CHAPTER 4: MAINTENANCE MANAGEMENT OF CONSTRUCTION MACHINERY

4.1 Introduction

Construction plant and machinery have an instrumental role in the industry's quest for increased productivity. The plant and machinery contribute to the greater success of the construction project by means of providing extra output, reduced manpower requirement, ease of work, timely completion etc. – all of which directly and indirectly improve the overall labour costs, faster execution, increased productivity and results in better profitability. Hence the plant and machinery has to be consistently available for useful intended service, for the effective execution of these projects.

According (MWRA 2009) reports, the benchmark budget on machinery maintenance has been considered at 90% for PM activities and 10% for corrective/breakdown maintenance. Anything less on preventive and more on breakdowns indicate there is urgent need for improvement – since larger spending on corrective maintenance also implies greater number of unplanned machinery shutdown, greater machinery wear, and lessened machinery useful life.

4.2 Human Work / Errors / Monetary Losses in Construction

The mechanization in construction has brought us a long way since introduction of computers in the construction plants and General Packet Radio Service (GPRS) controlled earth-moving machines have helped achieve the "Do-it-right-from-the-start" policy. Electronically controlled anti-collision devices and inbuilt safety devices are fitting examples of technology advancement. Projects once took over longer durations are executed in shorter span durations due to these advancement of technologies.

If there were no mechanization and modernization techniques developed in the construction industry, it would have led to a situation where the requirement of number of human resources versus activities would have become multi-fold. If a tower crane is not there in a construction site we can very well assume the number of persons required to lift a simple boulder to heights. The pictures which depict the construction of Egyptian Pyramids, using

huge blocks of rocks and through ancient rolling and levering methods are the fitting examples showing the ancient construction when there was no mechanization and modernization available. When the human involvement is prevalent, there needs to be more supervision, requirement of fulfilling the basic needs like shelter, food, sanitary requirements, transportations, logistics etc. The social needs of controlling these masses also become inevitable.

When there is a situation like everything by human or through manual means, it leads to the fact that the span of the projects are fully person dependent and becomes prolonged due to uneven skill levels available. This is one of the main reasons for our ancient construction activities executed in decades. To construct The Taj Mahal, it took about 20 years. In the modern time construction even the tallest skyscraper like Burj Khalifa which stands as high as 828 meters has been constructed within a span of just 5 years.

When we discuss about errors, the impact of the precision instruments like that of laser levels in construction, which measure the level of surfaces, can give zero tolerance, zero flat level for a large area of floors, which can never be achieved by human means, in stipulated time. Using auto-cad drawings and micro-stations precisely allow us to manage any complex designs. The computers are provided with artificial intelligence, which helps to generate its own drawings with only provision of certain data inputs. Global Positioning System (GPS) technologies help us to achieve precise locations just by click of buttons even in Amazon. There are even heavy machinery designed in such a way, that they locate the points of required area, level, it, compact it and give the required surface precisely in lesser time with the usage of GPS positioning devices and also through the modern instruments installed in these machinery.

The monetary losses are huge, when we think of machine less atmosphere in construction. Even though we cannot assume such a situation, but the impact of the same can be assumed. There will be plenty of humans and related necessities to be fulfilled involving lot of monetary requirement. The logistics, transportation – horizontal, vertical, material handling, execution methods, interruptions, delays, prolonged duration of projects, finishing trades, infrastructure requirements, the related chaos and confusion all would have cost huge money and hence monetary losses would have been multifold. Hence the role of plant and machinery

in construction has become inevitable due to their providing more advantageous benefits to the construction industry as a whole.

