a finishes, so the earliest time activity b can start is the maximum of the earliest finish times of its immediate predecessors:

$$EST_b = \max EFT_a \quad (2)$$

Equations 1 and 2 are used to find the earliest start and earliest finish times of all activities. At the finish state, the project completion time is obtained.

$$\text{Project completion time} = EST_{Finish} \quad (3)$$

The reason has been that as soon as we reach the Finish node, the entire project is complete. This calculation of the earliest start and finish times through equations 1 to 3 is usually called the forward pass of the CPM algorithm. To find the critical activities and critical path, we need to find two other equations. Let LST_b and LFT_b be the latest time activity b can start and the latest time it can finish without increasing the project completion time. Therefore,

$$LST_b = LFT_b - d_b \quad (4)$$

Suppose activity b is an immediate successor of activity a. Then activity a must be finished before activity b can start. Thus, the latest time activity a can finish is the minimum of the latest start times of all its successors:

$$LFT_a = \min LST_b \quad (5)$$

We use equations 4 and 5 to calculate the latest start times and latest finish times for all activities, beginning with the latest finish time for the Finish node as the project completion time. This set of calculations is called backward pass of the CPM algorithm because we work through the activities in backward order. We then calculate the slack also known as float of each activity b as the difference between the latest start time and earliest start time of activity b or the difference between the latest finish time and earliest finish time of activity b.

$$\text{Slack of activity } b = LST_b - EST_b \text{ or } LFT_b - EFT_b \quad (6)$$

For slack time, if an activity has a positive slack then that activity can has time adjustment. Its duration could increase by the amount of its slack without delaying the project (Ahuja and Orlin, 1993). Conversely, if an activity has zero slack, an increase in its duration will delay the project completion time. Therefore, the critical path consists of activities with zero slack.

In reality however, because of constraints in carrying out each activity, the activity time estimate cannot be certain (Adebowale and Oluboyede, 2011). Therefore using PERT analysis which follows beta distribution, the project completion time is computed in a similar manner as in the CPM approach, but by substituting the three estimates of the activity duration with the expected activity time t_e, (mean) as obtained in Equation (7), and by the variance of the activity completion time, σ, as shown in Equation (8). Expected time is the weight average of the three time estimates (optimistic (a), pessimistic (b) and most likely time (m)).
Using the formulae:

$$\text{Expected time mean } (\mu_p) = \frac{(a+4m+b)}{6} \qquad 7$$

$$\text{and Variance } (\sigma^2) = \left(\frac{b-a}{6}\right)^2 \qquad 8$$

$$\text{estimate of the standard deviation of activity time } (\sigma) = \frac{b-a}{6} \qquad 9$$

As a result of the uncertainty of completing the project within the desired schedule. Therefore, it will be useful to know the probability that the project deadline will be met. The first step is to find the variance and standard deviation of the total time along critical path, which is equal to the sum of the variances of activity times on the critical path. Then compute the probability that the project will be completed within the deadline time (i.e. the estimated completion + standard deviation).
Therefore, the expected completion time of the project (μ_p) can be derived as well as the variability or the standard deviation in the project completion time σ_p, as follows:

$$\mu_p = \max(\text{EFT}) = \max(\text{LFT}) \qquad 10$$

μ_p= sum of the expected duration for the activities in the critical path 11

$$\sigma_p = \sqrt{(\textit{sum of the variances of the duration for the activities in the critical path})} \qquad 12$$

Let d denote the possible project specified deadlines and X the total time required to complete the project. Due to the central limit theorem, which indicates that the sum of independent random variables can be approximately represented by a normal distribution as the number of random variables becomes larger, the project completion is approximated by a normal distribution with mean μ_p and standard deviation σ_p (Hillier and Lieberman, 2001).
The possible situations of interests are the probability that the project duration (X):

- does not exceed the deadline d, i.e., $P(X \leq d)$;
- does exceed the deadline d, i.e., $P(X \geq d)$.

