A USEFUL APPROACH TO MAINTENANCE SCHEDULING

J. I. SODIKI
P. O. BOX 11374
PORT HARCOURT

ABSTRACT

A five-step approach to facility routine maintenance scheduling is presented. The approach involves parts segmentation, identification of maintenance activities and frequencies, time and material analysis, compilation of schedules, and implementation and control, in that order.

The application of the method is illustrated with examples.

The method is particularly useful in organizations where expertise in detailed industrial engineering techniques, and relevant information on technical specifications and maintenance requirements are limited or absent. This situation is prevalent in developing countries.

1. INTRODUCTION

One of the factors militating against the achievement of enhanced productivity and full capacity utilization of industrial facilities in developing countries is the problem of poor maintenance. This problem arises due, partly, to political and cultural values; and partly due to a low level of awareness and technical expertise regarding maintenance matters.

Political and cultural values have in the case of Nigeria, for instance, resulted in difficulties in obtaining foreign currency exchange for the procurement of spare parts necessary for servicing industries. The managements of individual industries may find it difficult to quickly effect favourable changes to such political and cultural values; but they still have avenues for improving the awareness and technical expertise in maintenance, at least in individual industries.

Maintenance can be categorized into breakdown and scheduled routine maintenance. Breakdown maintenance arises when a malfunctioning or an observed deterioration in productivity occurs in a facility; while scheduled routine maintenance constitutes pre-planned actions which are carried out while the facility is still in a functional condition, with the intention of prolonging this condition.

A five-step approach to routine maintenance scheduling as exercised on various facilities is presented in this paper. The approach emphasizes the proper planning of maintenance man-hour requirements.

2. THE MAINTENANCE SCHEDULING PROCUDURE

2.1 Segmentation of Components

The first step in the suggested approach is to mentally segment the facility into smaller components requiring maintenance, together with the relevant technical specifications (where these are available). Thus, for rotating machinery, for instance, the list of components would include bearings, belts, gearboxes, electric motors, etc. Technical specifications such as type, rotational speed, and bore size would, for instance, be relevant for bearings, as these are usually needed to determine relubrication intervals and for replacement and re-ordering purposes.

A study of assembly and component drawings would normally indicate items requiring maintenance attention. A physical study of the facility, both while in operation and out of use, is very necessary for determining components that are likely to wear out or deteriorate, especially where drawings and technical data are not available.

2.2 Identification of Maintenance Activities and Frequencies

The type of activity required on each type of component is next determined. Thus, while for bearings, inspection, cleaning, relubrication and replacement would be necessary from time to time; belts would require inspection, cleaning, tensioning and replacement.

The frequencies of the different activities also have to be determined; that is, time intervals between cleanings, relubrications, tensionings, replacements, etc, have to be specified. At this stage, the manufacturer's maintenance requirements for each component have to be consulted, where these are available. Such requirements usually come in the form of routine maintenance programmes, graphs or notes.

In the absence of such stipulations, technical experience and advice of individuals would be useful.

2.3 Time and Material Analysis

A time and material analysis is carried out to determine the man-hour requirements as well as the materials and tools needed towards establishing a long-term stock control plan.

By aggregating the different times required for the maintenance of different component units, and giving some allowance for rest and other exigencies, the time required for a complete maintenance job can be calculated.

One way of doing this is by the technique of analytical estimating [1] whereby an experienced estimator breaks the job into component elements and estimates the time needed for each element. An alternative to analytical estimating may be an initial maintenance execution. This requires carrying out the actual maintenance activities in order to determine the mean times required for different maintenance activities as well as the stock requirements.

During the trial maintenance the relative locations of the different components of the facility should be studied with a view to determining the ease, or otherwise, of carrying out activities on several components during the same maintenance attention.

As much as it is possible, trial maintenance activities should be carried out at the frequencies established earlier on (as explained in section 2.2). This would minimize interference with production or operating schedules, since the facility's user department would have been previously informed about the times maintenance activities normally fall due.

Obviously, the alternative of trial maintenance takes a longer time to conclude than the method of analytical estimating and it is recommended either for situations where a reliable estimator cannot be employed, such as for not-so-common facilities, or as a complement to analytical estimating for such component elements of the facility which the estimator is unable to determine their work contents.