4.3 Importance of Plant and Machinery in Construction Industry

Plant and machinery dependency rate has been on the increasing trend in the construction sector. This is basically due to the following factors:

a) Non-availability of skilled labor,
b) Number of projects on the rise,
c) The demand for completion of fast track projects
d) The infrastructure developments in many parts of the world
e) The living conditions/requirements of the common man keeps improving

Varghese M.M (2000) mentions that according to Government of India estimates, approximately US$ 200 billion will be required over the next seven to ten years for basic infrastructure projects. Given that 20 % of the cost of such projects is associated with the required construction machinery, it is expected that the demand for construction machinery will increase substantially in the coming years. The projected demand of various types of construction machinery for the period 1997-2016 has been projected as high as six times higher than the present level. The hydraulic excavators which were 2000 in number for the period 1997-98 had increased to 6225 in the year 2000-01, jumped to 9350 for the year 2005-06 and will reach to a peak value of 14000 for the year 2015-16, simply confirming one information, the construction machinery market has a potential and growth in the years to come. This projects the consistent growth in the construction market and the demand for related plant and machinery.

The same scenario is for all the construction machinery viz., excavator loaders, front end loaders, crawler tractor dozers, mobile cranes, vibratory rollers, road rollers, asphalt pavers, dumpers, dozers, etc. The growth of demand for this machinery will be on the rising trend between the periods 1997-98 to 2015-16, from 200% to 700% range.

As discussed in earlier chapters the inter dependent activities in construction industry requires the continuous working of all the machinery at all times without interruption on the projects

for better progress, productivity, and profits, as the machinery dependency rate has become very high due to fast track projects in the present time.

4.4 General Classification of Construction Plant and Machinery

Generally the construction plant and machinery are classified based on their utility levels, as executed in the project sites. The following is the general classifications used in major building construction are based on their utility levels.

The classifications of machinery are generally limited to following levels:

1. Cranes
2. Earthmoving
3. Concreting
4. Lifting
5. Finishing
6. Utilities

A schematic arrangement is shown in the following figure 4.1,

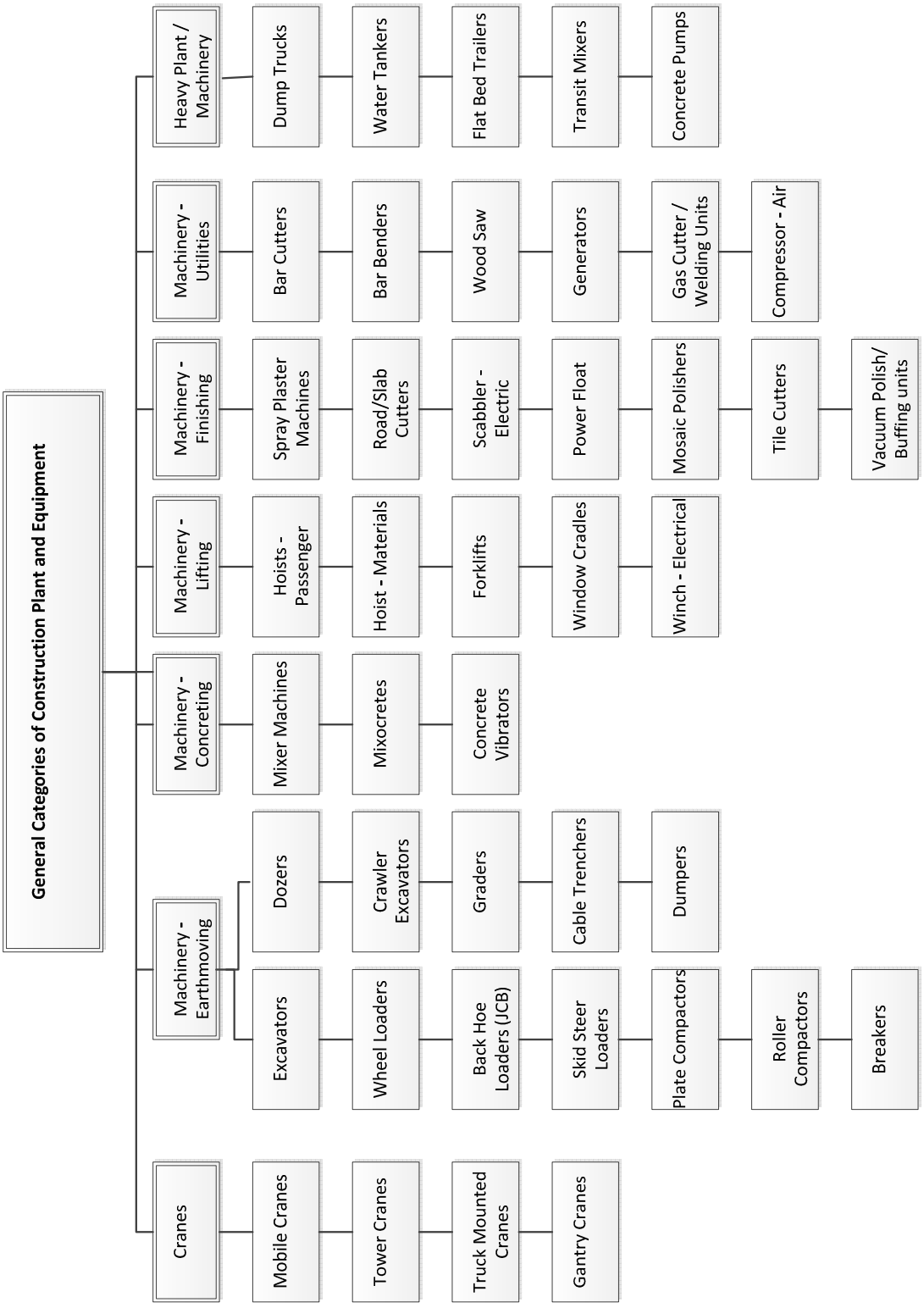

Figure 4.1 - General Categories of Construction Plant and Machinery

4.5 Importance of maintenance management to Construction Machinery

The competitive advantages gained through improved quality, improved delivery and increased flexibility would become nullified if they were obtained with excessive maintenance investments, which could make a firm's costs non-competitive and non-profitable (Dodson, B 1994). The plant and machinery breakdowns and associated maintenance costs continue to affect the optimization of plant utilization throughout the construction sector (David O, 2001). For construction industries, the plant and machinery contribute to the greater success of the construction project, by means of providing extra output, productivity, reduced manpower requirement, ease of work, timely completion etc. - which all directly and indirectly improve the overall labor costs, faster execution, and results in better profitability. Hence the plant and machinery has to be always available for useful service, for the better execution of construction projects. Hence the maintenance and upkeep of these plant and machinery, becomes necessary and important.

Generally the construction companies operate with two kinds of plant assets, owned fleet and the leased/rented fleet of machinery. The leased/rented fleet of plant and machinery are generally maintained by the rental companies. But both the owned and the rented machinery need to be maintained to the optimum level, so that they perform well to their maximum efficiency, without any interruption and they are always available for intended useful work.

The plant and machinery used in the construction industry also range from hand tools up to very heavy construction machinery. Various systems operated in the plant and machinery of include simple mechanical linkage systems to complicated high-pressure hydraulic circuits. The electrical systems also formed with simple connections to the complicated electronic, computer systems. Generally, the construction plant and machinery have various kinds of technologies built in including hydraulic/mechanical/electrical drives, electronic controls, electric systems, and so on. The presence of various types of technology/category mix on the construction machinery demands a robust maintenance in place and as well demand for proper planning of maintenance strategies. Some of the systems require simple preventive maintenance techniques, while the others may require a scheduled or condition based maintenance technique. Hence a thorough study should be made and analyzed to evolve at the best-fit system depending on the type of machinery.

Present construction technologies exert fast trend approach and delays are linked with financial losses due to penalties (Randy R, 1988). A strong case needs to be made since sophisticated as well as old generation machinery work together in the construction industry because of very high prices for the latest machinery. The plant and machinery of the construction industry are always subjected to work in the dust prone atmospheres and the maintenance is the ultimate necessity for their entire life. The machine versus number of activities is much higher in construction industries as listed in earlier chapters. Related works and activities which are parallel and dependent also get hampered during stoppages.

