Influence of Modification of Design out Maintenance & Design Out Information System For Maintenance Cost Control & A Lucrative Business (With Case Study).

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Abstract

Maintenance management is one of the main focuses in industrial sector. Maintenance in production environments is becoming increasingly complex as machines become more technologically advanced, therefore higher product quality, increased reliability, enhanced availability of plants, optimization of cost and choosing right maintenance policy plays a vital role in achieving a lucrative business. Generally the production and maintenance task goes together, nearly 43% of production cost generally goes to the maintenance task, and hence there is a possibility to reduce the maintenance cost. Thus in this paper an attempt is made to understand most important maintenance policy i.e. Design Out Maintenance (DOM). Where most of the maintenance concepts aim to minimize number of failure or effects of failures, Design out Maintenance aims "to eliminate the cause of maintenance". We apply the concept of redesign to all types of potential failures that causes problems in business performance. The paper also through light on the Design out Information System. Therefore it should result in a more economical production function and a more efficient maintenance function.

Keywords

Design out maintenance, Production, Redesign, High maintenance cost**,** Failures, Design out information system.

INTRODUCTION

In the present scenario if we think of life without a computer then it is very difficult for any firm or organization to survive in the market. In this cutthroat competition the emphasis on productivity is simultaneously embodied by safety, environment and ergonomics. Every physical asset put into service to fulfil specific functions, thus maintenance of this assets is inevitable and is generated from failure of components. Maintenance is generally recognized as a single largest controllable cost and status quo represents a challenge for leading managements to revaluate their maintenance strategies.

Tactical Maintenance: The Maintenance tactic whereby changes or modifications are done to the equipment to remove a failure cause, or to allow other maintenance strategies to be applicable in managing the consequence of the failure [1].

Design Out Maintenance: It is design oriented curative measure aimed at rectifying a design defects originated from improper method of installation or poor material choice etc. Design out Maintenance requires a strong maintenance design interface so that maintenance engineer works in close cooperation with design engineer. It is more suitable for its item/equipments of high maintenance cost. The choice to be made is between the cost of redesign and cost of recurring maintenance. If the maintenance cost or downtime cost of equipment is high, then the Design Out Maintenance strategy can often be effective. This strategy differs from all the others in that it is a one-off activity, as opposed to a repetitive activity designed to prevent failure. Design out Maintenance aims to redesign those parts of the equipment which consume high levels of maintenance effort or spares cost or which have unacceptably high failure rates. The high maintenance costs may have been caused by a number of factors, including:

- Poor maintenance.
- Operation of equipment outside of its original design specification.
- A poor initial design.

Although it is an engineering design problem, yet it is often a responsibility of maintenance department. It may be mentioned that a best maintenance strategy for each item should be selected by considering its maintenance characteristics, cost and safety. The Design out Maintenance strategy can only be implemented effectively if high maintenance cost items can be identified and the reasons for the high cost understood. It is often the best strategy to take when breakdowns are too frequent or repair is too costly [2].

The focus of DOM is to improve the design to make maintenance easier or even eliminate it. Ergonomic and technical reliability aspects are important here. As a result of these technical improvements machine parts last longer and maintenance engineers have to replace them less often. This makes the maintenance engineers casual users, people who are using a system at irregular intervals rather than having the fairly frequent use assumed for expert users (Nielsen 1993) [3].

REASONS FOR EQUIPMENT FAILURES

The reasons for equipment failures [4] may be summed up in the following manner:
1. Natural Degradation
2. Human Factors
3. Tolerance Stacking
4. Variation in Operating Parameters
5. Material Incompatibility of spares.
6. Local factors
7. Root Design Imperfections like unclear parameter definition, material incompatibility, energy transfer, design morphology, inappropriate signals etc. This is more so, since industrial equipment design cannot be standardized as functional requirements and local requirement vary from case to case. Hence at times, design of an industrial machine is a matter of tradeoffs, compromises and optimization and at times invalid assumptions leading to imperfections.

However, the underlying cause of the first six causes as listed above is Root Design Imperfections. Such causes are the basis of failures, delays and wastages in an organisation where technology is one of main factors of production. Tackling delays, wastages and failures is the answer to enhanced organisational performance since there is always an effective upper limit to ‘economy of scale’ and ‘equipment scaling’ once a factory is set up. Moreover, considerable investments are needed to improve economy of scale. The objective of DOM is to remove or tackle all such imperfection in a step by step manner by following a systematic but flexible methodology. The methodology is flexible in the sense that it varies in relation to an organisation’s degree of reliance on technology to produce its products and slowly over time evolves a customized system relevant to an organisation to meet its business challenges.

