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Organizational Bottlenecks in New Technology Implementation and Utilization

By

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This thesis is submitted as a partial fulfillment for the degree of Master of Science in Offshore technology, specialized in industrial asset management

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Abstract

The pace with which technology is currently developing is unparalleled in the history of mankind. Its development is continuously opening avenues through which tasks can be done in a more effective and efficient manner. It has therefore become the key for the sustained growth for any organization. But, despite its utility and need, organizations are unable to implement new technology.

This master thesis will present organizational bottlenecks which disable the implementation of new technology. The computerized maintenance management system of MEL has been used as a case study in this thesis. The current system in place is run primarily through a paper work order which is issued when maintenance action is required. The data on the work order is typed into a Microsoft Excel based system through which maintenance reports are generated to enable management to make decisions.

The thesis highlights the bottlenecks related to management, tradition, costs and skill of the employees disabling the upgradation of the system to meet the organizational needs. The problems arising as a result and the overview of the limited reliability and functional capability of the current system is also presented. The thesis also discusses why an attempt to automate the system has failed.

The thesis finally establishes the causes of the existence of bottlenecks restricting technology implementation. It then presents a model solution based on Technology Acceptance Model and Kurt Lewin's theory of change which can be applied to upgrade CMMS in line with new technology to minimize downtime and optimize asset performance.

Key Words: Technology acceptance, computerized maintenance management system, change implementation

List of Abbreviations

%DT – Percentage Downtime

CMMS – Computerized Maintenance Management System

DT – Downtime

ERP – Enterprise Resource Planning Software

Excel – Microsoft Excel

JE – Junior Executive (Equivalent to a foreman)

MIR – Manual Issue Requisition

MEL - Millat Equipment Limited

MEL ERP - Millat Equipment Limited’s Enterprise Resource Planning Software

MTBF- Mean Time between Failures

MTTR – Mean Time to Restore

TAM – Technology Acceptance Model

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1. Introduction

1.1. Background

The role of technology has become pivotal since the industrial revolution. The needs of the masses have change drastically and thereby methods through which they are satisfied. The need for greater output and new innovative solutions are on the rise due to the changing possibilities offered as a result of technological development.

The escalated pace of technological advance is driving organizations to adapt, change and implement the new technologies. Regardless of the unquestionable need to adapt and implement new technologies available, organizations are facing numerous challenges making the transitions from existing setups to the ones which comply with the advanced technology difficult.

Although, continuous transition and adjustment to the new technology is imperative for an organization to stay in business, organizations are faced with different hurdles while implementing and adapting new technology. Excessive resistance towards new technology implementation is one which the primary driver of organizations plunging in to bankruptcy. The resistance towards new technology is derived from the bottlenecks present in the organization against the adaption of new technology. The world has witness serval multinational even global icons fall as a direct result of failure to embrace the emerging technology. Notable mentions include Xerox, Nokia and Atari. Thus, it is evident that new technology implementation is necessary for productivity, innovation and asset performance and thereby ensures growth, development and sustenance of any organization.

In an organization, change of any type is often resisted regardless of its domain. From the layout of the machines to the production schedule, change is accompanied by a natural disinclination towards it. The bottlenecks and aversion to change is generally manifested through the traditional practices prevailing in the organizations, resistance in learning new technology and costs associated with it. Although the new technology implementation clearly enhances the productivity embracing new technology faces resistance.

1.2. Problem Formulation

Despite the advance in technology the CMMS being maintained by the planning and documentation section of the maintenance department in MEL is manual in nature. The fundamental problem is that it is solely running through a work order form. All the fields present on the work order form are hand written, they are later read and typed into an Excel based CMMS from which relevant reports are generated to enable management to take actions and make decisions. An attempt was made to automate the existing system by development of a CMMS module which could be integrated with the organization's ERP (MEL ERP) which mainly deals with production numbers, but it failed. In the light of these facts, following problems have been considered;

1. What are the causes of resistance towards upgradation?
2. Why has the attempt to automate CMMS failed?
3. Why is it important to upgrade?

1.3. Main Objectives & Sub Objectives

1.3.1. Main Objective

The primary objective is to identify bottlenecks in the implementation and utilization of new technology with respect to the CMMS prevalent in Millat Equipment Limited and suggest a model solution through which the bottlenecks towards CMMS automation can be eliminated.

1.3.2. Sub Objectives

1. Assessment of the CMMS at present.
2. Identification of bottlenecks, problems arising as a result of the presence of bottlenecks and its analysis.
3. Identification of the causes of existence of bottlenecks and presentation of a model through which the bottlenecks could be eliminated.

1.4. Research Method

Millat Equipment Limited was taken as a case study. Their existing maintenance management system was reviewed by analyzing the kind of work and the manner through which it is conducted on it. The research then highlights the bottlenecks in the way of the implementation of new technology and on grounds of the research proposes a model for the elimination of bottlenecks.

1.5. Scope & Limitations

The research aims to present tangible ways through which the unwillingness, inability, and resistance towards the embracement and implementation of a new, automated CMMS can minimized and even eliminated as the role of new technology in the growth of organizations is unquestionable. The research is primarily focuses on the maintenance management of Millat Equipment Limited.

2. Literature Review

2.1. Introduction

Resistance towards technology and unwillingness to let go of prevailing practices are the major hurdles in the way of new technology implementation. This chapter reviews theories which address the areas of resistance and change. The psychological aspect has also been considered.

2.2. Resistance towards Technology

According to Oxford dictionary resistance is defined as "*The refusal to accept or comply with something*". Thus resistance can be described as remaining unaffected or remaining intact. Resistance can more compressively be defined as the reluctance or unwillingness towards new ideas, concepts, models, or technology (Dent, 1995). When resistance is left unattended the forces and persistence which encourage the employee to maintain particular behaviors become stronger (Steinburg, 1992). Trainers and managers across the globe consider resistance as a key problem facing the organizations (West, 1994).

Technology is defined as "*The application of scientific knowledge for practical purposes, especially in industry*" as per the oxford dictionary. Technology in itself does not pose a challenge, it is the advancement in technology that the organization must adapt to, to stay competitive. Advanced technology integrated with production systems is a requirement to achieve high reliability in organizations (Karlene, 1989). But the benefits of new technology can only be reaped if the ability and willingness amongst the employees of an organization is present (Eason, 1992).

Thus, resistance towards technology can be described as reluctance to accept the proposed technological which is available. This is manifested by disapproving new technology as something negative and unnecessary. Thus in order to introduce a technological change or during the implementation of new technology, resistance is the key hurdle that must be addressed. It is therefore important that the key causes and reasons from which resistance results are discovered and addressed. Only by understanding and appreciating the causes of resistance can the solutions be developed (Kirkpatrick, 1993). However pinpointing the causes of resistance is the most challenging aspect while studying resistance (Sevier, 2003).

Resistance can only effectively be overcome once the underlying causes are targeted instead of spontaneous decisions targeted to bring an immediate change. One fundamental way of overcoming resistance is through focused training. Training often is met with resistance from learners who make the training ineffective, but this should not deter the management from executing it (Kotter, 1995). If the training is not focused and the aim is arbitrary the resistance towards change would rise instead of getting abated. There is clear evidence, that investment of any sort if properly designed and targeted is profitable for the organization (Clark & Estes, 2002).

In the current dynamic and global environment, implementation of new technology is no longer a choice to remain sustainable and competitive. Inability to transform the organization in line with new technology may lead to loss in both productivity and profits. It is essential to highlight that sustained success and completive edge of any organization are directly related towards its ability to learn and adapt (West, 1994).

2.3. Theory of Reasoned Action

Fishbein and Ajzen developed the theory of reasoned (Fishbein & Ajzen, 1975) which facilitates in understanding human behavioral outcomes. The theory has psychosocial roots and is linked with the behavioral school of thought in psychology. The theory aims at providing the link of human actions and behavior resulting from attitudes and norms.

According to this theory the underlying behavioral intention of a person to perform a certain action determines the actual behavior, meaning that intentions guide actions. The intentions of a person are based on pre-existing attitudes and subjective norms. Subjective norms are defined as "*the person's perception that most people who are important to him think he should or should not perform the behavior in question*" (Fishbein and Ajzen 1975, p.302). The attitude of a person is however determined by the consequence based on belief of the action, multiplied with the evaluation of consequence.

In short, theory of reasoned action hypothesizes actual behavior or actual performance is an outcome of intention which is shaped by the person's attitude and subjective norms. Factors other than attitude and subjective norm do shape the performance but only in an indirect manner. Factors having indirect effect upon behavior are classified as external variables which may include organizational structure and job characteristics. (Davis, Bagozzi and Warshaw, on 1989). A diagrammatic representation of the theory is as follows.

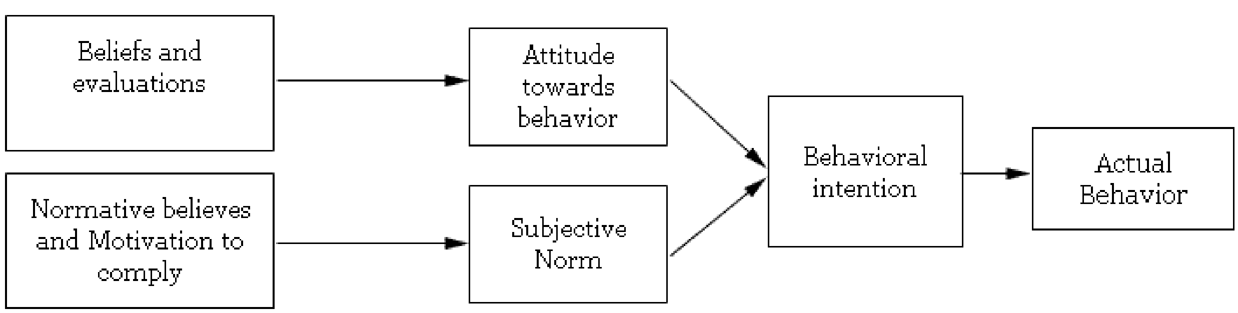


Figure 2.1 Theory of Reasoned Action (Davis, Bagozzi and Warshaw, 1989)

2.4. Technological Acceptance Model

The growing technological integration in organizations starting from the 70s posed the challenge of developing a criteria through which technological acceptance or rejection could be gauged. For this, technological acceptance model was developed by Fred Davis in 1985 (Davis, 1985). The theoretical foundation of this model is based on theory of reasoned action. The main objective was to device a model through which acceptability of technology could be predicted, so that along with the acceptability of a particular technological aspect the changes required to make it acceptable to the organizational employees could be developed.

Davis proposed that the actual use of technology is dependent upon the motivation of the user which is derived externally from the features and capabilities of a system. In technological acceptance model Davis substituted the components of attitude and subjective norm with perceived ease of use and perceived usefulness. The diagrammatic representation of the model is as follows.