Handfield (1993) made a finding that there is no significant relationship between the number of maintenance activities and Just-in-time (JIT) adoption in the U.S., which is in contradiction to the JIT literature which emphasizes the importance of maintenance rather than JIT as envisaged by Schonberger, (1986). To emphasize the above findings in the construction industry, even though there is general preventive maintenance techniques followed with standard procedures, the break downs on the plant and machinery are inevitable. However, if there is occurrence of frequent failures and breakdowns on the construction plant and machinery, the impact and associated maintenance costs continue to increase which will directly affect the optimization of plant and machinery utilization throughout the construction sector.

Hence the plant and machinery has to be always available for useful service, for the better execution of construction projects. The maintenance and upkeep of these plant and machinery, hence becomes necessary and important.

4.6 Application of Various Maintenance Systems for Construction Machinery in the UAE

The maintenance found its importance since invention of machines. For better execution of construction projects and the construction industry, similar to other industries, has started relying more and more on the mechanization for carrying out the construction works. In order to have a trouble free optimum performance of the machinery, the maintenance of the same is very much essential. The maintenance is often stated as an activity carried out for any machinery to ensure its reliability to perform its required functions (Mishra R.C., 2002).

If maintenance is not effective, it not only leads to halting of work but results in invariable loss of life and property. Whatever may be the trade or field, maintenance is paramount, at least to have a trouble free working environment, for various systems, machinery and fields. In order to achieve industry requirements, world-class maintenance performance in the respective field of operations, more and more companies including the construction industry are replacing their reactive, fire-fighting strategies for maintenance with proactive strategies like preventive, predictive and condition monitoring maintenance and aggressive strategies like total productive maintenance.

As present construction methods involve an approach on activities and delays and disruptions that are always linked with financial losses due to penalties from clients and consultants, a greater care should be given for machinery which works in projects. The new and latest machinery are always expensive compared to the budget provisions of the project and serious attention need to be given since sophisticated machinery as well as old generation machinery work together in the construction industry. The wear and tear rates of these machineries are likely to be very high. Most of these machineries are operated by human operators who work in close proximity with the work and the maintenance cannot be overlooked.

As construction projects will need all the machinery mix to work together consistently for the desired growth, the strategies of maintenance management - preventive, predictive and breakdown all should work together to facilitate effective utilization of the construction machinery. The construction plant and machinery management team should have all good maintenance strategies with the following objectives as per the flow process in figure 4.2