OBJECTIVE

Design out Maintenance apart from in the safety case, the last resort strategy. The objective is to redesign the particular system or component to decrease the need for maintenance by removing unwanted failure modes. In the case of safety related failures, it is used by default to remove failure modes for which no suitable preventive tasks can be found. In all other cases, it is used based on economic considerations when no suitable preventive task could be found and corrective maintenance (direct maintenance cost plus the cost of lost production) will be too expensive. A detailed economic trade-off study should always be done in such case before proceeding with the design-out strategy. This should prove that the cost of the design work plus the consequential cost (manufacture, modification of existing machinery, system changes and stock changes) is less than the cost of corrective maintenance (direct maintenance cost plus the cost of lost production). The prime objective of a maintenance management strategy is to achieve the optimum balance between equipment performance, availability and the cost of maintenance. Reducing the spend on maintenance can have serious consequences to production.

Example 1:- In one Pottery Company [5], in an attempt to reduce costs following reduced profits, the maintenance staffs were halved. As a direct result, a machine failed causing £90,000 of damage and lost production. Later, with outside help and improved maintenance procedures they were able to save 15% of their total production costs.

Example 2:- A Ministry of Technology Working Party report in 1971 estimated that maintenance was costing the United Kingdom around £3 billion per year [5]. They considered that by improving maintenance management and paying greater attention to other factors in the equipment life cycle substantial savings could be made. The life cycle approach to maintenance cost reduction has since been defined as Tero Technology. The British Standards Institution defines Tero Technology as; "A combination of management, financial, engineering, building and other practices applied to physical assets in pursuit of economic life cycle costs. Its practice is concerned with the specification and design for reliability and maintainability of plant, machinery, equipment, buildings and structures, with their installation, commissioning, operation, maintenance, modification and replacement, and with feedback of information on design, performance and costs.”

Design out maintenance may be needed because of following reasons.

1. If the original design is not adequate.
2. Availability of much cheaper & better spares Consumables & components etc.
3. Change in statutory obligations, especially with respect to safety, pollution on environmental needs etc.
4. Non availability of spares or components, because of obsolescence.
5. Equipment/component not made as per design or not erected or commissioned as per specification.

6. Change in performance parameters & need from original specification.

Such Design out Maintenance (also called as maintenance modification) can be done in one instalment (such as total replacement or revamping) or in the form of small continuous improvements (generally preferred by Japanese – Kaizen) [6]. Again, the DOM differs with plant modification & up-gradation jobs to the extent that the aim of design out maintenance is limited to eliminate the cause of maintenance [7].

First thing that is needed in DOM system is to specify clearly the requirement, to chalk out various methods to achieve it & select one that is ideally suited to the given conditions. In maintenance, engineering cost considerations guide all decisions making & at every step. A very simple method would be to observe the behaviour patterns, & fix target for the future. To give a specific example, supposing that the consumption of a particular size of a ball bearing in a plant in the last five years is 3000,5000,4500,6000 & 6500 pieces respectively. Now, one has to forecast its consumption for next year. An exhaustive study should be made to examine the load conditions & the life of the bearing which is dependent upon a large number of variables .A theoretical study howsoever exhaustive it may be, will still have some amount of uncertainty & the exercise would be time consuming .Let a target be fixed for 5000 pieces of consumption & then study the actual causes immediate beginning is made & efforts are directed without delay to get better results in actual practise.
The target how ever has to be

1. Realistic or achievable.
2. Quantitative & qualitative.
3. Time based.
4. Self imposed.

INFLUENCE OF D.O.M.

Design out maintenance (D.O.M) technique in its simple terms provides complete investigation by answering appropriate questions set out in logical order. The procedure can channel engineers' thoughts along the fruitful lines when he is faced with problem .To illustrate the points, the following two problems can be citied:

1. Burning out pot motors in a manmade fibre plant. These are small motors of 200 watt, each rotating a pot at 8000 rpm, designed to collect and spin yarn. There are 15,000 such pot motors in continuous service and do not have any individual starter or over current protection.
2. Pusher mechanism of dryer breakdowns frequently.