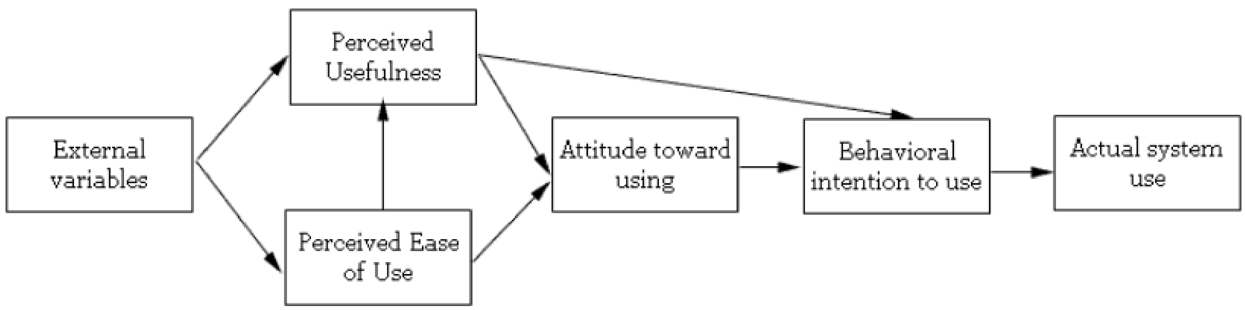


Figure 2.2 Technology acceptance model (Davis, Bagozzi and Warshaw, 1989)

Perceived usefulness: “T*he degree to which an individual believes the use of a system could enhance job performance*” (Davis, 1993, p. 477).

Perceived ease of use: “*the degree to which the individual believes that using the system would require little or no mental and physical effort*” (Davis, 1993, p. 477).

Actual System Use: Outcome of individual behavior regarding the system (Davis, Bagozzi, & Warshaw, 1989).

Similar to theory of reasoned action, Davis in his technology acceptance model argues that technological acceptance is dependent upon behavioral intention which is derived from the attitude of a person towards a particular technological system. Here the fundamental difference between the theories is that the intention to use technology is determined by attitude only in technology acceptance model whereas the intention to do in theory of reasoned actioned is determined by attitude and subjective norms. According to technology acceptance model the attitude towards using a technology is formed by the person’s perception dependent on 2 factors i.e. perceived ease of use and perceived usefulness. Thus the perception is based upon the utility and the impact that the system would have on the output along with the ease with which the user can utilize the technology. Research by Larcker and Lessig has shown that perceived usefulness and perceived ease can be considered as two distinct variables (Larcker and Lessig, 1980). But at the same time there exists a direct link in between the two as well. If two systems of equal utility exist the user would opt for the one which has greater perceived ease of use (Dillon and Morris, 1996).

The concept of perceived ease of use is based on self-efficacy a concept proposed by Albert Bandura (Bandura, 1982). Self-efficacy is "*people's faith in their ability to carry out a particular behavior or produce a desired outcome.*" (Feldman, 2011, p.452). It can be established through the concept of self-efficacy that a system which is easy to use would yield greater self-efficacy. Technology which is easier to use will allow the user to have more control over what the user wants. By using a tool which requires less effort or is easier the user will be able to spare time and energy which can be channeled to accomplish other tasks.

According to the technology acceptance model the impact of perceived usefulness on behavioral intention is greater than perceived ease of use as there exists a direct link between the two (Davis, Bagozzi and Warshaw, 1989). Therefore the utility in doing the job better provided by new technology's implementation has a greater influence on the actual system use than the perceived ease of use. This has been proven by Schultz and Selvin in 1975 (Shultz and Selvin, 1975). The correlation of perceived usefulness and system usage was reconfirmed by Robey in 1979 (Robey, 1979).This is because the performance of an employee is linked with extrinsic awards such as increase in salary and promotions (Davis, Bagozzi and Warshaw, 1989). It must however be noted that there are studies that suggest that there exists not empirical relation between perceived usefulness and system usage notable mentions included Szajna (1996) and Lucas and Spitler (1999).

2.5. Technology Acceptance Model's Extensions

Critiques such as Cahu believe that as the technology acceptance model only uses 2 variable to describe actual use, and therefore believe that it is over simplified (Chau, 1996). Another critique is that the model only provides a general framework rather than a specialized one. (Mathieson, 1991). These deficiencies in the model lead to the creation of extension to the original model. One of the extension is known as TAM2. TAM2, developed by Venkatesh & Davis, it gives more weight to perceived usefulness in terms of influencing actual behavior by postulating that perceived usefulness is affected by social and cognitive processes (Venkatesh & Davis, 2000). The social processes include subjective norm, image and voluntariness whereas the cognitive processes includes output quality, job relevance, result demonstrability. A diagrammatic represent is presented below.

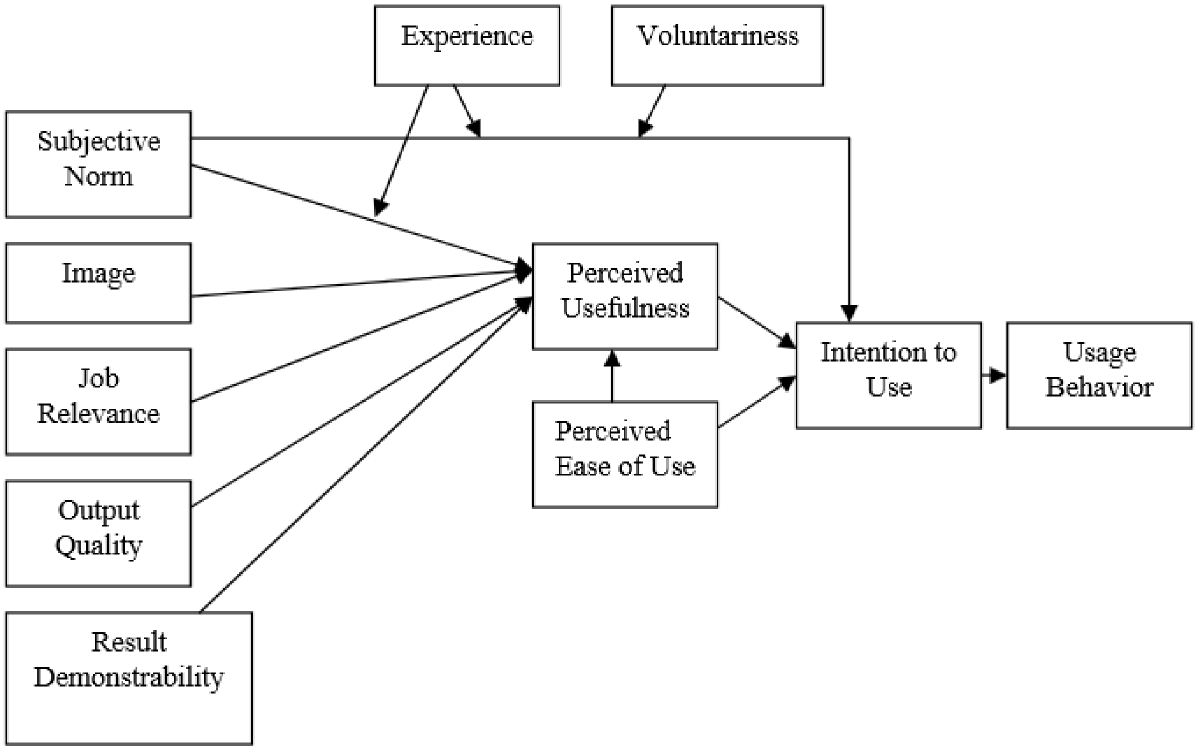


Figure 2.3 Technology Acceptance Model Extension TAM 2 (Venkatesh & Davis, 2000)

A more recent extension of the model is presented by Mc Farland and Hamilton (Mc Farland and Hamilton, 2006). According to them system usage (the dependent variable) is affected by three mediating variables which are computer efficacy, perceived ease of use and perceived usefulness. The three mediating variables are directly affected by six external factors which are task structure, computer anxiety, prior experience, organizational support, system quality and other's use. The notable thing about this extension is that it also suggests a direct link between the external and dependent variable. Another notable point is that according to this extension computer efficacy is the most significant mediating variable as it affects perceived ease of use which affect perceived usefulness. The diagrammatic representation of the model is as below.

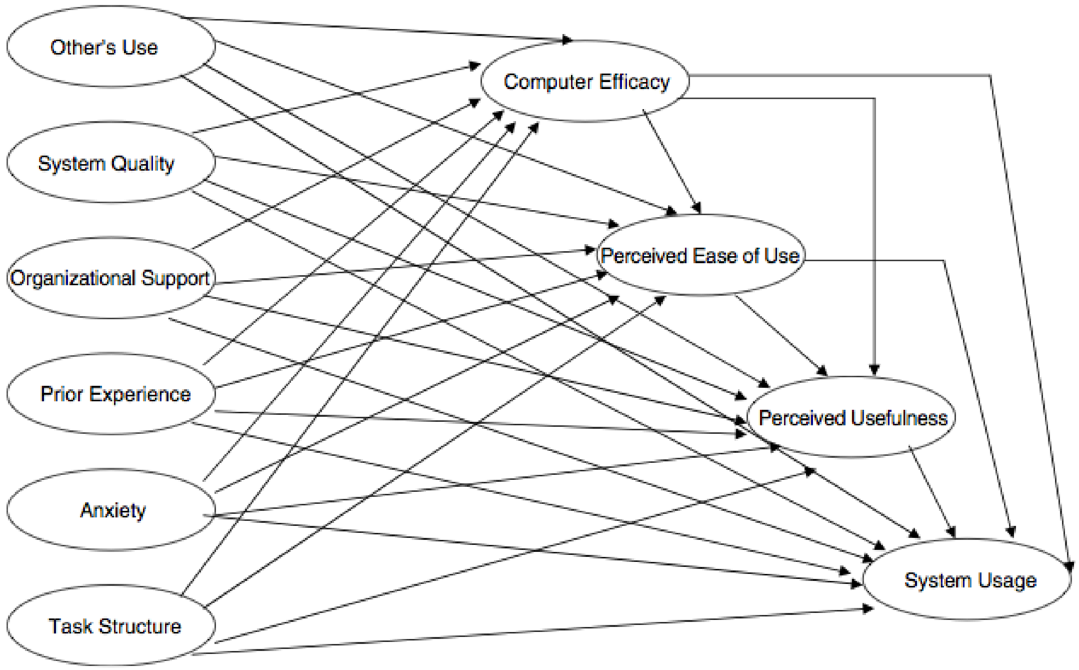


Figure 2.4 Technology Acceptance Model Extension (Mc Farland and Hamilton, 2006)

2.6. Kurt Lewin's Change Model

"It is not the strongest of the species that survives, nor the most intelligent, but the one most responsive to change" – Charles Darvin

The global organizational environment is dynamic. Organizations must continually reassess their technological approach to sustain business. Technology is continuously changing the scope and work of the organizations (Robbins and Judge, 2013). New technology can only by implemented once the old is replaced or substituted. This transformation requires change.

One approach towards change is suggested by Kurt Lewin where he argues that intended positive change can occur as an outcome when the organization manage their change. He argues that effective change can be brought through by first unfreezing then changing followed up by refreezing as represented in the diagram below (Lewin, 1951).

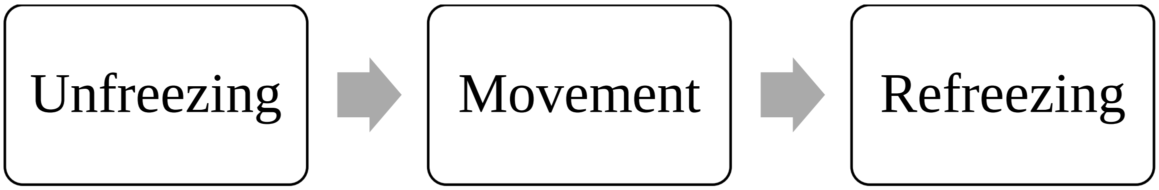


Figure 2.5 Lewin's Three Step Change Model (Lewin, 1951)

The three terms can be defined as (Robbins and Judge, 2013, p. 585).