The approach consists of converting X into a standard normal distribution and determining the area under the normal curve from standard normal distribution table. To that end the Z value is computed as follows:

$$Z = \frac{X-\mu_p}{\sigma_p}; \quad \text{where: } X = d$$

RESULTS AND DISCUSSION

The List of Activities undertaken for the Mayer 78/18 Filler breakdown maintenance project at 7up Bottling Company, Aba Plant is as outlined in Table 1. Also in Table 2, the paths and path lengths of the project network was outlined in order to ascertain the path with mean critical activities. Six paths as obtained from the project network in Figure 1 are given in Table 2, along with the calculations of the lengths of these paths. The path lengths range from 134 hours to 139.45 hours for the longest path. The Critical Activity path for the breakdown maintenance project was obtained as Start-A-B-C-G-H-I-N-P-Q-R-S-Finish, at (Estimated) project duration of

139.45 hours or approximately 7.43 days (at 24 hours per day for activities A and B; and 8 working hours per day for the remaining activities) as the minimum possible duration for this project.

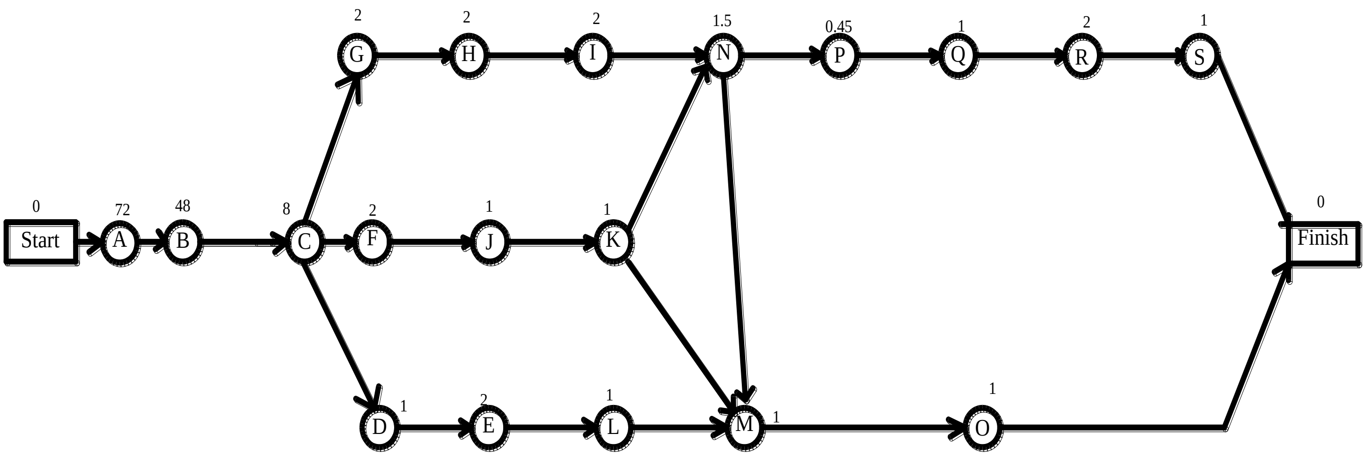

Figure 2: Network Representation for the Mayer 78/18 Filler overhaul project

Table 3, summarizes all the Activity times (Start, Finish, and Slack Times) arising from the forward and backward process in figure 3. Thus, addressing the question of when can the individual activities start and finish (at the earliest or latest) if no delays occur. For the slack for each of the activities, zero slack, indicating that any delays in these activities will delay project completion and this is how PERT/CPM identifies the critical path(s). The analysis of the measured multiple time estimates of the Expected Times and Variances of the duration of each activity is presented in Table 4. In Table 5, μ_p and σ^2 for activities on Critical Path of project was calculated and applied in approximating the Probability of Meeting the project Deadline.

Table 6 shows the various cadre and size of personnel required for the breakdown maintenance project as well as the cost implication of each activity in the project schedule. The manpower required for the various activities involved in the project was determined as one (1) engineer, one (1) technician, two (2) craftmen and two (2) unskilled workers. From the table also, it was gathered that the sum of sixty-four thousand, four hundred and seventeen Naira and fifty Kobo (₦64417.5) is required as the labour cost in this maintenance project.