2.4 Compilation of Maintenance Schedule

The compilation of the schedule could then be done in such a form that the component parts of the facility which require maintenance, together with the descriptions of maintenance actions and their incidence (i.e. the times when they should be carried out) can easily be read.

The schedule should be in agreement with the time analysis such that the required man-hours to accomplish a given maintenance activity can be achieved at any particular time.

It should also be ensured that the man-hour inputs between equal time periods are not very different from one another, except for some special periods such as when the facility is deliberately put out of use in order that a major maintenance activity can be executed (for example, during an end-of-year maintenance). In other words, the schedule should be balanced in terms of manning levels.

Portions of the schedules are sometimes displayed on planning boards and in other convenient manner for quick reference. Today, the computer is widely utilised in information storage, analysis and display for the purpose of maintenance scheduling.

2.5 Implementation and Control

The implementation and control of the schedule is, next, done to carefully assess it and make necessary adjustments. At this final stage of scheduling, man-hour and material allotments may change due to emerging realities. Such adjustments will take some time, depending on the complexity of the facility and the accuracy of the initial man-hour and material assessments.

One useful technique in the implementation and control stage is the determination of the optimum amount of scheduled maintenance, although its implementation at the inception of the scheduled maintenance scheme may not always be recommended as it requires obtaining data over a long period of time and conducting controlled experiments.

3. OPTIMUM AMOUNT OF SCHEDULED MAINTENANCE

As maintenance, whether scheduled or breakdown maintenance, is a service to production, it is necessary to ensure that just sufficient maintenance is done to aim at the lowest total cost of production.

This requires that the maintenance costs (scheduled and breakdown) on defects which do not affect the volume of production must be reduced as much as possible, while ensuring safety and other necessities. On the other hand, when defects lower the quantity of production, a reduction in the cost of the product may be achieved by increasing the volume and cost of maintenance.

One intention of scheduling maintenance work is to reduce breakdowns, and so the maintenance costs and losses due to resulting breakdown generally decrease as those due to scheduled maintenance increase and vice versa. As it is easier to plan and analyse scheduled maintenance than breakdown maintenance, the determination of the portion of the total maintenance man-hours which should be assigned to scheduled maintenance to achieve the lowest total costs can be done. This is done by varying the percentage of the total man-hours spent on scheduled maintenance and obtaining the corresponding costs (maintenance costs, and total losses in production due to both scheduled and breakdown maintenance downtime) for the facility [2]. Maintenance costs must include man-hours, materials and spare parts. Losses in production must include losses arising from downtime of other facilities operating in series with, and which are inactive due to the inactivity of, the one under consideration.

Figure 1 [2] represents the graph used to determine the optimum amount of scheduled maintenance. The U-curve is obtained by adding together the cost of breakdown and scheduled maintenance; the lowest point on the curve being the optimum level of maintenance.

4. APPLICATION OF THE SCHEDULING PROCEDURE

It is found that the scheduling procedure outlined above can be applied to a variety of facilities as exemplified as follows.

4.1 Production Machinery Maintenance

The procedure has been applied to the maintenance scheduling of feed milling machinery and has been reported [3]. In segmenting the parts of the mill, assembly drawings were not utilized, as these were absent. Rather, a physical examination and study of the mill, both while in operation and while it was shut down, was done to determine components that needed maintenance attention.

Maintenance activities and frequencies were identified as outlined in section 2. For instance, graphs of relubrication interval against rotational speed for bearings of different bore sizes [4] were useful in determining relubrication intervals.

A time analysis done for part of the feed mill is shown in Table 1 [5]. From the total time spent on scheduled maintenance per year, average time spent per week (assuming 44 working weeks)

$$= \frac{43760}{60} \times \frac{1}{44}$$

$$= 16.58 \text{ man-hours}$$

or average time/day (assuming a 5 – day working week)

$$= \frac{16.58}{5}$$

$$= 3.32 \text{ man-hours}$$

Thus, from the time analysis, 3.32h should be spent on scheduled maintenance per day per workman.

In implementing the schedule, 2 maintenance men were assigned to take charge of 2 mill lines (both men working together). In the absence of any major breakdown, each mill line was run for an average of 6h of an

8h working day, leaving about 2h for scheduled maintenance work. Thus a total of about 4 man-hours was made available for scheduled maintenance on each mill line per day. And a total of about 4h was spent on the 2 mill lines by each man per day on scheduled maintenance.