First steps towards D.O.M is to enunciate the problem clearly .To enunciate the problem one should have to have knowledge of the equipment , its behaviour and nature of the defect and the seriousness of its effect . While applying D.O.M one must constantly take into consideration appropriate questions in logical order such as-

A. The cause of defect and means of eliminating the cause.
B. Any method of detecting the defect that can cause breakdown before it occurs.
C. Elimination of the function.
D. More reliable alternate means of performing the function.
E. Improvement in the present means of performing function.

Outline the problems at hand (from 1) [8]. The following information would be useful for completing this form:

a) A brief description of the defect as observed should be expressed. Precise definition is not necessary.

Problem 1- Pushing mechanism gives way.

Problem 2 - Burning of pot motors.

b) Function of defective unit-Here, we should write down the main activity that equipment is designed to perform.

Problem 1 - In the dryer, there are twenty trucks stored one after another .A new truck is kept in position, pusher is started and it pushes the truck in position while pushing out the last truck.

Problem 2 - Pot motors drives the pot and rotates it at 8000 rpm when yarn is collected and given twist.

c) Total maintenance cost, this is an important data and should be carefully assessed. The annual cost of material and labour which should include per capita over head charges.
d) Shutdown cost, in this area; the maintenance engineer will have to give some attention. In this cases where there is no production loss, the cause may affect quality and this too should be assessed.
e) Any other information, relevant information connected with the problem.

FORM 1

OUTLINE OF PROBLEM

	PROBLEM 1	PROBLEM 2
Location	Spinning Department	Dryer Department
Defect	Burning of pot motors	Failure of pusher mechanism
Function of defective unit	Driving pot collecting yarn	Pushing truck carrying yarn cakes
Maintenance cost per annum(Rs in lacs)		
Labour	2.40	0.10
Material	9.00	0.40
Others		
Total	11.40	0.50
Shutdown loss (Rs in Lacs)		
Profit	0.75	0.10
Raw Material/Services	1.25	0.20
Idle or Additional		
Labour	0.25	
Others	0.50	
Total	2.75	0.30
Grand Total	14.15	0.80
Other Information		

Modification of present design or system.

This aspect of DOM procedure provides the greatest scope for the maintenance engineer, but the more rewarding result's often come from the consideration of eliminating or substituting the function, & this should never be undervalued. In this step careful study has to be made of the defects & its cause & these should be classified & dealt separately.

The logical questions arising here are:

1. Any bearing of defect's on design of equipment or present process?
2. What are possible causes of the defects?
3. How can each cause can be eliminated?
4. How can defect be eliminated or reduced?
5. How causes & effects be eliminated?

Problem 1: The pots motors in service get overload and overheated. There is no provision of tripping the motor when it is overloaded hence ultimately it burns out and the pot is stopped and yarn production of position is automatically discontinued. If we can stop the pot motor when its body temperature reaches a limit of 50 Degree Celsius, we can save the motor from burning and also ascertain the cause and rectify it. Various possible causes being

1. Pot might not be clean. In process some salt get collected round the pot and increase load on pot motor beyond limit.
2. The cause of this trouble might be improper humidity and temperature round the pot.
3. Pot might in itself be rough causing high friction at 8000 rpm. The surface of the pot should be polished and meticulously clean.
4. Some part of the pot might be damaged causing imbalance.
5. Electric connection to pot motor might be loose.

On examination, at any stage, if cause is found this must be rectified otherwise the danger of defect will continue to cause effect and burn out the good motor which is subsequently replaced. Through the application of liquid crystal technology to a small portion of pot motor body can be applied a liquid crystal film which will change colour and offer warning as soon as body temperature reaches the limit 50 degree Celsius a visual inspection could then be arranged and such motors could be stopped manually in proper time before they burn out the cost of system modifications is negligible as compared to benefits derived and by this modifications , a net saving of Rs. 8 lacs annually has been reached.

Problem 2: The pusher mechanism fails due to excessive and sudden loads experienced by it. Various possible causes are:

1. It is likely that the cake truck body fouls with the dryer body sometimes, as the cake trucks are subjected to high temperature inside the dryer and cooler temperatures outside, their bodies get deformed and fouls with tins sheet body of the dryer. At times, the body of the dryer gets damaged; tin sheets get torn and do not allow free movement of the trucks inside the dryer. The body of each truck must be checked for correct dimensions, before it is sent inside the dryer.
2. It is further likely that the cake trucks have do not lot to movements on rough concrete floor, its wheel bearings get thereby damaged. It is also observed that wheel bearing replacement is very high. These damaged bearings cause lot of resistance in pushing inside the dryer.
3. It is possible that the design of the pusher mechanism is inadequate.