Table 1: List of Activities for the Mayer 78/18 Filler overhaul project

Activity	Activity Description	Immediate Predecessors	Estimated Duration (hours)
A	Ordering and Receiving of required spare parts and maintenance equipment	-	72
B	Setting up of Maintenance team	A	48
C	Preparation of job schedule/work order	B	8
D	Dismantling and Inspection of all Snift block and Filling organ assembly	C	1
E	Repair/Replacement of damaged Snift block and Filling organ components	D	2

F	Dismantling, Inspection and Servicing of the Mixing Bowl assembly	C	2
G	Dismantling and Inspection of the Lift Cylinder assembly	C	1.5
H	Inspection of Seals and O-rings of the Lift Cylinders (78)	G	2
I	Repair/Replacement of the damaged components of the Lift Cylinders	H	2
J	Dismantling of the Main Drive assembly	F	1
K	Inspection and Servicing/Repair of Main Drive components	J	1
L	Dismantling of product line Ferrule and Couplings	E	1
M	Inspection and Servicing of Ferrule and Couplings on the product line	K, L, N	1
N	Inspection and Servicing/Repair of the Rotary Joint assembly	I, K	1.5
O	Dismantling, Inspection and Servicing of the Switch lever assembly	M	1
P	Alignment check for the pulley/belt and gear trains of the Drive assembly	N	0.45
Q	Pressurization of the Mixing Bowl assembly	P	1
R	Installation of Instrumentation/Control devices on the Filler	Q	2
S	Testing of the Bottle Filling Machine/Commissioning	R	1

Table 2: The paths and path lengths for Mayer 78/18 Filler overhaul project network

Path No	Path	Path Length (total time in hours)
1	Start-A-B-C-G-H-I-N-P-Q-R-S-Finish	72+48+8+1.5+2+2+1.5+0.45+1+2+1=139.45
2	Start-A-B-C-G-H-I-N-M-O-Finish	72+48+8+1.5+2+2+1.5+1+1=137
3	Start-A-B-C-F-J-K-N-P-Q-R-S-Finish	72+48+8+2+1+1+1.5+0.45+1+2+1=137.95
4	Start-A-B-C-F-J-K-M-O-Finish	72+48+8+2+1+1+1+1=134
5	Start-A-B-C-F-J-K-N-M-O-Finish	72+48+8+2+1+1+1.5+1+1=135.5
6	Start-A-B-C-D-E-L-M-O-Finish	72+48+8+1+2+1+1+1=134

Table 3: Summary of Activities (Start, Finish, and Slack Times)

Activity	EST	EFT	LST	LFT	Slack	Critical Activity
Start	0	0	0	0	0	Yes
A	0	72	0	72	0	Yes
B	72	120	72	120	0	Yes
C	120	128	120	128	0	Yes

D	128	129	133.45	134.45	5.45	No
E	129	131	134.45	136.45	5.45	No
F	128	130	129.9	131.5	1.5	No
G	128	129.5	128	129.5	0	Yes
H	129.5	131.5	129.5	131.5	0	Yes
I	131.5	133.5	131.5	133.5	0	Yes
J	130	131	131.5	132.5	1.5	No
K	131	132	132.5	133.5	1.5	No
L	131	132	136.45	137.45	5.45	No
M	135	136	137.45	138.45	2.45	No
N	133.5	135	133.5	135	0	Yes
O	136	137	138.45	139.45	2.45	No
P	135	135.45	135	135.45	0	Yes
Q	135.45	136.45	135.45	136.45	0	Yes
R	136.45	138.45	136.45	138.45	0	Yes
S	138.45	139.45	138.45	139.45	0	Yes
Finish	139.45	139.45	139.45	139.45	0	Yes