Unfreezing: "Changing to overcome the pressures of both individual resistance and group conformity"

Movement: "A change process that transforms the organization from the status quo to a desired state."

Refreezing: "Stabilizing a change intervention by balancing driving and restraining forces."

Lewin states that organization before change are in a state of equilibrium. The equilibrium sate is also referred to as status quo which must be unfrozen in-order to accommodate the change. Just as in the theory of physics when an organization is the state of equilibrium forces are balanced and therefore it remains "stationary" and thereby unwilling to accommodate change. According to Lewin every change is an outcome of 2 types of forces. The driving forces which encourage change and the restarting forces which discourage the change.

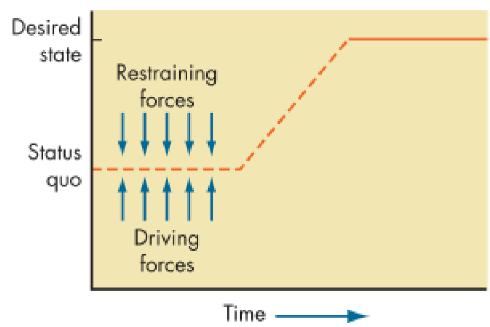


Figure 2.6 Lewin's Forces (Robbins and Judge, 2013)

To reach the desired state a shift is required from the status quo. The shift can be achieved either by increasing the driving forces while keeping the restraining forces constant or vice versa. The most preferable method is to simultaneously increase the driving forces while decreasing the restraining forces. The inability to unfreeze due to high restraining forces are generally exist in organizations who have achieved successes in the recent past as change on offer is considered unnecessary (Audia, Locke and Smith, 2000). In organizations where a strong culture and traditional practices exists, incremental change is more likely to be adopted, where as a radical change is opposed by high restraining forces (Sørensen and Sorensen, 2002). In such organizations culture presents the greatest threat to change as research proves that for a change to be effective it has to happen quickly (Amis, Slack and Hinings, 2004).

3. Case Study: CMMS of Millat Equipment Limited

3.1. Introduction of the Company

Millat Equipment Limited (MEL) is a part of Millat Group which in all contains four companies. MEL is a leading manufacturer of transmission gears primarily for tractors in Pakistan. Its products include ring, helical, spiral and bevel gears along with transmission shafts and hydraulic lift pumps (Millatgears.com, 2016).

MEL contains four engineering department which are design and development, production, maintenance, and quality control. The department of maintenance was probed into to determine the organizational bottlenecks in new technology implementation. For this technological use at present and the problems arising due to the gap between the existing and available technology was first analyzed to discover the bottlenecks for new technology implementation.

3.1.1. Focus

The situation of new technology and its implementation was analyzed in the planning and documentation section of the maintenance department. The focus of assessment was on the computerized maintenance management system (CMMS) at present, along with documentation and progress monitoring mechanism of new technology Capital-Expenditure (CAPEX) projects.

3.2. CMMS Module

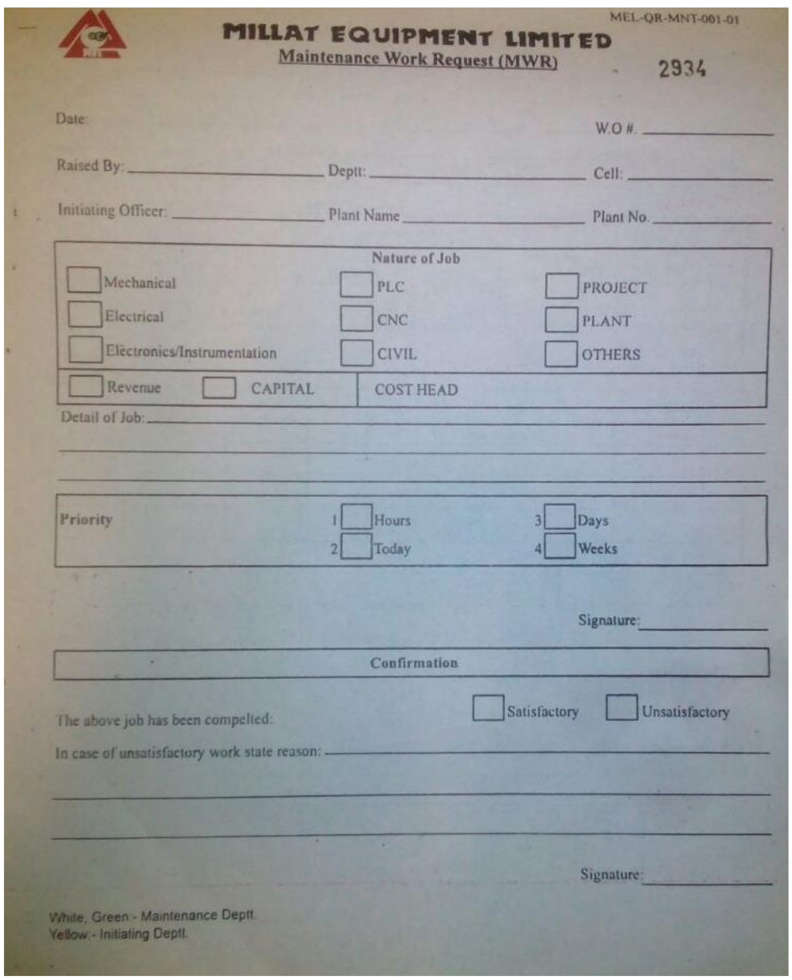
It is pertinent to highlight that MEL does have a centralized ERP system based on Oracle (MEL ERP). This system mainly deals with the routine production of gears and therefore is utilized primarily by the production and quality control departments. Maintenance personnel usually use MEL ERP system to make purchases of spares which are required if not already present in the inventory by “Indents” and to issue stock present for the troubleshooting of a particular machine examples include bearings, seals, relays etc. To issue a particular maintenance item a maintenance official must log on to MEL ERP and generate a Manual Issue Requisition (MIR).

It is also important to highlight that the maintenance department with the collaboration of the IT department has developed a basic interface through which the work orders can be electronically generated. The new module developed enables the respective departments to generate/issue maintenance work orders electronically, but this initiative has so far failed, the departments continue to raise manual work orders instead of electronic work orders. The working of the manual CMMS is present below.

CMMS is supposed to contain a database of company's maintenance operations (Mather, 2003). In Millat Equipment Limited, the efficiency of the entire maintenance department is gauged on largely three main KPIs the percentage downtime (%DT) and the mean time to restore (MTTR) and commissioning of new technology through CAPEX. To determine and evaluate the progress of these parameters a mini CMMS system is developed on Microsoft Excel.

3.2.1. Work Order Generation & Data Collection

Whenever a machine requires troubleshooting which is often due to a breakdown a maintenance work order is initiated on a paper the work order form is as below.


MEL-QR-MNT-001-01

MILLAT EQUIPMENT LIMITED

Maintenance Work Request (MWR)

2934

Date:

W.O #. ____________

Raised By: ____________ Deptt: ____________ Cell: ____________

Initiating Officer: ____________ Plant Name ____________ Plant No. ____________

Nature of Job

☐ Mechanical ☐ PLC ☐ PROJECT

☐ Electrical ☐ CNC ☐ PLANT

☐ Electronics/Instrumentation ☐ CIVIL ☐ OTHERS

☐ Revenue ☐ CAPITAL | COST HEAD

Detail of Job: ____________

Priority 1 ☐ Hours 3 ☐ Days

2 ☐ Today 4 ☐ Weeks

Signature: ____________

Confirmation

The above job has been compelied: ☐ Satisfactory ☐ Unsatisfactory

In case of unsatisfactory work state reason: ____________

Signature: ____________

White, Green - Maintenance Deptt.
Yellow - Initiating Deptt.

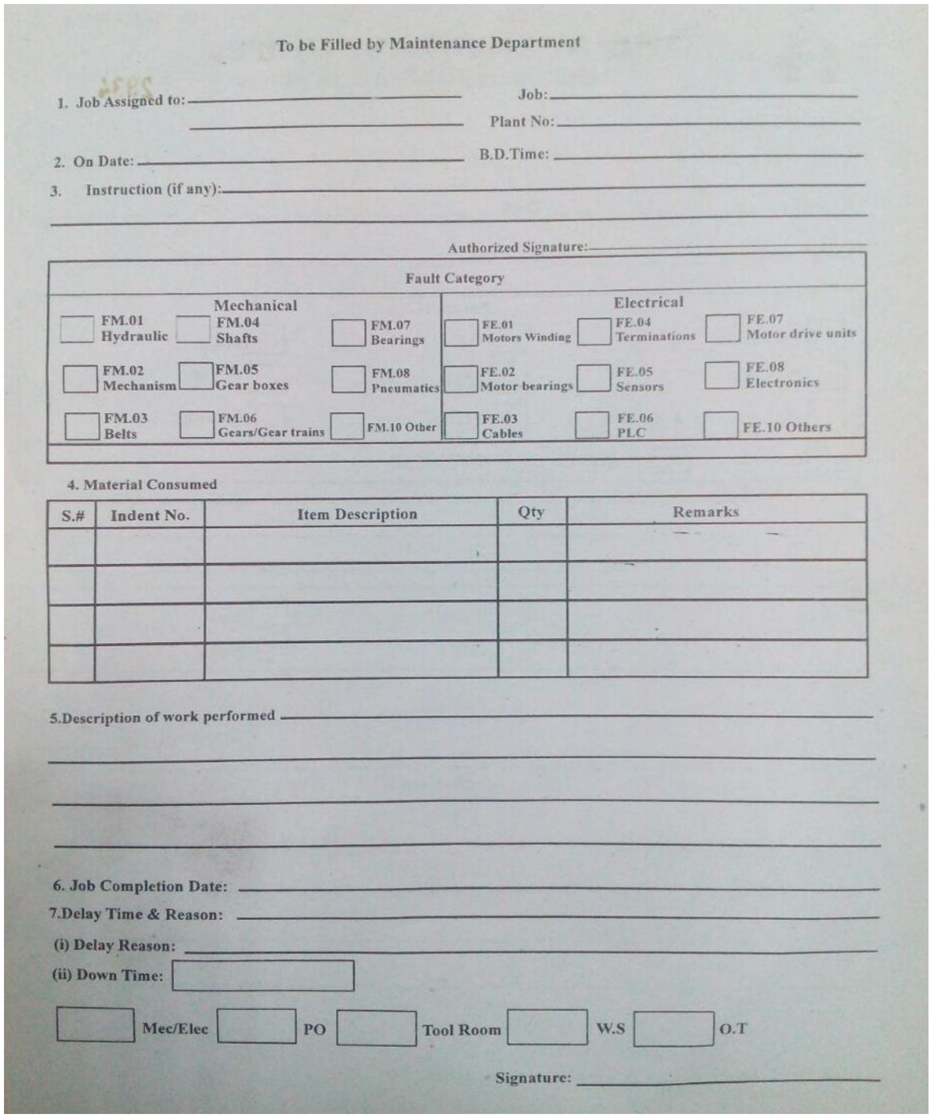
Figure 3.1 Front Side of the Maintenance Work Order

The definition of Work Order fields along with examples is given below.