Maintenance schedule compilations for electric motors and belt drives prepared for one feed mill line are shown in Tables 2 and 3 respectively. The schedule shows only weekly routine maintenance work done by 2 men, consistent with the time analysis.

4.2 Automobile Fleet Maintenance

The maintenance scheduling of a fleet of vehicles may be likened to that of a group of production machinery, where a vehicle now takes the place of a machine. However, for a fleet of motor vehicles, the steps of the scheduling procedure concerned with part segmentation, and identification of maintenance activities and frequencies may not be necessary where the vehicle manufacturers specify activities and frequencies in their routine maintenance programmes, as is usually the case. Where the maintenance frequencies so specified are in terms of distance covered by the vehicle, it may sometimes be necessary, for convenience of scheduling, to relate these distances to time periods (i.e. weekly, monthly, yearly, etc). This can be done by estimating from the mileage recorder the average period taken by a particular vehicle to cover a specified distance. An example of a manufacturer's routine maintenance programme is shown in Illustration 1[6].

A time analysis for the programme of Illustration 1 may be in the form of Table 4 which is drawn up with the assumption of 2 men (a worker and a mate) working together, as most automobile workshop tasks can be accomplished by a team of this size.

We note that each of the maintenance types in the table can be repeated in an exact whole number of times in 360 months. In order words, 360 months represent the least common multiple of the periods between maintenance activities of any given type.

From Table 4, total time for scheduled maintenance in 1 month on 1 vehicle

$$= \frac{1534}{360} \text{ h}$$

We now wish to produce a maintenance schedule for a fleet of 20 vehicles for 40 months

$\therefore$ Total time for scheduled maintenance in 40 months on 1 vehicle

$$= \frac{1534}{360} \times 40\text{h}$$

$$= 170\text{h}$$

$\therefore$ Total time for scheduled maintenance in 40 months on 20 vehicles

$$= 170 \times 20$$

$$= 3400\text{h}$$

Thus total man-hours needed from the 2 men in 40 months

$$= 3400 \times 2 = 6800\text{h}$$

Total man-hours needed in 1 day (assuming 22 working days per month)

$$= \frac{6800}{40 \times 22} = 7.7 \text{(say 8h)}$$

Thus the team of 2 men would need about 4h each day for scheduled routine maintenance. To create more room for activities other than scheduled routine maintenance and to accommodate unforeseen situations, a team of 3 men working 3 to 4h each day on scheduled maintenance might be employed to accomplish the required work on the schedule of Table 5.

Table 5 is a typical maintenance schedule which may be compiled for the fleet of 20 vehicles for 40 months. The schedule shows 6-monthly, 18 - monthly, 30 – monthly, and 40 – monthly maintenance based on the programme of Illustration I and the foregoing time analysis. By this schedule, between 3 and 7 vehicles are to be attended to per month (excluding the weekly maintenance).

Thus the available man-hours should be adequate to handle this workload, the weekly maintenance and other activities.

A maintenance schedule for a fleet of 22 forklift trucks which was compiled following similar steps and which was successfully executed has been reported previously [7].

4.3 Building Maintenance

A building may be segmented into its component structures such as roof, ceiling, walls, floors, electrical services, plumbing services, the building surroundings, etc for the purpose of maintenance scheduling.

The various maintenance activities required need to be identified. Building premises would require tidying up; roofs require cleaning and recoating; floors require cleaning, chemical treatment and protection; walls need to be repainted; and so on.

The frequencies of maintenance attentions depend much on the nature and extent of activity that takes place within the building. For instance, the light-coloured walls of a factory building in which black carbon compounds are processed would naturally require more frequent painting, due to the carbon compound's coloration, than the walls of a design architect's or engineer's office. The frequencies also depend on the maintenance consciousness of the building occupier or owner.

However, in order to provide some guide, several literature specifying maintenance requirements for building components are available [8]. These are complemented by specific building product manufacturers' specifications. Thus paint makers may specify intervals between repaintings and floor surface treatment chemical manufacturers may specify frequencies of re-application of their products.

A convenient way of setting out a time analysis for scheduled building maintenance is to aggregate allotted time according to trade groups. For instance, all times required for painting are aggregated together and all times for office cleaning (which can be done by unskilled labour) are put together. This method facilitates the determination of man-hour requirements for the different trades; the trades for a building being very diverse and including painters, masons, plumbers, electricians, air conditioning craftsmen, etc.