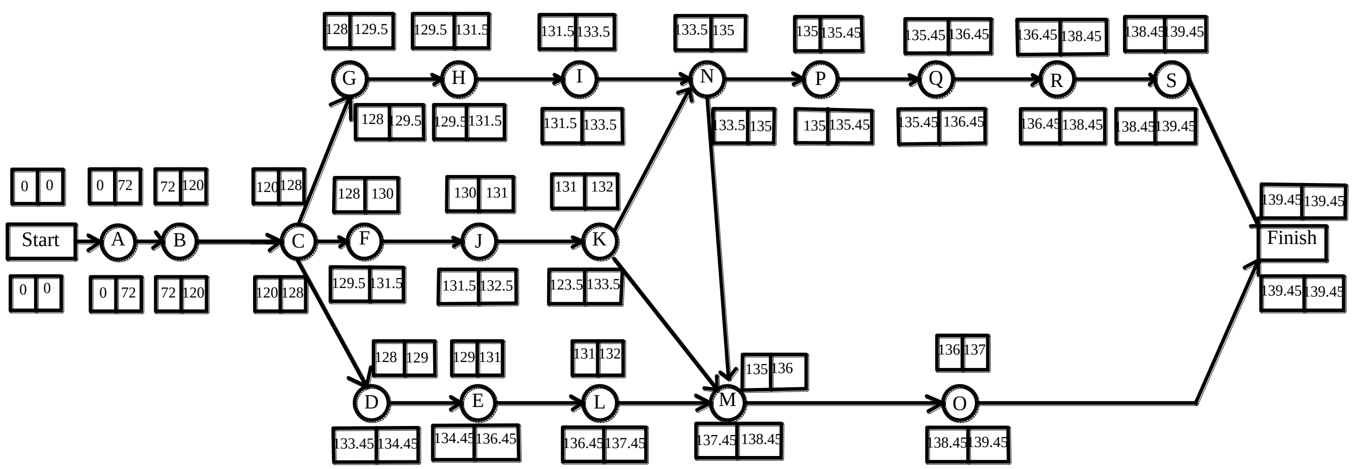

Figure 3: The complete project network showing ES and EF (in boxes above the node) and LS and LF (in boxes below the node) for each activity of the Mayer 78/18 Filler overhaul project

Table 4: Expected Times and Variances of the duration of each activity for the Mayer 78/18 Filler overhaul maintenance project

ACTIVITY	Optimistic Estimate (a)	Most Likely Estimate (m)	Pessimistic Estimate (b)	Expected time mean $(\mu_p) = \frac{(a+4m+b)}{6}$	Variance $(\sigma^2) = \left(\frac{b-a}{6}\right)^2$
A	68	72	76	72.000	1.778
B	42	46	48	45.667	1.000
C	7	9	12	9.167	0.694
D	0.75	1	1.5	1.042	0.016
E	1.5	1.8	2	1.783	0.007
F	1.75	2	2.25	2.000	0.007
G	1	1.3	1.5	1.283	0.007
H	2	2.2	2.5	2.217	0.007
I	1.75	2	2.25	2.000	0.007
J	0.75	1	1.5	1.042	0.016
K	0.8	1	1.25	1.008	0.006
L	0.6	0.8	1	0.800	0.004
M	0.75	1	1.5	1.042	0.016
N	1.25	1.6	1.8	1.575	0.008
O	0.8	1	1.25	1.008	0.006
P	0.5	0.75	1	0.750	0.007
Q	0.8	1	1.25	1.008	0.006
R	1.5	1.75	2	1.750	0.007
S	0.75	1	1.5	1.042	0.016

Table 5: Calculation of μ_p and σ^2 for Activities on Critical Path of Mayer 78/18 Filler overhaul maintenance project

Activities on Critical Path	Expected time mean	Variance
A	72.000	1.778
B	45.667	1.000
C	9.167	0.694
G	1.283	0.007
H	2.217	0.007
I	2.000	0.007
N	1.575	0.008
P	0.750	0.007
Q	1.008	0.006
R	1.750	0.007
S	1.042	0.016
	$\mu_p = 138.459$	$\sigma^2 = 3.537$