Two modifications were suggested:

1. Between the motor and pusher mechanism, on the coupling, a safety pin should be put so that whenever pusher mechanism is subjected to undue load, the pines give way and disengages mechanism parts.
2. The movement of the dryer truck could be made smooth when running on rough concrete floor. This could be done by laying as MS channel passage and all trucks should move on these channel. The cost of this modifications would be Rs 60,000/- and the bearing replacement would be reduced to one-third at least.

A rig should be made set up before the dryer. Each truck should pass through the rig. The rig overall dimensions should be made 1/2’’ shorter than the dimensions of the dryer body. Once any such modifications are incorporated, in due course these should be evaluated to ascertain, if modifications to plant and equipment should be carried out with caution and prudence. More often that do not, fault does not lies with the design of the equipment. A design is generally perfected before nit is marketed and the defect is caused by improper application or in the system of use.

FORM 2
MODIFICATION

		Problem 1	Problem 2
A	What are the defects necessitating repair or replacement.	Burning of pot motor.	Breakages of mechanical parts of pusher mechanism
B	What are possible causes	Unclear or defective pot salt formation / lose electrical connections.	1 Fouling of cake truck with dryer body. 2 Bad wheel bearings.
C	How can cause can be eliminated	Check pot motor body temperature	Check body dimension of truck before sending it to dryer
D	Modification Suggested	Liquid crystal temp. Indication – frequent checking of pots	-Rig to check truck body dimension -MS Channel laid out for improvement of truck on rough concrete floor
E	Financial justification Cost of modification Saving expected Pay- off period Time of implementation	20,000 Rs/- 8,00,00 Rs/- Less than one month 3 months	60,000 Rs/- 25,000 Rs/- 2 years 4 months

CASE STUDY

The concept of DOM may be illustrated through real life cases and examples. Though there are many cases, all cannot be discussed due to space limitations. Hence, the problems are divided into three types: simple, intermediate difficulty, higher difficulty and problems from each category are selected as illustrations. Then the overall effect of DOM in an industry is shown and discussed.

Simple Case:

Problem: A shaft fractures within 3 to 6 months of operation from the bearing shoulder area.

Method	Actions	Cost	Effects
Conventional	Replace shaft as it breaks	High	Loss of productivity. Recurring cost
DOM	Redesign the shaft with shoulders < 5% change in diameter & change material.	One time cost. Cost equal to original shaft	Life enhanced to 10 years. No loss of productivity due to shaft breakage. No recurring cost. Life cycle costs much lower, low inventory. Maintenance free.

Table 1

Case of intermediate difficulty:

Problem**:** Dry hot abrasive material falling on a rubber conveyor belt from a chute. Creates a lot of dust and causes secondary damages to other elements of the conveyor system. Makes inspection difficult due to unhygienic condition and dusty atmosphere in an enclosed space.

Method	**Actions**	**Cost**	**Effects**
Conventional	No definite answer. Clean regularly by casual workers. Inspect whatever best was possible and replace when defects were found or after a breakdown.	High	Loss of productivity. Recurring cost. Secondary damages high. High inventory. High maintenance effort.
DOM	Redesign the system by matching the velocity of falling material to that of the belt.	Practically no cost.	No loss of productivity. No recurring cost. No secondary damages. Maintenance effort nil. Low inventory.

Table 2

Case of Higher Difficulty:

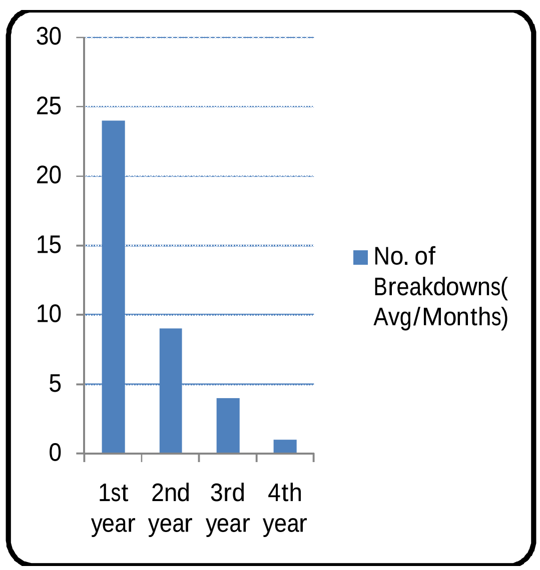
Problem: In a particular conveyor of a steel mill, the motors usually tripped at least once a month. The average current consumption was 12 amps which at times shot to 18 amps. There were cases of many bush bearing failures and failure of other components.