Field	***Definition***	***Example***
Raised By	The name of the department raising the work order.	Production
Department	The name of the sub-department or a specified area of the department which raises the work order.	Spur Gear
Cell	The name of the cell of the department.	Spur Gear A
Initiating Officer	The name of the officer who initiates the work order. Normally done by a JE (Junior Executive).	Name of the JE
Plant Name	Name of the machine.	Milling
Plant Number	Number of the machine. This is a MEL ERP based number to identify a particular machine.	162027
Nature of Job	Signifies the nature of job. If the work order is for a breakdown the job would either be electrical or mechanical in nature.	Mechanical
Priority	This signifies the priority of the work order. This bears little to no value as no provision to record priority exists in the Excel based CMMS.	Hours
Detail of Job	The apparent problem with the machine as noticed by the worker or cell in-charge.	Lubrication Problem
	After the Completion of Maintenance Work	
Confirmation	Upon completion of work the work order is closed by the signature of the person who raised the work order.	N/A

Table 3.1 Description of Maintenance Work Order Fields

Everything field is handwritten along with the date and time. The work order is then submitted to the maintenance's planning and documentation department where it is received. The work order is then forwarded to either the mechanical or the electrical team depending upon the problem. Depending on the problem the work order is routed by the planning and documentation department to the section in-charge of the concerned department who is by rank an Assistant Manager. For instance if the work order is of the Ring Gear cell of the production department, the work order after receiving will be routed to the Assistant Manager of Ring Gear Cell. The concerned section in-charge assigns the job to his junior staff and instructs them regarding the work to be carried out.


To be Filled by Maintenance Department

1. Job Assigned to: ______________________ Job: ______________________
Plant No: ______________________

2. On Date: ______________________ B.D.Time: ______________________

3. Instruction (if any): ______________________

Authorized Signature: ______________________

Fault Category					
Mechanical			Electrical		
FM.01 Hydraulic	FM.04 Shafts	FM.07 Bearings	FE.01 Motors Winding	FE.04 Terminations	FE.07 Motor drive units
FM.02 Mechanism	FM.05 Gear boxes	FM.08 Pneumatics	FE.02 Motor bearings	FE.05 Sensors	FE.08 Electronics
FM.03 Belts	FM.06 Gears/Gear trains	FM.10 Other	FE.03 Cables	FE.06 PLC	FE.10 Others

4. Material Consumed

S.#	Indent No.	Item Description	Qty	Remarks

5.Description of work performed ______________________

6. Job Completion Date: ______________________

7.Delay Time & Reason: ______________________

(i) Delay Reason: ______________________

(ii) Down Time:

Mec/Elec PO Tool Room W.S O.T

Signature: ______________________

Figure 3.2 Rear Side of the Maintenance Work Order

The required maintenance work is then carried out after which the same work order is given to the parent department for closure if the machine runs in a satisfactory manner the work order is closed by signing on work order document under the confirmation section.

Before submitting the work order to the planning and documentation department the concerned mechanical or electrical team classifies the type of the problem.

Following are the categories of faults:

Mechanical Fault Categories	*Electrical Fault Categories*
1. Hydraulic	1. Motor Windings
2. Mechanism	2. Motor Bearings
3. Belts	3. Cables
4. Shafts	4. Termination
5. Gear Boxes	5. Sensors
6. Gears / Gear Trains	6. PLC
7. Bearings	7. Motor Drive Units
8. Pneumatics	8. Electronics
9. Others	9. Others

Table 3.2 Maintenance Fault Categories

Then the section in-charge handwrites any spares used in the process of maintenance in section 4 of the work order form. The item description, quantity used and the indent number (if an item required during maintenance is purchased through indentation on MEL ERP) is read off from the MEL ERP and is hand written along with material discarded during the maintenance operation. For instance if the fault was of mechanical nature related to type category 7 i.e. bearings the section in-charge is supposed to hand write the type of bearing replaced by handwriting the details of the bearing discarded and the issuance of number of the new bearing that is installed.

Any delay to due to the procurement of a non-available spares or machine work such as drilling or turning on a lathe machine is noted separately in section 7 so that downtime due to these delays can be separated from the real troubleshooting time. The description of delays is given in the following table.

Field	***Definition***
Mec/Elec	If a work order is raised to the mechanical team and upon diagnosis it is realized that the fault is electrical, the downtime in hours is attributed to the electrical team and not the mechanical team through this provision in the work order.
PO	If during maintenance, a spare which is not available in the inventory is required it is purchased through indent. From the time of indent until arrival of the spare the time in hours is written in this section.
Tool Room	If a spare requires machine work such as turning, facing, gridding etc. The time required to carry the required operation is attributed to the tool room.
W.S	If the troubleshooting of a machine requires re-winding of the electrical motor the downtime of hours is attributed to the winding shop.
Other	If the downtime is due to delay of any other form it can be noted in this section.

Table 3.3 Description of Delay Reasons (Section 7 of Work Order)

In short, the entire process starting from the initiation of the work order to the closure along with the details of the fault are manually noted.

3.2.1.1. Calculation of %DT & MTTR

After the end of every calendar month the entire data collected on paper is typed into an Excel file which serves as a CMMS module. Through the data at least all the following reports are generated.

1. Monthly Breakdown Report
2. Monthly Breakdown Report Cell Wise
3. Fault Analysis Report (Mechanical)
4. Fault Analysis Report (Electrical)

Supplementary Reports include;

1. Down Time Report – Contains the downtime in hours due to maintenance of the last 6 months including the current month.
2. Down Time % Report – Contains the downtime percentage due to maintenance of the last 6 months including the current month.
3. Trend Report – Contains the MTTR and %DT of the current and the last six months.
4. Top 5 B.D – Contains the list of top five breakdowns based on the longest time taken to troubleshoot.

3.2.1.1.1. Monthly Breakdown Report

This is the main report through which the monthly performance of the maintenance department is gauged as it determines the %DT and MTTR. Little attention is given to MTBF but it is still calculated and is a part of the report. The formulae used for the calculation are simple and listed in the report. A pictorial view a monthly breakdown report is as bellow;

No. of working days = 21							
No. of working Hrs. / day = 8							
Total No. of Machines = 452							
PARAMETERS	**Units**	**Mechanical**		**Electrical**		**Aggregate**	
PERFORMANCE							
No. of breakdowns (N)	No.	46		51		97	
Total Available Time (Ta) (Hrs.)	hrs.	75936.00		75936.00		75936.00	
Total Downtime (TDT) (Hrs.)	hrs.	440.00		189.60		629.60	
Total Uptime (UT) (Hrs.)	hrs.	75496.00		75746.40		75306.40	
Downtime % (DT%)	%	0.58		0.25		0.83	
MTBF (Mean Time Between Failure)		3.65		3.29		1.73	
MTTR (Mean Time To Restore) (hrs.)		9.57		3.72		6.49	
Down Time (Hrs)		**Hrs.**	**%**	**Hrs.**	**%**	**Hrs.**	**%**
Mechanical		233.00	0.31	5.00	0.01	238.00	0.31
Electrical		32.00	0.04	123.60	0.16	155.60	0.20
Purchase		17.00	0.02	3.00	0.00	20.00	0.03
Tool Room		158.00	0.21	0.00	0.00	158.00	0.21
Winding Shop		0.00	0.00	58.00	0.08	58.00	0.08
D & D		0.00	0.00	0.00	0.00	0.00	0.00
TOTAL		**440.00**	**0.58**	**189.60**	**0.25**	**629.60**	**0.83**

Total Available Time (Ta) (Hrs.)	= No. of working days* Hrs. per day * No.of ma
Total Downtime (TDT) (Hrs.)	= Total Down time due to breakdowns
Total Uptime (UT) (Hrs.)	= Ta - TDT
Downtime % (DT%)	= TDT*100 / Ta
MTBF (Mean Time Between Failure)	= Ta / (No. of machines * No of Breakdowns)
MTTR (Mean Time To Restore)	= TDT / (No of Breakdowns)

Figure 3.3 Monthly Breakdown Report – March 2016

It can be seen that for the month of March maintenance team took on average 6.49 hours to recover a machine from breakdown and that the machines were down by 0.83% of the total time.

3.2.1.1.2. Monthly Breakdown Report Cell Wise

This is similar to the monthly breakdown report. The only major difference is that it represents the detail of MTTR and %DT cell wise. This report enables the maintenance management to access the performance of teams operating in different cells. As evident form the data below the MTTR of Shaft cell is 7.40 and that of CNC is 2.20 which to the maintenance management means greater efficiency of maintenance in CNC as compared to shaft cell. A pictorial view a monthly breakdown report cell wise is as bellow;

No. of working days = 21																	
No. of working Hrs. / day = 8																	
PARAMETERS PERFORMANCE	Units	Shaft		CWP & Diff.		Spur & Coupler		CNC		HPC		Ring Gear		HT		QC, BCA, Store, T.R	
No. of Machines	No.	142		66		80		16		11		20		55		62	
No. of breakdowns (N)	No.	42		11		26		10		2		6		47		10	
Total Available Time (Ta) (Hrs.)	hrs.	23856.00		11088.00		13440.00		2688.00		1848.00		3360.00		9240.00		10416.00	
Total Downtime (TDT) (Hrs.)	hrs.	311.00		32.70		58.90		22.00		6.50		198.50		65.50		361.70	
Total Uptime (UT) (Hrs.)	hrs.	23545.00		11055.30		13381.10		2666.00		1841.50		3161.50		9174.50		10054.30	
Downtime % (DT%)	%	1.30		0.29		0.44		0.82		0.35		5.91		0.71		3.47	
MTBF (Mean Time Between Failure)	hrs.	4.00		15.27		6.46		16.80		84.00		28.00		3.57		16.80	
MTTR (Mean Time To Restore) (hrs.)	hrs.	7.40		2.97		2.27		2.20		3.25		33.08		1.39		36.17	
Down Time (Hrs)		**Hrs.**	**%**	**Hrs.**	**%**	**Hrs.**	**%**	**Hrs.**	**%**	**Hrs.**	**%**	**Hrs.**	**%**	**Hrs.**	**%**	**Hrs.**	**%**
Mechanical		160.00	0.67	26.00	0.23	13.50	0.10	3.00	0.11	6.50	0.35	29.00	0.86	17.50	0.19	17.70	0.17
Electrical		89.00	0.37	6.70	0.06	23.40	0.17	19.00	0.71	0.00	0.00	17.50	0.52	46.00	0.50	4.00	0.04
Purchase		12.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.00	0.24	0.00	0.00	318.00	3.05
Tool Room		11.00	0.05	0.00	0.00	3.00	0.02	0.00	0.00	0.00	0.00	144.00	0.00	0.00	0.00	22.00	0.21
Winding Shop		39.00	0.16	0.00	0.00	19.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.02	0.00	0.00
D & D		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL		**311.00**	**1.30**	**32.70**	**0.29**	**58.90**	**0.44**	**22.00**	**0.82**	**6.50**	**0.35**	**198.50**	**5.91**	**65.50**	**0.71**	**361.70**	**3.47**