In approximating the Probability of Meeting the Deadline;
Let
T = project duration (in weeks), which has (approximately) a normal distribution with mean $\mu_p = 138.459$ and variance $\sigma^2 = 3.537$,
d = deadline for the project = 145 hours.
Since the standard deviation of T is $\sigma = 1.881$, the number of standard deviations by which d exceeds μ_p is

$$Z = \frac{d - \mu_p}{\sigma_p}$$

$$Z = \frac{145 - 138.459}{1.881}$$

$$Z = \frac{6.541}{1.881}$$

$$Z = 3.477$$

Therefore from *standard* normal distribution Table,
P($X \leq 3.477$) = 0.50 + 0.4997 = 0.9997 or 99.97%. Hence, there is about 99.97% probability that the project will be completed on time. Alternatively the Excel function NORMSDIST(Z) can be used to seek the probability corresponding to the z value.
What is the probability that the project lasts more than 145 hours?
P($X > 145$) = 1 - P($X \leq 145$) = 1 - 0.9997 = 0.0003 or 0.3%.
There is a 0.3% probability that the project will not be completed on time.

Table 6: Analysis of Labour requirement and Cost breakdown of Activities for the Mayer 78/18 Filler overhaul project

Activity	Labour Requirement	Estimated Duration (hours)	Amount (₦)
A	-	72	0.00
B	-	48	0.00
C	-	8	0.00
D	1 engineers, 1 technicians, 2 craftmen and 2 unskilled labourers	1	3150
E	1 engineers, 1 technicians, 2 craftmen and 2 unskilled labourers	2	6300
F	1 engineers, 1 technicians, 2 craftmen and 2 unskilled labourers	2	6300
G	1 engineers, 1 technicians, 2 craftmen and 2 unskilled labourers	1.5	4725
H	1 engineers, 1 technicians, 2 craftmen and 2 unskilled labourers	2	6300
I	1 engineers, 1 technicians, 2 craftmen and 2 unskilled labourers	2	6300
J	1 engineers, 1 technicians, 2 craftmen and 2 unskilled labourers	1	3150

K	1 engineers, 1 technicians, 2 craftmen and 2 unskilled labourers	1	3150
L	1 engineers, 1 technicians, 2 craftmen and 2 unskilled labourers	1	3150
M	1 engineers, 1 technicians, 2 craftmen and 2 unskilled labourers	1	3150
N	1 engineers, 1 technicians, 2 craftmen and 2 unskilled labourers	1.5	4725
O	1 engineers, 1 technicians, 2 craftmen and 2 unskilled labourers	1	3150
P	1 engineers, 1 technicians, 2 craftmen and 2 unskilled labourers	0.45	1417.5
Q	1 engineers, 1 technicians, 2 craftmen and 2 unskilled labourers	1	3150
R	1 engineers, 1 technicians, 2 craftmen and 2 unskilled labourers	2	6300
S	1 engineers, 1 technicians, 2 craftmen and 2 unskilled labourers	1	3150
TOTAL		139.45	64417.5

CONCLUSION

This paper addressed the problem of the application of project scheduling in the breakdown maintenance of the Mayer 78/18 Filler project at 7up Bottling Company Plc, Aba Plant using CPM and PERT methods. Implementing the CPM/PERT analysis, the project took an optimal duration of 139.45 hours which is approximately 7.43 days (at 24 hours per day for activities A and B; and 8 working hours per day for the remaining activities) to be completed. Having 99.97% probability that the project will be completed on time. Also, the sum of sixty-four thousand, four hundred and seventeen Naira and fifty Kobo (₦64417.5) was required as the labour cost in this maintenance project with personnel made up of one (1) engineer, one (1) technician, two (2) craftmen and two (2) unskilled workers.

It is therefore, recommended that the results of this study be implemented in the planning and scheduling of breakdown maintenance of Bottle Filler Machine to ensure adequate and timely execution of the project.

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