A time analysis based on the typical shop office cleaning programme in Illustration 2 [9] is presented in Table 6. The functions in the programme of Illustration 2 can be performed by a team of up to four persons.

For a cleaning staff strength of 4, from Table 6, average time spent per person daily in cleaning

$$= \frac{3819}{4 \times 365} = 2.6\text{h (say 3h)}$$

By this analysis, each cleaner might be assigned to other activities for the remaining 5 hours of an 8 – hour shift.

A similar analysis should be done for the other trade groups to determine manning levels in each group.

Table 7 illustrates a routine maintenance schedule compilation covering a period of two years for a building. From the schedule, the extent of work (whether yearly, 6 - monthly, etc) for each trade group can easily be read off for any particular month. The detailed work description for each maintenance attention can then be obtained from the different routine work programmes such as that in Illustration 2.

While compiling the schedule it should be ensured that the required man-hours to accomplish a given maintenance attention can be achieved at any particular time. For example, within the month of June 1993 there should be adequate man-hours in the relevant trade groups to accomplish the 6 – monthly painting and the 3 – monthly plumbing maintenance.

5. CIRCUMSTANCES INFLUENCING THE OPERATION OF MAINTENANCE SCHEDULES

Maintenance schedules should be flexible enough to accommodate changes arising from some influential factors. Such factors include the following.

5.1 The Maintenance History

An important function in the organization of maintenance is record keeping. A system must be set up to record relevant information on all repairs, part replacements and scheduled routine maintenance for all facilities. Such records are normally kept by means of computers and history cards or books. The maintenance history sometimes shows that a component of a given facility had recently received maintenance attention due to a breakdown; and it would be too soon and uneconomical to repeat the same attention presently required by the routine maintenance schedule. For example, if an engine oil refilling for an electric generating plant was done one week back as a result of an accidental damage to the oil sump, occasioning the loss of all the oil, it may be expedient not to change the oil in a present maintenance attention, even though the routine schedule stipulates such action. The expediency, or otherwise, of the converse action of carrying out an activity which is not yet due can also be decided from the maintenance history.

5.2 Sudden Malfunctioning of Equipment

While scheduled maintenance work aims at reducing incidents of unexpected and sudden equipment malfunction (i.e breakdowns), such incidents sometimes occur inevitably. When they do, steps are usually taken to remedy the malfunction as a priority, while necessary adjustments are made on the routine maintenance schedules.

5.3 The Facility Operating Schedule

As maintenance is essentially a service aimed at optimum productivity of facilities, production schedules may sometimes necessitate adjustments being made on the maintenance schedule. For instance, if in a manufacturing organization, production targets which had been delayed due to late arrival of some essential raw material must still be achieved, maintenance activities could be rescheduled to be implemented at the time raw materials were being awaited. This ensures that subsequent production is not hitched by maintenance activity.

5.4 Delayed and Wrong Requisition of Maintenance Materials

Delays in the delivery to the maintenance department of spare parts and materials needed for maintenance work would necessitate modifications on the maintenance schedules, in the same way as the delivery of spares and materials of wrong specification would bring about adjustments on the schedules since these naturally cause delays.

5.5 The Available Maintenance Work Force

As maintenance schedules are usually drawn up with the available work force in mind, an unexpected reduction in man-hours, for instance, by trade union industrial strike action, may necessitate adjustments on the maintenance schedules.

5.6 Workers' Negative Behavioural Patterns

In any work environment where the work force is ill-motivated and poorly supervised; or where workers are intrinsically insubordinate, obstinate and truant; the general outlook is one that lacks coordination and commitment with the result that output of good quality work suffers. Such a situation would obviously adversely affect the execution of scheduled work and necessitate changes in the maintenance schedules.

6. SUMMARY AND CONCLUSION

As a contribution towards improving the maintenance planning function, a five-step approach to the scheduling of routine maintenance of facilities which had been successfully applied in some organizations is presented.