Total Available Time (Ta) (Hrs.)	= No. of working days* Hrs. per day * No.of machines
Total Downtime (TDT) (Hrs.)	= Total Down time due to breakdowns
Total Uptime (UT) (Hrs.)	= Ta - TDT
Downtime % (DT%)	= TDT*100 / Ta
MTBF (Mean Time Between Failure)	= Ta / (No. of machines * No of Breakdowns)
MTTR (Mean Time To Restore)	= TDT / (No of Breakdowns)

Figure 3.4 Monthly Breakdown Report Cell Wise – March 2016

3.2.1.1.3. Fault Analysis Report (Electrical & Mechanical)

Downtime due to a particular fault category data is recorded in these reports so that the management can access which type of fault is causing the most breakdowns. A pictorial view a fault analysis report mechanical as bellow;

Sr.#	Machine Type	No. of B.D	TDT Hrs.	Avg. DT / BD	FAULT ANALYSIS REPORT FOR THE MONTH ON MARCH, 2016 (MECHANICAL)																	
					Hydraulic	DT Hrs.	Mechanism	DT Hrs.	Belts	DT Hrs.	Shafts	DT Hrs.	Gear Boxes	DT Hrs.	Gears / Gear Trains	DT Hrs.	Bearings	DT Hrs.	Pneumatics	DT Hrs.	Others	DT Hrs.
1	Gear Hobbers	8	69.00	8.63	1	15.00	2	14.00	1	1.00	0	0.00	1	7.00	0	0.00	0	0.00	3	32.00	0	0.00
2	Gear Shavers	1	4.00	4.00	0	0.00	0	0.00	0	0.00	0	0.00	1	4.00	0	0.00	0	0.00	0	0.00	0	0.00
3	Gear Shapers	3	181.00	60.33	0	0.00	2	21.00	0	0.00	0	0.00	0	0.00	1	160.00	0	0.00	0	0.00	0	0.00
4	Copy Lathe / Turning	7	45.30	6.47	4	20.80	2	18.00	0	0.00	0	0.00	0	0.00	0	0.00	1	6.50	0	0.00	0	0.00
5	Grinders	9	63.00	7.00	3	43.00	1	1.00	2	3.00	0	0.00	1	3.00	0	0.00	1	13.00	0	0.00	1	0.00
6	Tooth Roundings / Chamfering	3	8.50	2.83	0	0.00	1	3.50	1	1.50	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	3.50
7	Broach	0	0.00	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
8	CNC Machines	2	3.00	1.50	0	0.00	1	2.00	1	1.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
9	Other Machines	13	66.20	5.09	3	36.50	8	27.70	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	2.00	1	0.00
TOTAL		**46**	**440.00**	9.57	**11**	**115.30**	**17**	**87.20**	**5**	**6.50**	**0**	**0.00**	**3**	**14.00**	**1**	**160.00**	**2**	**19.50**	**4**	**34.00**	**3**	**3.50**
Avg. DT/Fault Category		9.57			10.48		5.13		1.30		0.00		4.67		160.00		9.75		8.50		1.17	

Figure 3.5 Fault Analysis Report Mechanical – March 2016

3.3. Purchases

There are two types of purchases; revenue expenses and CAPEX. The main difference between the two is that revenue expenses are costs incurred to keep production going such as cost of spares which may be oil seals, bearings, and hydraulic oil etc. for the machines. Parts under 1000 PKR are bought with hard cash whereas parts ranging from 1000 to 100,000 PKR are procured through a crossed cheque against the vendor.

CAPEX costs are investments in smart technology through which savings can be made. For instance a SCADA control system (Supervisory Control and Data Acquisition) on furnaces would ensure lower fuel consumption and vibration analyzer would help lower the number of breakdowns resulting in less downtime and greater productivity. Although the fundamental difference between the two lies in the return on investment, the actual practice is that any item worth less than 100,000 PKR is considered as revenue where as if it is over 100,000 PKR is consider as a CAPEX even if it does not provide a return on investment. As per the company record other than the services such as energy audit or ISO 9001 inspection no individual spare costs over 100,000 PKR.

The entire layout of the plant is cellular based. For the sake of clarification between the two purchases consider ring gear cell as an example. Two types of gears are produced in the Ring Gear cell i.e. Internal Ring Gear and Planetary Ring Gear. These are produced on 19 identical gear shaper machines present in the Ring Gear cell.

ITEM CODE	ITEM NAME	QTY REQUIRED	QTY ORDERED	QTY AVAILABLE	QTY BALANCE	MATERIAL ANALYSIS	DRAWING	MATERIAL AVAILABILITY	WORK ORDER TO TOOL ROOM	SERVICE INDENT	GATE PASS	MARKET SERVICES	RETURN TO STORE	INSPECTION	MIR	STATUS	REMARKS	Fabrication Detail	Vendor
150204031010	Saddle Assembly	12			11	OK	OK											Repairing	Haji iqbal
150203023010	Cutter Spindle	12	0	0	11			0	0					0			Hard Chrome / Grinding	Repairing	BISMILAUAH hardchrom
117010100010	Spindle Bush	12	0			0k	OK	0	0								Casting	Fabrication	Haji iqbal
150212011010	Spline shaft	12	0		0				0					0			Hard Chrome / Grinding	Repairing	German hardchrome
150203030110	Counter Shaft	12	6	0	0	OK	OK	5	5t\r			1market					Turning + Teeth Grinding	Fabrication	Afzal
112030590150	Main Shaft	12	6	0	0	OK	OK	5	5t\r			1market					Turning	Fabrication	Afzal
T/R	Cam Shaft	12	0	0				0						0			Turning	Fabrication	
15011050284	23 Teeth Spur gear	12	2	0		OK	OK	0		OK	OK	2market					Teeth cutting market	Fabrication	Afzal
150211050378	33 Teeth Spur Gear	12	2	0		OK	OK	0	0	0k		2market					Teeth cutting market	Fabrication	Afzal

Figure 3.6 Spare List of Ring Gear Cell

The list of critical spares of the Ring Gear cell is represented in the Figure 3.6 above. This list is not exhaustive in nature as it does not cover all the spares which may include O-rings, link belts and pulleys. All of the parts mentioned above are spares and thus their procurement would fall under revenue expenses.

3.3.1. CAPEX – Proposed New Technology

At the end of every financial year every department including maintenance develops a budget which is based on revenue expenses and capital expenses. Capital expenses form the most part of the budget as in this the maintenance department proposes the new technology that would be beneficial in reducing costs through less downtime and maintenance. The budget is as below. Item 2.1 "Vibration Analyzer" for instance is proposed for the preventive and predictive maintenance of gear shapper machines present in the Ring Gear cell primarily but can be used on other machines as well depending upon availability. According to the principles laid out by the company, there are two main reasons for this purchase being classified as a

CAPEX. Firstly it costs more than 100,000 PKR and secondly its application would yield savings. The CAPEX budget is as follows.

CAPEX Budget Maintenance			
Sr. No.	**Description**	**Qty**	**Amount (Rs. In Thousands)**
1	**Machinery Up-gradation & Reliability and Productivity Improvement**		
1.1	PLC`s And HMI`s (50 I/O's) for machines old Control Panels upgradation.	9	1,775
1.3	PLC`s and HMI`s (Induction Machines)	1	500
1.4	Machinery Development misc.		700
.			
2	**Maintenance Equipment and Software**		
2.1	Vibration Analyzer Equipment	1	550
3	**Electrical & Instrumentation Equipment**		
3.1	AVR`s for TOCCO Machine	2	3200
3.2	Soft Starter for Motor Generator on EMA Machine	1	550
3.3	Instrumentation Lab Equipment	1	250
3.4	Thermal Image Analyzer	1	600
4	**Plant Supervision and Monitoring**		
4.1	Furnaces SCADA System (for all furnaces)	1	2,500
4.2	Power Distribution SCADA System (for 30 Panels)	1	1,800
4.3	SCADA Server PC **** IT Budget***		
4.3	SCADA Software Upgradation	1	300
4.4	Thermal Mass Flow meters (gas) (for Gibbons & Birlec Furnaces)	2	750
6	**Energy Conservation**		
6.1	Burner Automation and SQF Burner Replacement with Fuel efficient Burner Self Recuperative Burners(one	4	6,000
6.2	Upgradation of Instruments and Control System of old EndoGas Generator.	1	1,500
6.3	LED Lights	636	795
7	**MACHINERY OIL FUMES EXTRACTION SYSTEM**		
7.1	Cutting Oil Fume Extraction System (Electrostatic Precipitator) to be installed on hobbing machines	15	2,925
7.2	(Coolers, Exhaust Fans, Ducts, Diffusers)	10	4,800
8	**UTILITIES**		
8.1	Piping Extension for Cooling Water Line	1	500
8.2	Oil Dispenser Trolleys	4	280
8.3	Oil Filteration unit	1	3,500
8.4	Heat Exchangers (Plate type)	6	900
8.5	Air Compressor Dryer	1	300
			34,975

Figure 3.7 CAPEX Maintenance Budget MEL

The list appears to seem exhaustive in terms of the proposal of the purchase of new technology at the first glance. Although the proposed capital investment may all be beneficial for the organization, a key aspect has been left out. There is no proposal for the procurement of an automated module of CMMS, and until a proper CMMS solution is implemented the documentation as discussed below will remain a problem.

3.4. Documentation

The material used in troubleshooting of breakdowns or during preventive maintenance is to be recorded in the space provided in the maintenance work order. This practice is hardly followed, because of which spares used during the troubleshooting of breakdown become impossible to track.

For a Capex to materialize and be commissioned it must go through the following stages in a chronological order;

Stage Number	*Stage Name*	*Activity Definition*	*Done on MEL ERP or Excel*
1	Design	Design and requirement of a technology is made.	Excel
2	BOQ	BOQ – bill of quantities includes parts, material and or outsourced labor required.	Excel
3	Sourcing	Contact with potential technology providers is made.	Outlook, Excel
4	Quotes	At-least 3 quotes supplied from vendors are procured.	Excel
5	Case	This refers to the case file. The entire data from stage 1 to 4 is recorded in a file.	Excel
6	Approval	Only when the steps above are complete is the project initiated in the ERP.	MEL ERP
7	Indents	Purchases to be made are done.	MEL ERP
8	Fab/Ins	The actual fabrication and installation.	Excel
9	Commissioning	The final commissioning of technology.	Excel

Table 3.4 CAPEX Progress Stages

The aspect of documentation is so overlooked that even in the new extension of CMMS module in the MEL ERP developed no provision has been added with regards to the monitoring, control, progress and the documentation of CAPEX projects.

Except for the issuance of material, inventory inspection and approval all the rest of the work is carried out on Excel sheets. The CAPEX projects such as vibration analyzer equipment (item 2.1 in the budget above) are initiated in the MEL ERP system only when the 5 stages are complete from design requirement to the quotes. When a CAPEX it is finally initiated it must pass through the following stages in MEL ERP to be approved for procurement. The entire stage 6 is done on MEL ERP.