Method	**Actions**	**Cost**	**Effects**
Conventional	Lubricate, inspect, replace.	High, since failures did not reduce.	Loss of productivity. High recurring costs. High maintenance efforts. Higher inventory.
DOM	Redesign through small viable modifications taking the entire equipment as a system.	Very low	No tripping observed for five months after modifications. Average current consumption dropped to 8 amps. No failures of other components. No maintenance effort. Fewer inventories.

Table 3

Overall effect of DOM:

When DOM was applied to a fabrication company the results were impressive. This company was having on the average of 24 failures a month with their critical machines. After an integrated effort of the application of DOM the number of failures came down to one failure per month for the critical machines (46 in number). The graph (1) below illustrates the result achieved over a period of four years.



Graph 1

It is interesting to note that over a period of five years, market forces have pushed down the company's selling price almost to the extent of 20%. But even with lower selling price the company is making more cash gains than they did when selling prices were higher. Also note the reduction in cost as reflected in the maintenance budget (a reduction of about 58%) and the improvement in quality. Note that management with a sharp focus on reliability improvement of equipment achieved market leadership position from a lower position in about two years time. This has been possible through continuous improvement in design of equipment and productive system and subsequent rise in sustained productivity, quality and cost reduction (the key factors to face competition).

DESIGN OUT INFORMATION SYSTEM

Information System handles the flow and maintenance of information that supports a business or some other operation. It contains information about significant people, places and things within the organization or in the environment surrounding it [9]. An Information System can be defined technically as a set of interrelated components that collect (or retrieve), process, store and distribute information to support decision making and control in an organization. Also, in addition to supporting decision-making, information systems help workers and managers to analyse complex problems, to develop new products and to integrate the various modules and departments. Moreover the 'transmission losses in inter-departmental communication are reduced considerably leading to better coordination and improved transparency (information sharing) within the organization as a whole.

For design out maintenance to prove effective. It is necessary to have a good management information system to help the maintenance manager to plane, execute and control all activities under his care. The maintenance manager, more than anyone else, is constantly engaged in the selection of a best course of action out of several alternatives identifications and diagnosis of problematic areas in the day-to-day working need information in Decision-making. Decision making is the basic and fundamental function of any management, without which on activity can commence. Success of an individual manager and his department is judge by the result produced which is dependent upon the correctness of his decisions. There is no way of guaranteeing the correctness of decisions, but a good information system should be

1. Accurate
2. Timely and relevant
3. Concise- exception oriented
4. Economical
5. Dynamic and adaptable

Data collection needs effort and costs times to money. There is no cost involved in not having an information system, but decisions based on hunch or mood alone, without giving due considerations to relevant data and information can brings incalculable loss. Very often it is simply not possible to take any decisions without accurate information and data being at hand

Sometimes, overdue importance is laid on getting all the information and perfect information in maintenance management, when new problem are faced everyday quick and timely actions are to be taken and cost considerations guides all actions including, data collection and information system, decisions may have to be taken at times on imperfect information. As a matter of a fact having no information and also too much information, both tend to take management ineffective. It is here that the need arise for developing scientific management information system that will make the maintenance manager's role, easy and effective, keeping the cost of the system itself low. The cost elements in designing an information system are –

1. Cost of designing the system.
2. Cost of information handling equipments and machine e.g. Typewriter, calculating machines, computer, etc.
3. Skilled man hours for operating the equipments.
4. Programme developing, consisting of obtaining, recording, communicating and storing data and knowledge.
5. Executive time.

The scientific method of decision making according to peter drucker [10], consists of the following constituents:

1. Define the problem
2. Analyse the problem
3. Search alternative and possible solutions
4. Select the most appropriate solutions
5. Convert decisions into actions
6. Evaluate and develop feedback system

In maintenance management, the information system must provide the necessary intelligence on a timely basis to help the manager to plan execute and control. For the system to be effective, two basic needs are:-

- It should provide all essential data connected to all problems at hand, with & convenience.
- It should be adaptable & responsive to the management needs.