Basically, the approach involves the following steps. Firstly, the facility is segmented into component parts. Secondly, the required maintenance actions and the frequency of individual actions on each part are determined. Thirdly, a time analysis is done to determine the man-hour requirements. During this stage the materials and tools required are also determined to enable proper stock control to be done. The fourth stage involves the compilation of the schedule in a convenient form. The fifth and final stage is the implementation and control stage whence necessary changes may be done on the schedule, as well as on the man-hour and material requirements. At this stage a technique of determining an optimum amount of scheduled maintenance may be useful. Examples are given to illustrate the application of the approach. The chosen examples are routine maintenance scheduling of production machinery, automobile fleets, and buildings.

Finally, circumstances which may necessitate adjustments, from time to time, on the schedules are exemplified as the facility's maintenance history, sudden malfunctioning of equipment, the facility's operating schedule, delayed and wrong requisitions, the available workforce, and workers' negative behavioural patterns.

The approach will be useful in situations where expertise in detailed industrial engineering techniques such as methods study, analytical estimating, statistical forecasting, etc, within an organization is limited or absent. It is also useful in situations where information on technical specifications and maintenance requirements of the facility are limited. Such situations are prevalent in the developing countries.

However, once the required expertise and information become available, the schedules should be reviewed in line with standard industrial engineering techniques.

REFERENCES

1. **Pierson, F. O. and Mossor, H. C.,** Labour Costs for Typical Operations in Building Maintenance. In: Morrow, L. C. (Ed.), Maintenance Engineering Handbook, McGraw – Hill, New York, 1966.
2. **Stewart, H. V. M.,** Guide to Efficient Maintenance Management, Business Publications Limited, London, 1986.
3. **Sodiki, J. I.,** Maintenance Planning and Engineering of Feed Milling Machinery – A Case Study, Proceedings of the 7th Annual Conference of the Nigerian Institute of Industrial Engineers, pp 89 – 94, Enugu, 1990.
4. SKF Group, Bearing Maintenance and Replacement Guide, SKF Group, England, 1977.
5. **Sodiki, J. I.,** Maintenance Scheduling for a Feed Mill, Technical Report to National Animal Feeds Co. Ltd., Port Harcourt, 1986.
6. **Haynes, J. H. and Strasman, P. G.,** Ford Escort Owners Workshop Manual, J. H. Haynes and Co. Ltd., England, 1974.
7. **Sodiki, J. I.,** Planning for Automobile Fleet Maintenance – A Case Study, Paper Presented at the 2nd International Seminar on Maintenance of Transport Facilities, Kano, 1989.
8. **Morrow, L. C.** (Ed.), Maintenance Engineering Handbook Section 6: Maintenance of Buildings, McGraw-Hill, New York, 1966.
9. **Sterzinger, G.,** Cleaning of Industrial Plant Offices. In: Morrow, L. C. (Ed.), Maintenance Engineering Handbook, McGraw-Hill, New York, 1966.