Figure 3.8 CAPEX Approval Steps

Although the initiation of CAPEX is done in MEL ERP the progress of CAPEX projects is recorded and analyzed on excel files as represented in the Table 3.4 above. This is because MEL ERP does not have a module through which the progress can be monitored. In the maintenance department the progress of CAPEX projects and their documentation come under the ambit of planning and documentation section. The following represent the way through which the progress of a CAPEX project is measured;

CAPEX Projects

Sr #	Tasks	Remarks	Status								
			Design	BOQ	Sourcing	Quotes	Case	Approval	Indents	Fab/Ins	Comm
CJ 1	PLC`s And HMI`s	2 are under conversion, 2 will be done next July	OK	OK	OK	OK	OK	OK	OK		

Figure 3.9 CAPEX Progress Stages

It can be seen that the approval process and indentation forms only 2/9th portion of all the stages that a CAPEX projects has to go through. Which means two things that MEL ERP cannot be used to evaluate the progress of a CAPEX project and that there is a wide gap which exists between current and the desired functionality of the MEL ERP system.

4. Findings, Results & Analysis

The core objective of this study was to investigate the bottlenecks in the implementation of new technology. For this Millat Equipment Limited was used as a case study. The maintenance management system, new capital projects and the documenting procedure were analyzed in the previous chapter. This chapter presents the findings and critical analysis of the data gathered. The bottlenecks towards the implementation and utilization of new technology are first discussed, followed up by the problems arising as a result of the bottlenecks are discussed.

4.1. Bottlenecks to New Technology Implementation

Bottlenecks to new technology implementation are those hurdles which incapacitate organizations from embracing and implementing new technology. It is evident from the case study that the prevailing technology to deal with the maintenance management is far from ideal. Despite having the financial muscle to bring in the required changes in the CMMS system for accurate statistics and documentation the following bottlenecks are the reasons which bar MEL from the implementation new required technology.

4.1.1. Management

The main reason for the gap between the existing technology and the available technology can be attributed to the lack of the will of management, due to which there is no focus on the improvement of MEL ERP extension of the CMMS module. This may be a direct result of resistance of change due to which management is clearly in a state of denial to accept that module of CMMS needs an upgradation and that manual Excel based CMMS should be abolished. There are several reasons of why management is unwilling to incorporate a more efficient CMMS system in place of the current one.

4.1.1.1. Culture & Tradition

The current CMMS has deep roots within the organization. It is worthy to highlight that the current system of maintenance management has been in place since the foundation of the organization itself back in 2002. The entire cycle from issuance of the work order until the signing off is manual in nature i.e. the fields are filled out manually be the concerned persons, for instance if a gear hobber present in the Spur Gear A cell breaks down the work order is manually written by the concerned cell in-charge. The concerned cell in charge is usually a JE

- Junior Executive equivalent to a foreman, who by specifying the time, date, and nature of the problem and through the virtue of his signature issues out a work order. This provides traditional authority to the cell in charge, as the machines fit for production and those which are under maintenance are virtually decided on the desire or whim of the cell in charge, often resulting in bogus work orders. This issue is addressed in greater detail in the problems section. After the issuance of the work order the required maintenance work is carried out. The most frequent form of work orders are breakdowns. When the fault is rectified the work order again requires the approval of the cell in charge so that it can legally be closed. This again brings the JE into play as he has the authority to decide whether or not the machine is functional regardless of the reality on ground. He can for instance choose to declare a machine operational by signing the work order off for a number of reasons, one of which may his cordial relations with the JE of maintenance department, but he can also choose to do the contrary as well. The cell in charge can refuse to sign of a work order even when the machine is operational due to proper maintenance. This too can be an outcome of serval reasons one of which can be to deliberately keep the machine under maintenance while it is producing. By doing so the JE can increase his production efficiency on paper as he is able to produce the same amount of gears as he normally would but with one less machine is under "breakdown maintenance".
An automated CMMS system through which the work order can be generated automatically if and when the machine breakdowns would be meet severe resistance from the side of the work order issuance department as they would lose control over traditional authority issuing and closing the work order. Furthermore it will eliminate the traditional authority of issuing and closing a work order that the JE has.

4.1.1.2. Organizational Structure

The "power" to issue a worker order is vested in all the officials from JE to the head of the department. It is pertinent to highlight here that JE is officially at the bottom of the hierarchy of executive officers as represented below.

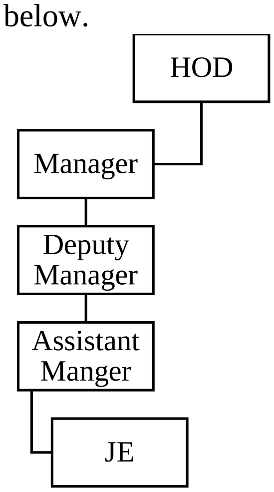


Figure 4.1 Executive Hierarchy at MEL

Upon the breakdown for instance a gear hobber present in Spur Gear A the manager production department or even the head of department can legally issue the work order, but this is hardly ever done. This is mainly because the senior management is often unaware of the on-floor situation as they are restricted offices performing managerial tasks such as planning, coordinating and controlling owing to the burden of work to be performed making issuance of a work order from a senior executive is considered against convention. This makes JEs the undisputed on-field masters of their territorial jurisdiction i.e. his cell despite being at the bottom of hierarchy of the executives. Automating the CMMS would result in even greater amount of work to be done by the executives. This is because at the moment the JEs are not computer literate enough to understand the peculiarities of an automated CMMS. To equip and enable JEs to carry maintenance management on computer would require training from the senior executives. Furthermore the senior executives would have to carry out the clerical work of a JE until he becomes skilled to do it himself adding to the burden of work. Therefore the senior hierarchy would prefer the status quo over the change of automation as the extra work associate over powers the benefits that would stem out of the new system.
The automation of CMMS would affect the senior executives in a similar way. At present the maintenance CAPEX projects are handled and reported independently by the concerned in-charge. The concerned in-charge can be anyone from the Assistant Manager to the Manger. The head of the maintenance department decides on whom amongst the senior executives would be responsible for a particular CAPEX project. The projects are allocated on the basis of educational background, competencies and prior work experience, but the head of department can choose to delegate a project by overlooking the said aspects as well. At the moment the concerned in-charge of a CAPEX project records and communicates the progress of his project by himself and reports is directly to the head of department by passing the chain of command. Since the system is not automated and no executive between the in-charge of a project and the head of department is exists a great possibility of data tempering.

4.1.1.3. CMMS Assistant

The roots of the current CMMS are so that deeply embedded in the organization that because of manual maintenance management a special CMMS assistant is legally authorized to planning and documentation department by the statutes developed by the human resource department. The main job of the assistant are to collect work orders that have been “closed” and type out all the data present on them on maintenance management excel sheets. The maintenance assistance works under the JE (maintenance planning and documentation). It is the responsibility of the CMMS assistant to receive the work order after by recording the exact time on which it was received. The timing written by the CMMS assistant later helps in determining the duration under which the machine underwent maintenance, therefore for correct statistics this time alone is the most crucial variable as all the CMMS reports explained in chapter 3 are dependent upon it. This makes CMMS assistant a very important person, as until the worker order is received and registered by the assistant, it has not documentary value. He also serves as a filter by not accepting work order that he is directed not to accept. For instance a deputy manager maintenance could instruct the CMMS assistant to not receive work order of a particular machine weather or not it’s functional with the collaboration of the issuing department. One reason of doing this could be to improve the MTTR and %DT. Through the current CMMS data can be manipulated in favor of maintenance by not accepting the work order and in favor of the issuing department by accepting it while the machine is operational. An automated CMMS would eliminate the role of CMMS entirely which in turn would snatch the authority of maintenance department to filter work orders they do not want to receive.

4.1.1.4. Organizational Politics

The goal of every department is to perform and prove equal to the key performance includes set by the chief executive of the company. The two most crucial KPIs for the maintenance department are the MTTR and %DT, both of these are generated by the planning and documentation section of the maintenance department. The problem is that as the reports are generated by planning and documentation section of the maintenance department on Excel spread sheets which they can easily be manipulate. There is only one internal auditor in the organization and for him to ensure that the reports generated are genuinely accurate, he would have to go through and match all the manual work orders received with the ones that have been typed into the Excel based CMMS system. This is neither possible nor is feasible which provides the maintenance department with the liberty to manipulate reports in their favor. Whether or not the data is tempered with, is unknown since the volume of the work orders is too large to be checked. In any case, this provides the maintenance department the ability to control the outcome of the report which naturally acts as a barrier towards CMMS automation.

4.1.1.5. Job Description

The officials may argue that replacing the contemporary CMMS system with an automated one is above their pay grade or even illegal. This is true as the job description of the CMMS JE is to ensure the generation of all the reports mentioned in chapter 3, by the end of the first week of the month. According to the job description all the section of planning and documentation in the maintenance department is carrying out their work exactly in accordance to what they are being asked to do. There is no provision of a bonus or even acknowledgement if an employee works beyond what is expected. There are no motivation schemes such as employee of the month or monetary rewards to encourage innovation and creativity. Emphasis is laid on getting the work done through the concerned standard operating procedure. Therefore, employees, in particular the senior executives focus on getting the work done as expected of them and not more. The in-flexibility in the contracts and job description is another reason for the non-implementation of new technology.

4.1.2. Cost

A third party already built software can be purchased for as low as 30 $ a month (Maintenance Assistant, 2016). The point to be considered is that, whether its purchases and implementation would be beneficial in practice. Replacing the current excel based CMMS with a fancier version would be no different in essence until the data would require by the software to generate the reports would be typed in instead of being automatically feed in. The implementation of a proper automated CMMS would require capital expenditure. An automated and integrated system in which organizational assets are equipped with sensory equipment to automatically prompt the need of maintenance action required, along with the fault type would require a considerable amount of capital investment. This would be a capital intensive purchase as it would require purchase of required sensory equipment along with skilled labor to install it. It is estimated that upgradation of one machine would require 50,000 PKR whereas the total number of machines are 452 making the cost of upgradation over 22 million PKR making it 64% of the total proposed budget of the maintenance department.

4.1.3. Lack of Skill

In the current setting where the maintenance of the entire organization is based on breakdown maintenance. The first step towards automation would be the introduction an electronic module through which the work order can be electronically initiated and closed. Such a module could later be further developed and synchronized with sensory equipment installed on shop floor machines so that the need of manual work order initiation could entirely be eliminated through automation.

The ERP based module of CMMS developed by in-house by the IT and the maintenance department has failed. The system has failed for two main reasons. Firstly, for the electronic module of CMMS to work the concerned employees must have the capacity to be able to use the proposed system i.e. for the system to work the JEs of all the departments must have basic ability to use computers. Secondly, as the system is drastically different from the old system being run on Excel it is hard for planning and documentation department to substitute a perfectly well functioning system with a new one which they can understand. With respect to development the core issue is that the in-house IT department admits of not having the time and capability to design and implement the CMMS through which the same work and reports can be generated as from the current system.

4.2. Problems Due to the Non-implementation of New Technology

The following are the list of problems arising as a result of the non-implementation and utilization of technology with respect to the prevalent system of CMMS.

4.2.1. Core Problem

The maintenance of the entire plant is based on the pattern of breakdown maintenance. Although preventive maintenance schedule exists and it is carried out on periodic basis the quality of preventive maintenance is very low due to which the focus remains on breakdown maintenance. As discussed earlier the two main KPIs of the maintenance department are the MTTR and %DT. The KPIs of the management are faulty as they too are based on breakdown maintenance. Ideally the preventive maintenance should be coupled with predictive maintenance to minimize if not eliminate the breakdowns.