Advantages

Implementation of DOM means freedom from failures. This is done by improving the life of a component, machine or event. There are various types of failures in an organisation [11]. Equipment fails. Quality fails. Process fails. Product fails and so does safety. Needless to stress that improvement in one aspect leads to the improvement of other aspects as well. However, there still remains a need to develop reliability of each of these aspects individually. Whatever aspect, the organisation chooses to improve; the improvement in implementation of DOM has far reaching effects like the following:

1. Reduction of cost and improvement in profits.
2. Improvement in Quality, markets and products.
3. Improvement in Productivity and Cost effectiveness of internal processes of an organisation.
4. Improvement in Technology, Safety [12] and Environment.
5. Improvement in Human Talent [13], Innovative capability and Knowledge base of an organisation.
6. Improvement in Information.
7. Companies need to do the improvements only once. Thereafter the company gains ongoing benefits.
8. Recurring cost of maintenance [14] is reduced to nil or minimum. And maintenance effort is also reduced to the minimum. It follows that maintenance planning is reduced to the minimum.
9. With design imperfections removed and functionality improved, quality is improved and the process is also made more stable.
10. Investment made in DOM will pay for itself.
11. With design out information system you have a good management information system to help the maintenance manager to plane, execute and control all activities under his care.

Prerequisites

1) It needs a management team that believes in innovation and is market driven. Without market demands innovation is not possible since innovation is a response to customer demands.
2) DOM would need investigators who are competent and knowledgeable and are provided the time and funds to do the analysis/synthesis to make the desired improvements. It means that investigators need to know in depth the physical and chemical laws, principles and effects to solve engineering problems. Research shows that the average engineer knows 50 to 100 physical and chemical laws, principles and effects which can be used for solving engineering problems, but there are over 6000 such effects described in scientific literature [15].

Key Findings

- DOM's concept of redesign may be applied to all types of potential failures so that the intrinsic life is enhanced. In the now traditional approach only those failures that were not age related and also not susceptible to condition monitoring were treated to reliability improvement through design out. DOM extends this to all modes of failures affecting business performance through the understanding of the complex interrelationships between different modes of failures, observing the system as a whole and design thinking.
- Operational cost is minimized, so are the delays and wastages. Quality losses due to malfunctioning of equipment are minimized. Therefore, the companies would be not only being able to reduce their operating costs to the minimum but also achieve and sustain a very high level of quality (6σ).
- Through the application of DOM, maintenance effort is greatly reduced and maintenance planning is simplified and optimized to the barest possible. Potentially this feature may useful to downsized companies.
- On continuing application organisations would become highly competent to engineer new technology as and when the need comes to gain competitive advantage.
- Engineering knowledge base (a new factor of production) of the organisation is greatly improved. It would help an organisation to respond to competitive forces effectively within a short time.
- DOM is a better method when compared to the existing methods since one only needs to make the improvement once to gain ongoing benefits.
- However, the approach would gain a bad name if applied by less competent/untrained people. This of course has been the problem that has plagued CBM and indeed maintenance improvement generally [16].
- The Design out information system provides the necessary intelligence on a timely basis to help the manager to plan execute and control, for the system to be effective.

CONCLUSION

There are several conclusions that can be drawn out of this paper. DOM has emerged as a key competitive strategy for business organizations in the global marketplace. An effective implementation of DOM program can focus on addressing the organization's maintenance related problems, with a view to optimize equipment performance. In recent years, many organizations have demonstrated that significant improvements in business can be achieved through DOM. DOM concepts and philosophy can be effectively employed to realize fundamental improvements of manufacturing performance in the organization, thereby leading the organizations successfully in the highly competitive environment. DOM can prove to be an effective global strategy for rendering firms a consistent enhancement of performance in terms of achieving strategic core competencies. Thus, in the highly competitive scenario, DOM might prove to be one amongst the best of the Maintenance strategic initiatives that can lead the organizations to scale new levels of achievements and could really make the difference between success and failure of the organizations. The study validates the relevance of strategic DOM initiatives into the manufacturing strategy for realization of organizational objectives in the successful organizations. The study clearly reveals that the successful implementation of DOM program & Design out information system can facilitate the manufacturing organization's quest for achieving enhanced manufacturing performance leading to competitive advantage.

ACKNOWLEDGMENT

I am thankful to Department of Mechanical Engineering of MANIT Bhopal India for providing the required facilities needed for the successful completion of this paper. I am also thankful to those who have helped me directly or indirectly for accomplishment of this work.

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