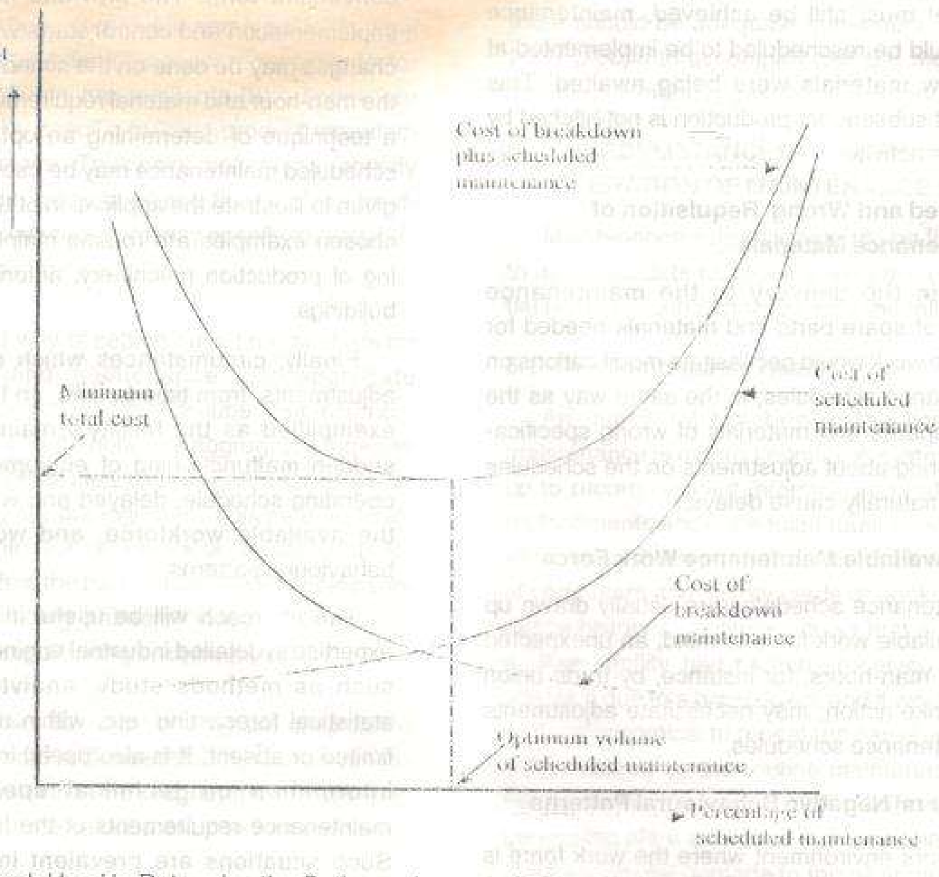

Figure 1: U - Graph Used to Determine the Optimum Amount of Scheduled Maintenance for a Specific Facility.

Illustration 1; Typical Vehicle Maintenance Programme

Weekly or every 250 miles (400 km)

1. Check the level of the engine oil
2. Check the battery electrolyte level
3. Check the coolant level in the radiator
4. Check the fluid level in the automatic transmission unit (where fitted)
5. Check the brake reservoir fluid level
6. Top up windscreen washer fluid container
7. Check tyre pressures (including the spare)

Six - monthly or every 6000 miles (10,000 km)

8 Drain engine oil and renew filter
9 Lubricate dynamo rear bearing (where fitted)
10. Clean spark plugs and set gap
11. Clean and adjust (or renew) distributor contact points
12. Check and adjust, if necessary, carburetor idling and mixture
13. Check engine oil filler cap and emission control valve
14. Check and adjust valve clearances
15. Check fan belt tension and adjust if necessary
16. Clean fuel pump screen or separate fuel line filter
17. Check manual gearbox oil level
18. Check rear axle oil level
19. Check tightness of rear road spring U bolt nuts
20. Adjust drum brakes and check linings for wear
21. Check front disc brakes for pad wear
22. Check brake flexible hoses for deterioration
23. Check all cooling system hoses for deterioration
24. Check exhaust system for damage or leaks
25. Check steering ball joints for wear or damaged rubber dust excluders
26. Check steering gear rubber bellows for deterioration
27. Check clutch free movement and adjust if necessary
28. Oil all engine controls, door hinges and locks etc.
29. Check condition of steering shaft flexible coupling and renew if necessary

Eighteen - monthly or every 18,000 miles (29,000 km)

30 Renew air cleaner element
31 Renew brake servo air filter (where servo fitted)

Thirty - monthly or every 30,000 miles (48,000 km)

32 Clean, repack with grease and adjust front wheel bearings

Forty - monthly or every 40,000 miles (64,000 km)

33 Renew all flexible brake hoses, cylinder seals and hydraulic fluid within the system.

Illustration 2: Typical Shop Office Cleaning Programme

(Adjacent to machine-shop area, in use three shifts, men's and women's rest rooms and conference room included: asphalt tile floor, painted walls, metal furniture).

Once each shift

1. Replenish soap, and tissue dispensers
2. Sweep rest room floors
3. Clean washrooms

Once each day

4. Sweep office floors
5. Empty wastepaper baskets
6. Empty and wipe ash trays and smoking stands
7. Dust tops of desks, tables, and file cabinets
8. Empty pencil sharpeners
9. Clean chalk boards and erasers
10. Clean drinking fountains
11. Spot-clean doors, partition glass, walls
12. Wet-mop rest room floors
13. Clean toilet bowls
14. Clean urinals
15. Clean plumbing supply lines, drainpipes
16. Clean mirrors
17. Clean supply closet
18. Replenish napkin dispenser
19. Empty napkin disposal receptacles

Once each week

20. Wet-mop and machine-buff office floors (alternate with No. 21)
21. Machine-scrub and buff office floors
22. Machine-scrub and buff rest room floors
23. Dust furniture
24. Dust window sills, ledges
25. Wash interior glass, display cases, shelves, doors
26. Wash ash trays and smoking stands
27. Vacuum air vents
28. Wash toilet booth partitions
29. Acid-clean toilet bowls and urinals