4.2.2. CMMS

The entire system is CMMS is manually driven by the tradition authority of the JE and the CMMS assistant. As a result of this a number of conflicts arise. This serves as the instigating reason for the rivalry between the maintenance and departments seeking the services of the maintenance department. The rivalry between the maintenance and the production department is the most notable, instead of working as a team for the greater good of the organization the two departments have become each other's rivals.

4.2.3. Errors in Filling Work Order

The planning and documentation section acknowledges that the data filled in the work order form can have mistakes. Upon inspection of the work orders themselves it can be seen that none of the work orders contain all the information required. Furthermore, there is no way of knowing and validating the data recorded on the work order form. For instance if a lathe machine in the shaft cell breaks down due to a malfunctioning bearing, the maintenance in-charge can either accidently or deliberately tick the fault category as hydraulic. There are many reasons as to why this can be and is deliberately done. One reason could be to hide the truth from the management. If for instance a mechanical team is given the target to ensure no breakdown occurs due to bad bearing through preventive maintenance for a given month and a bearing related breakdown does occur the section in-charge could conveniently hide the true cause by ticking the any other plausible fault category other than bearings.

4.2.4. Errors in Recording the Information

All the information brought through work orders to the planning and documentation department are typed into excel sheets serving as the company's CMMS. While typing there is a high risk of mistyping the actual information and at the beginning of the month when the reports are produced checking the data entered against the data present on paper is not-feasible.

4.2.5. Issuance of Spares

Issuance of spares whilst troubleshooting a breakdown is a common practice. All the items present in the inventory are issued through MEL ERP system but there exists no link between the issuance of an item against a breakdown to the work order number making the process of estimating the cost of a breakdown impossible. The work order form which is manually filled has space where the maintenance team must write the details of the material consumed or discarded but it is very rarely filled. Even if a work order contains information about the material used, the information is of no use to the planning and documentation department since there is no head in the Excel based CMMS where the material used against a particular work order is recorded.

4.2.6. Reliability of Data

This is perhaps the most problematic manifestation of the current manual CMMS. Since from the point of the breakdown to the resolution the entire data is gathered manually, a number of problems can occur. Every field present in the manual work order from can be miss-written and miss-recorded. This could both be a result of human error REFERCENCE, or a deliberate attempt to manipulate data. Data can be manipulated from the maintenance side, the department seeking maintenance and from the consent of both sides as well. Whatever be the case accident or deliberate data adulteration, either way the reliability of the data suffers greatly. The reports that are generated at the end of every month are based on this data and since the reliability of the data is questionable so become the reports which are generated from it. This disables management from getting a clear picture of the ground realities and there by prohibits them from making constructive managerial decisions.

4.2.7. Capex Projects & Documentation

There is no way of projecting the real progress of a project in the CMMS. The list of CAPEX projects and related documentation are all made on Excel. The list of CAPEX projects proposed may appear to be exhaustive in nature as it has projects of wide variety both mechanical and electrical in nature. However no attention is given to the upgradation of the current CMMS. The budget estimate is nearly 34 Million PKR whereas no attention has been given towards the automation of the CMMS, which questions the need of the CAPEX items proposed. It should be noted that only the CAPEX items approved by the board of governors are fabricated and commissioned. Transformation towards condition based maintenance by strong preventive and predictive maintenance should be the focus but nothing in the budget reflects that except for the vibration analyzer. This clearly implies that the budget of the department is made to impress rather than express and address the real issues which require attention and technological upgradation. Because there is no way of projecting real-time progress of the CAPEX projects, the top management becomes aware of a project only when it has reached the approval stage, the time at which 6^{th} step after in the stages through which a CAPEX must pass through (figure 7 of chapter 3), at this stage management disproves most CAPEX project for which the design, BOQ, sourcing, quotes and case file are all complete for reasons such as lack of fund and on non-requirement basis. Engineers and managers can be saved from the trouble of working on projects that will eventually be disapproved if the CAPEX progress system is automated to show the management real time progress of the projects.

All the documentation of the details of the CAPEX projects along with their progress is done on excel as shown in Figure 5 of chapter 3. The planning and documentation section is supposed to be the center where the latest information exists but this is not the case because different CAPEX projects are assigned to different members or teams of maintenance department who create their own files to show their performance resulting in a plethora of Excel files depicting the progress of CAPEX projects, leading towards uncontrolled duplication and errors in reporting.

Furthermore, it must be noted that the list of spares of machine is made in excel (figure 4 of chapter 3). It is generally made and up-dated by the JE (cell's foreman). For every spare the available inventory quantity can only be read of MEL ERP without and provision of copy and paste. Thus in order to update the file foreman must type in the item code of a particular spare to obtain the available quantity making the process tedious and impractical.

5. Causes of Bottlenecks existence & Model Solution

This chapter highlights the causes behind the existence of bottlenecks present with the help of literature and theories discussed in chapter two. Then the chapter suggests concrete solutions through which the identified bottlenecks can be eliminated to pave way for a new automated CMMS which effectively caters the needs of the organization through the implementation and use of new technology.

5.1. Causes of Bottleneck Existence

5.1.1. Employee Resistance

It is evident from the findings that the upgradation of the CMMS remains unchallenged because of the resistance from the employees of both the maintenance department and other departments who avail the services of maintenance. It is widely believed that as the current CMMS is serving the needs and requirements therefore the argument of upgradation carries little weight. The problems is that since the subject of upgradation has been left unattended from the beginning the restraining force have become too strong resulting in severe persistence. With the passage of time the inability to adapt will become strong unless checked and rectified (Steinburg, 1992).

5.1.2. Averse behavioral Intention

The resistance of employees towards upgradation of CMMS is a manifestation of their behavioral intention as per the theory of reasoned action. The behavioral intention is determined by the subjective norm and attitude towards behavior. Upon considering the attitude variable it can be see that employees feel threatened by the upgradation and implementation of an advanced automated CMSS because of two serious consequences. Firstly, the new system would put the traditional power of the employees at jeopardy and secondly the upgradation would eliminate the possibility of data manipulation. Some even fear that they would lose their job as result. Thus it can be said that attitude towards upgradation is technology averse, as the attitude is directly determined by the beliefs and consequences.

The subjective norm guiding the behavioral intention towards the upgradation of CMMS is based on the individual though process of the employees. According to the theory of reasoned action each employees cognitively determines the value of upgradation of CMMS to those who are close and who he deems important. If the number resisting the change are greater than those who support it, the subjective norm of the employee would too be against upgradation. In this case it is evident that JEs all across the organization are against the upgradation, making it convenient for every newly appointed to promoted JE to join the clan resultantly making it proportionally more difficult for a new JE to support the use of new technology with respect to CMMS via the virtue of independent thinking.

When applied in this case, the theory of reasoned action postulates that the behavioral intention towards CMMS upgradation are guided by attitude towards technology and the subjective norm related. Evidently, both of the elements are in direct opposition of technology resulting in intentional disinclination towards the upgradation and acceptance of a new CMMS.

5.1.3. Faulty Attitude

Although, the theory of reasoned action helps in understanding the reasons for averse behavioral intention it does not provide reasons responsible for why the attitude and subjective norm are opposed to the upgradation and use of the newly built maintenance module. The model of technology acceptance helps establish the reasons for this. According to technology acceptance model the role of subjective norm in guiding the behavioral intention can be overridden by the attitude towards technology alone, indicating that if the upgradation acceptance attitude of an individual carries enough strength, the views of the employee's colleagues and those he considers important would not matter.

5.1.4. Difficulty in understanding usefulness & using

According to the technology acceptance model, the strength in the attitude towards the upgradation of CMMS is dependent upon its perceived ease of use and perceived usefulness. Both of these clubbed together from the actual system use. The perceived usefulness is dependent upon the perceived ease of use, whereas the perceived ease of use is directly dependent upon the technological efficacy and in this situation the familiarity with the working of organizational ERP to make use of the new module of maintenance developed. But computer efficacy is just one aspect which governs the perceived ease of use, other factors include organization support, prior experience and the quality of the system as per the extension suggested by Mc Farland and Hamilton.

5.1.4.1. Poor Quality of ERP

The ERP extension of the CMMS is unable to perform and generate the reports that are currently being generated by the Excel. It is true that data required by the system is not being fed into it but on the other hand it is also true that even if the data required is automatically fed it does not have the ability to generate any reports which are important for the senior maintenance executive to make decisions. For instance the crucial monthly breakdown report through which key indices such as MTTR and %DT are determined cannot be generated through MEL ERP module of CMMS. Furthermore, its graphical interface is substantially different from the manual work order making it difficult for the user to understand and implement it.

5.1.4.2. Organizational Support & Lack of Training

The ground reality is that because of the work load of manufacturing, the entire organization is fixated on achieving the targets instead of striving to improve systems. It is because of this reason there is no organizational support to increase the actual system use of the new CMMS module and improve and develop its functioning to effectively meet the demands of a proper CMMS.

It must be understood that the introduction of technology can only occur if the employees are capable of making use of the technology. Therefore, introduction of technology related to CMMS will continue to meet resistance until the sources of data input i.e. the JEs are capable of its utilization. Thus far, no attention is given on the training of the employees, in particular JEs who lack the basic understanding, operation and utility of computers let alone the organizational ERP. According to the data provided by the human resource department, every JE is given basic training on the working of ERP system prevalent, at least once per year. This clearly is not sufficient to inculcate the basic understanding required. The problem is not the training alone, even if a schedule for training is developed to inculcate and improve computer literacy, it would face sever resistance from the JEs as unwilling to learn. This is because they believe that in the current setup there is no need for it and that developing computer efficacy is difficult.

5.1.5. The Imbalance of Forces

As per the model suggest by Lewin until the driving and restraining forces remain in equilibrium they will continue to cancel each other out resulting in no change. The causes of bottlenecks mentioned above can all be classified as restraining forces preventing MEL from adopting change. There are 3 driving forces. Firstly, the managerial will to improve CMMS in order to make quick and informed decisions for better performance based on true and accurate real-time data. Secondly, channeling of the human resource of planning and documentation department for more productive purposes such as maintenance of machines. Thirdly, winning the Kaizen departmental awarded (yearly awarded to the most innovative department). For a system to be in equilibrium the forces of restraint must equal the driving forces. This makes the case of MEL peculiar in nature. According to the study and findings it appears that MEL is not in a state of equilibrium as the number of restraining forces are greater in number than the driving forces. It can therefore be logically deduced that he MEL is regressing instead of progressing with by adopting technological change.

5.2. Model Solution for Bottleneck Elimination

At the moment MEL is unable to embrace and adapt new technology related to CMMS because of the lack of intentions to embrace technology. Intentions of an employee to use technology are always formed before the actual use of technology (Oliver, 1977). According to Amoako-Gyampah the willingness of employees to use ERP based systems to carry out required tasks is based on the perception of the employee or user. The perception is determined by the usefulness of technology and the actual system usage (Amoako-Gyampah, 2007). Furthermore, according to empirical studies the perceived usefulness is the most important factor leading to actual system usage. By managerial effort to improve perceived usefulness through support and training, greater system usage can be ensured. Thus in order to achieve actual usage of computerized CMMS focus should be on the amelioration of the perceived usefulness.