30. Paraffin-treat toilet seats
31. Spray rest rooms for insect control

Once each month

32. Wash rest room walls
33. Machine-scrub and refinish rest room and office floors

Once each 3 months

34. Wash desks, tables, chairs, file cabinets

Once each 6 months

35. Wash light fixtures
36. Wash wastepaper baskets
37. Wash exterior glass

Once each year

38. Wash walls and ceilings

TABLE 1 : TIME ANALYSIS FOR FEEDMILL MAINTENANCE (ASSUMING ONE WORKMAN)

TYPES OF ITEM FOR MAINTENANCE	NUMBER OF EACH TYPE OF ITEM ON THE MILL (A)	OBSERVED MEAN TIME ON MAINTENANCE OF EACH TYPE OF ITEM (min) (B)	TOTAL MAINTE-NANCE TIME ON EACH TYPE (min) (C) = (A) x (B)	ESTIMATED NO. OF MAINTE-NANCE CHECKS PER YEAR (D)	TOTAL MAIN-TENANCE TIME ON EACH TYPE PER YEAR (min) (E) = (C) x (D)
Electric Motors (with controls)	16	20	320	44	14,080
Belts	31	15	465	44	20,460
Bearings	34	20	680	3	2,040
Gear Boxes	5	20	100	1	100
Platform Scales	2	60	120	12	1,440
Silos	2	480	960	4	3,040
Weigh Bin Scales	1	30	30	12	360
Bagger	1	60	60	12	720
Inlet Receivers	2	15	30	12	360
Check Gates	2	15	30	12	360
Total time spent on scheduled maintenance in 1 year				=	43,760

TABLE 2: MAINTENANCE SCHEDULE FOR ELECTRIC MOTORS AND THEIR CONTROLS

ELECTRIC MOTOR LOCATION AND DENTIFICATION	RATING	WEEK-DAY OF MAINTENANCE				
		MON	TUE	WED	THUR	FRI
Portable Auger	220/440V, 1440rpm, 2hp	x				
Concentrate Auger (from silo)	220/440V, 3600rpm, 20hp	x				
Corn Auger (from silo)	220/440V, 3600rpm, 20hp	x				
Hammer Mill	230/460V, 3540rpm, 25hp				x	
Hammer Mill Outlet Screw Conveyor	230/460V, 1200rpm, 1.5hp				x	
Weigh Bin Smaller Inlet Screw Conveyors (2 in number)	230/460V, 1725rpm, 2hp	x				
Weigh Bin Bigger Inlet Screw Conveyor & Limit Switch	415V, 1445rpm, 5.5hp	x				
Weigh Bin Outlet Screw Conveyor	230/460V, 1725rpm, 2hp				x	

KEY TO SYMBOL x = Weekly Maintenance

TABLE 3: MAINTENANCE SCHEDULE FOR BELT DRIVES

BELT DRIVE LOCATION	MAKER'S IDENTIFICATION	NUMBER ON DRIVE(S)	WEEK DAY OF MAINTENANCE				
			MON	TUE	WED	THUR	FRI
Concentrate Auger (from silo)	Fenner B1490 B57	2	x				
Corn Auger (from silo)	Hutchinson 320 57 L2 S	2	x				
Hammer Mill	Fenner B2020 B78	1				x	
Hammer Mill Gear Boxes	89 PY SINGAPORE	1				x	
Weigh Bin Smaller Inlet Screw Conveyors	Fenner B1260 B48	4 (2 per drive)	x				
Weigh Bin Bigger Inlet Screw Conveyor	Hi-Power B51 L2 S 31	2		x			
Mixers	Power Flite B120 550 U 1	6		x			
Mixer Gear Boxes	Hi-Power II B51 V80	1					x