As a result of increasing competition and pressure on the industry, the implementation of technology is becoming a global phenomenon which cannot be denied (Muroyama, 1988). In the current scenario MEL is in need of a change. The following steps provide a model which can be adopted to bring about change needed through which bottlenecks preventing the automation of technology with respect to the CMMS can be eliminated.

1. **Development of a Complete CMMS solution**

Prior to technology acceptance the most important aspect is gauging the utility of technology with respect to the work which needs to be performed. Perceived usefulness of a technology will only be developed once it possess output quality and result demonstrability (Venkatesh & Davis, 2000). The CMMS maintenance module's MEL ERP extension does not have the capability to perform the tasks that the current manually driven Excel based CMMS has. The MEL ERP extension of the CMMS is incapable because of the following reasons, the resultant effects are also highlighted.

- It only provides provision for the initiation and closing of work orders.
- It has no reporting mechanism. It is incapable of generating any of the reports discussed in chapter 3.
- Its interface is drastically different from that of the manual work order making it difficult for the concerned employees to understand and implement.
- There is no provision for the classification of maintenance faults.
- There is no provision for the issuance of spares required for a particular breakdown. For the issuance of spares, material issue requisition (MIR) is required on a separate module on the same ERP making the process of material tracking and breakdown costing inconvenient.
- Time is the most crucial factor in maintenance, especially in breakdown maintenance. In the MEL ERP extension the downtime of a machine starts when the work order is initiated and ends when the work order is closed. The initiation and closure of the work order is just as dependent on the person clicking as it is on the person signing the manual work order, rather than on the actual state of machine. Time is not based on data electronically provided through sensory equipment.
- There is no provision of shifting downtime to other departments when the need arises. For instance, if the spare required for maintenance is under the process of procurement, there exists no provision in the ERP to shift the time of procurement away from the maintenance downtime to the procurement downtime as there is in the manual work order in section 7.

- There is absolutely no section detailing the CAPEX projects and their progress.

Unless and until the ERP extension of the CMMS is developed to perform the tasks required more effectively, accurately and with greater ease, shifting towards the current extension would be not possible. All the changes, with the exception of automated initiation and closure of work order based on sensory data can be brought by programming and smart graphic designing. The MEL ERP extension of CMMS should be as similar to the manual work order as possible both by functionality and visual appearance. If the said changes are beyond the capabilities and skills of the IT department, the requirements should be outsourced as strategic outsourcing of projects have multiple benefits (Heckathorn and Matson, 1998). By incorporating the required changes through a redesign both perceived usefulness and ease of use can be increased.

2. Freezing by Increasing Data Reliability

According to Lewin's model presented in chapter 2, for a change to occur the first step is "unfreezing" from the status quo. As highlighted earlier, the case of MEL is peculiar in nature since the restraining and driving forces are not in equilibrium primarily because the number of restraining forces outnumber the driving forces. As a result of this imbalance, MEL is retreating in terms of technological acceptance rather than being in a stagnant status quo state. Hence, the current state is alarmingly dangerous. To enable the process of unfreezing leading to movement in the direction of technological acceptance, it is pertinent to freeze the system so that it ceases to grow more dependent upon the manual ERP with every passing day. It is therefore, important to achieve equilibrium by increasing the number and thereby the force of driving forces which promote acceptance of an automated CMMS prior to unfreezing. This can be achieved by reducing the incentive to use manual work orders. One of the reasons why manual work orders are in existence is because of the ability of concerned personnel to manipulate data. By deputing a special independent task force, the validity and reliability of data can be ensured. The task force should be divided in 2 teams. One team should have the responsibility of examining the validity work orders initiated and closed. The second team should ensure that the data on work orders and corresponding data entered in the Excel sheets the match each other. If complete verification becomes non-feasible a random sample of work orders should be collected and inspected regularly to ensure that no data manipulation is occurring until the shift towards automation is complete. By verifying data the traditional illegitimate authority of issuance and closing a work order without the actual need will be minimized. This can occur simultaneously with step 1.

3. Unfreezing by Focused Training and User Friendly Design of ERP

Unfreezing can occur only as a result of intention to bring change. Therefore it can be said that the stage of unfreezing is directly linked with increasing the perceived usefulness and perceived ease of use of technology. This requires capacity building in the domain of computer efficacy. Only when the employees are computer literate enough, can the exploitation of technology to an optimum extent truly occur. Focused training can help achieve this goal. Training on computer literacy should be dished out to JEs in particular on regular basis. If the idea of training is met with resistance it should only be given to those who voluntarily want to have it. If the training is successful in achieving its goal i.e. computer literacy it would create different classes of employees in the organization automatically compelling those who do not have computer efficacy to develop it. Ryan & Deci have linked perceived usefulness and perceived with extrinsic and intrinsic motivation (Ryan and Deci, 1991). Employees successful in completing training should be acknowledged through a reward system based on merit.

4. Movement through Adaptive Design

"*It takes time for individuals to learn, but collective organizational learning takes longer.*" –Professor J.P. Liyanage

In this phase the concerned employees should be given targeted training regarding the use and application of MEL ERP based CMMS. It is important to realize that the proposed changes regarding CMMS module in MEL ERP can be brought about swiftly as they primarily require re-programing and interface re-designing of the existing module. This however is not desirable as the pace of technological change must match the time to required to learn and adapt. Technical development and improvement in the CMMS are important but organizational learning is the key. Only through organizational learning and implementation can the exploitation of the proposed CMMS module can be maximized.

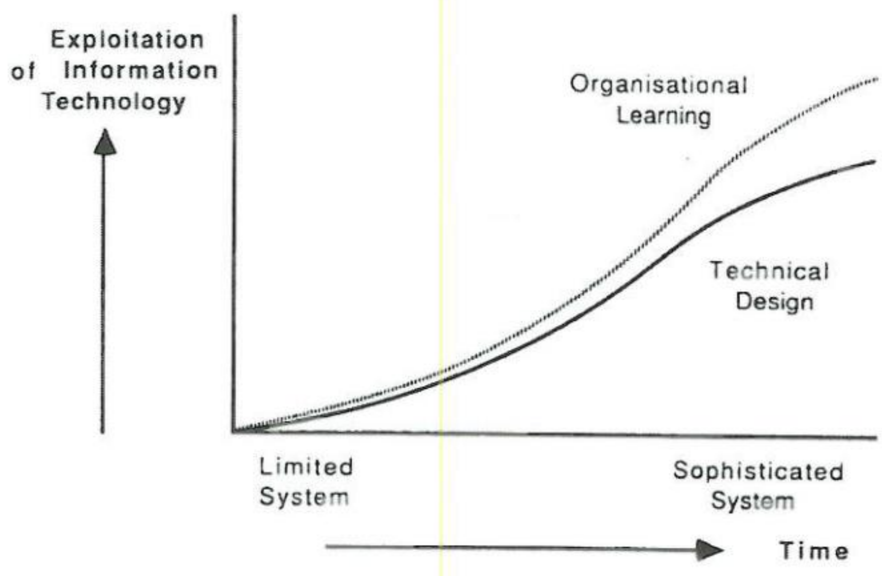


Figure 5.1 The Evolutionary Development of Information Technology Systems (Eason, 1992)

As represent in the graph above the technical development and organizational learning go hand in hand. There are no sudden developments because technical development is based on organizational learning. Sudden transformation should be avoided, and changes in the MEL ERP module and the overall mode of maintenance from breakdown to condition based should be gradually brought since spontaneous changes often meet failures.

Initially the ERP based module should complement the existing manual Excel based ERP as much as possible. Management should not underestimate the power of technology (Trist & Bamforth, 1951). The development of the module should not be based on what can and cannot be done by the IT department of the organization. Although technology has its limitations, but the ERP module can certainly be developed to comply with the existing manual ERP. There is simply no use of having technology if the labor cannot comprehend and exploit it fully hence is it necessary to incorporate the social aspects of an organization in to technical systems. The work order form despite its limitations should initially be incorporated in the ERP extension of CMMS so that understating can be easier. This will facilitate the process of organizational learning easier and thereby the concerned employees would be able to comprehend and apply it instead of discarding it. With due advance of time changes in the module and even in the mode of maintenance from breakdown to condition based should be brought.

5. **Refreezing**

Once an adaptable version of the CMMS module is developed and introduced, it is pertinent to rid the organization of the old system. For this two fundamental changes are required. Firstly, the job description of the employees especially the staff of the planning and documentation section of the maintenance department in MEL should be updated in line with the new module. The new job descriptions should not be rigid in specifying the exact duties of the employees, rather they should be flexible enough to allow further changes in the development of CMMS. Secondly, the existing data recorded in excel sheets should be transferred in the ERP based CMMS to completely flush the system of any remains of the old Excel based manual system.

Change is a dynamic process. Technology will keep on presenting more efficient and suitable solutions as a result of its evolution. No solution is a perfect solution. Management therefore, should continuously look to introduce changes in the MEL ERP based CMMS in a cyclic manner. The process of unfreezing should immediately follow the process of freezing to allow continuous development of the CMMS.

6. Conclusion & Way Forward

6.1. Conclusion

This thesis used the maintenance management system prevalent in MEL as a case study to highlight the bottlenecks in new technology implementation. The thesis initially addresses theories and models through which the identification and solution to the bottlenecks is done in the section of literature review.

The review of literature is followed by a detailed analysis of the maintenance management system prevalent in the organization. Upon analysis it is revealed that the entire CMMS is being run on data collected on a maintenance work order form which is later typed into Excel sheets for the generation of reports. MEL's ERP extension of CMMS exists but has failed to substitute the manual CMMS.

The problems caused by the manual ERP system have been highlighted along with reasons for the non-upgradation and non-implementation of CMMS along with the failure of MEL ERP extension of CMMS module. The bottlenecks responsible for the resistance in the technology and factors responsible for the existence of bottlenecks are highlighted. A chronological solution has been suggested through which the elimination of bottlenecks to new technology implementation with respect to the maintenance management system can be achieved.

6.2. Way Forward

Organizations around the globe have shifted from breakdown maintenance towards proactive condition based maintenance. MEL however is still fixated on the principle of "fixing when it breaks" i.e. breakdown maintenance. The entire plant is running on a reactive mode maintenance. This is having grave implications such as increasing downtime, shorting of asset life and increasing indirect cost such as spares. Because of the unpredictability revenue budget cannot be estimated and controlled and the deteriorating condition of machines is posing safety threat to workers who operate them.

The existence of the reactive mode of maintenance prevalent in MEL can be attributed to the manual Excel based CMMS. It is apparent from the data presented in chapter 3, that maintenance management system is reactive in nature, having no flexibility towards transformation to condition based maintenance resulting in bottlenecks in new technology implementation that have prevented the use and development of the ERP extension of CMMS.

MEL should promptly upgrade the existing manual Excel based CMMS. By reaping maximum benefits out of technology related to CMMS through deliberate and effective application, MEL can ensure better maintenance action, greater machine life, low downtime and maximum productivity.

Introduction and implementation of new technology will always face resistance in the form of bottlenecks. The bottlenecks need to be realized and checked so that organizations can accept and adopt technology necessary not only for efficiency and greater effectiveness but for survival. MEL is no different. It must avail the technological opportunities presented to ensure sustained growth.

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