KEY TO SYMBOL x = Weekly Maintenance

TABLE 4: TIME ANALYSIS FOR SCHEDULED AUTOMOBILE FLEET MAINTENANCE

TYPE OF MAINTENANCE ACTIVITY	AVERAGE TIME TAKEN FOR EACH MAINTENANCE ACTIVITY BY TWO MEN (a) in hours	NO. OF EACH TYPE OF MAINTENANCE ACTIVITY IN 360 MONTHS (b)	TOTAL TIME FOR EACH TYPE OF MAINTENANCE ACTIVITY (c) = (a) x (b) in hours
Weekly	1	$\frac{360}{1/4} = 1440$	1440
6 – Monthly	1	$\frac{360}{6} = 60$	60
18 – Monthly	0.5	$\frac{360}{18} = 20$	10
30 – Monthly	0.5	$\frac{360}{30} = 12$	6
40 - Monthly	2	$\frac{360}{40} = 9$	18
Total time for scheduled maintenance in 360 months on 1 vehicle		=	**1534**

TABLE 6: MAINTENANCE SCHEDULE FOR A FLEET OF 20 VEHICLES FOR 40 MONTHS

VEHICLE NUMBER	MONTH OF THE YEAR 1993												MONTH OF THE YEAR 1994												MONTH OF THE YEAR 1995												MONTH OF THE YEAR 1996				VEHICLE NUMBER
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	
1	o						+						+						o					+						△						+				□	1
2	△	o						+						+						o					+						△					□	+				2
3		△	o						+						+						o					+						△					□	+			3
4			△	o						+						+						o					+						△					□	+		4
5				△	o						+						+						o					+						△					□	+	5
6		□			△	o						+						+						o					+						△						6
7	+		□			△	o						+						+						o					+						△					7
8		+		□			△	o						+						+						o					+						△				8
9			+		□			△	o						+						+						o					+						△			9
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14		+						+						o						+						+	△					o					+		□		14
15			+						+						o						+						+	△					o					+		□	15
16	□			+						+						o						+						+	△					o					+		16
17		□			+						+						o						+						+	△					o					+	17
18			□			+						+						o						+						+	△					o					18
19	o			□			+						+						o						+						+	△					o				19
20		o			□			+						+						o						+						+	△					o			20

NOTES

1. Weekly maintenance is not shown
2. The 18 - monthly and 30-monthly maintenance activities also incorporate the 6 - monthly maintenance.

KEY TO SYMBOLS

+ = 6 - Monthly maintenance
o = 18 - Monthly maintenance
△ = 30 -Monthly maintenance
□ = 40 -Monthly maintenance

TABLE 6: TIME ANALYSIS FOR SCHEDULED OFFICE CLEANING

TYPE OF CLEANING FUNCTION	NO. OF WORKMEN REQD FOR PARTICULAR CLEANING FUNCTION (a)	AVERAGE TIME TAKEN FOR EACH FUNCTION (b) (in h)	MAN-HOURS REQD FOR PARTICULAR FUNCTION (c) = (a) x (b)	NO. OF EACH TYPE OF FUNCTION IN 1 YEAR (d)	TOTAL MAN-HOURS FOR EACH TYPE OF FUNCTION IN 1 YEAR (e) = (c) x (d)
Once-a-shift (3 shifts a day)	2	0.5	1	3 x 365 = 1095	1095
Daily	2	2	4	365	1460
Weekly	4	4	16	52	832
Monthly	4	4	16	12	192
3 - Monthly	4	6	24	4	96
6 – Monthly	4	8	32	2	64
Yearly	4	20	80	1	80
Total man-hours for scheduled cleaning in 1 year				=	3,819

TABLE 7 : SCHEDULE FOR BUILDING MAINTENANCE

BUILDING TRADE	MONTH OF THE YEAR 1993												MONTH OF THE YEAR 1994											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PAINTING						○						□						○						□
MASONRY												□												□
ROOF												□												□
IRONMONGERY AND WELDING					○						□						○						□	
CARPENTRY												□												□
ELECTRICAL		□			x			x			x			□			x			x			x	
PLUMBING			□			x			x			x			□			x			x			x
AIR CONDITIONING	x			○			x			□			x			○			x			□		

KEY TO SYMBOLS

X = 3 - Monthly Maintenance
○ = 6 - Monthly Maintenance
□ = Yearly Maintenance

NOTES

1. Only 3 - monthly, 6 - monthly and yearly maintenance are listed.
2. The building trades listed are not exhaustive. Other trades may be included and some removed depending on the components of the particular building.
3. Yearly scheduled maintenance shall include 6 - monthly and 3 - monthly maintenance and 6 - monthly maintenance shall include 3 - monthly maintenance.
4. The detailed work description for each maintenance can be obtained from the different routine work programmes, such as Table 1.