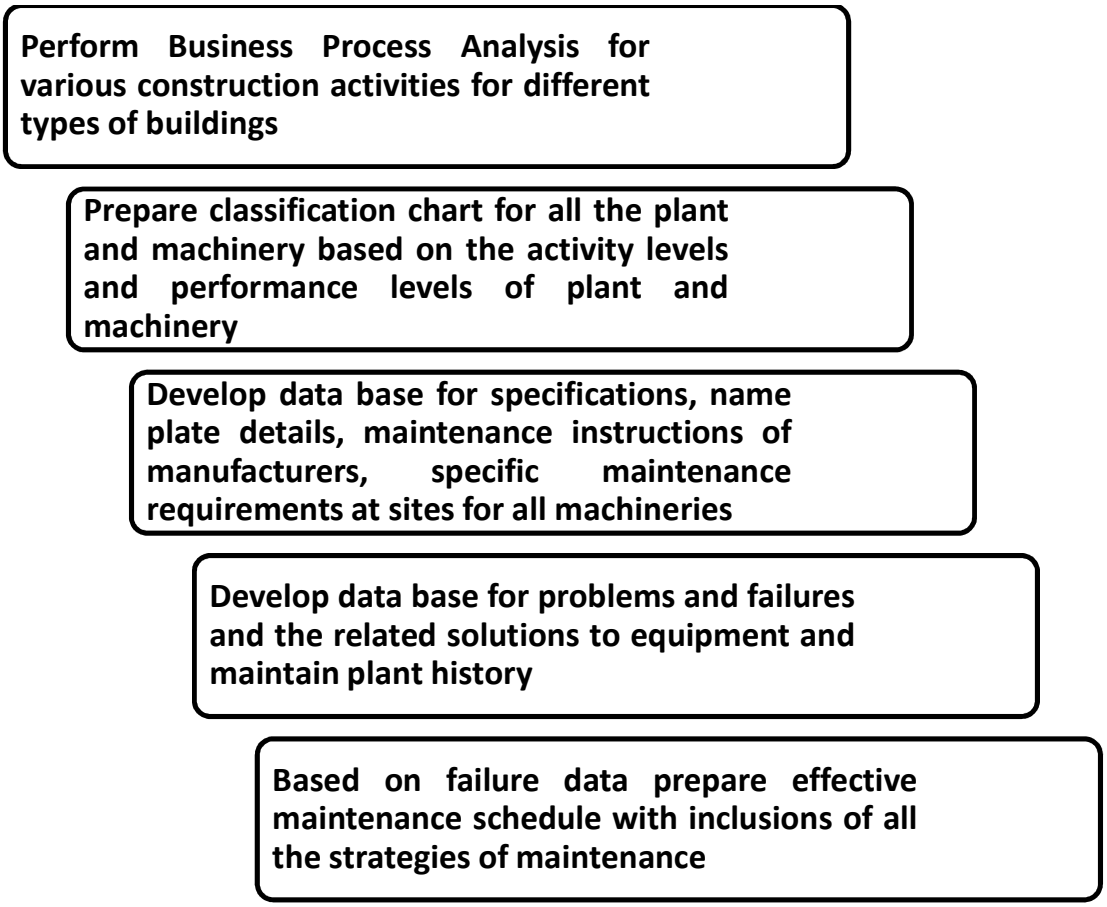

Figure 4.2 Procedural Objectives to Maintenance of Construction Machinery

4.7 Preventive Maintenance of Construction Machinery

An efficient preventive maintenance programme should be well planned and organized. It should be systematic and thorough, and adherence to it should be ensured through proper supervision. By an effective execution of the same, the need for component overhauls is determined prior to a breakdown. In other words, preventive maintenance is effective in overcoming the problems associated with the wearing of components.

PM may include work performed on selected equipment through service contracts, inspections, cleaning activities, testing, lubrication efforts, and scheduled shutdown service. The most significant activity to occur in PM is inspection, which should lead to early detection and correction. Preventive maintenance ensures availability of the components and the machinery.

The preventive maintenance check lists are the guidelines given to the mechanics for carrying out various schedules of maintenance. Oversight errors on the checklists, reduced skill levels

of the mechanics during the execution of the preventive maintenance activities contribute to the failure process. Lapses and misses occurring in preventive maintenance schedules also lead to temporary deterioration of components and subsequent failures. This underlines the requirements and importance of a well- planned and well executed preventive maintenance management in the organizations.

Annual maintenance is scheduled with a 52 week programme break up and the schedules are identified as follows:

- 250 hours/ 750 hours/1500 hours and annual fitness certification works for the hourly operating machinery like wheel loaders, dumpers, compressors, generators, forklifts, roller compactors, skid-steer loaders, back hoe loaders and mobile cranes.
- It is measured as monthly, quarterly, half yearly and annual maintenance for other smaller equipment.
- For vehicles it is done on the basis of 5000, 15000, 30,000 and annual/60000 kilometers

4.8 Construction Machinery Breakdowns

Today world class competitiveness is a must for construction companies. With the financial crisis in place all over the world, multi-tasking, globalization, venturing into new related fields, cutting of costs, ensuring effective utilization of the resources has become necessary for the organizations. As the competition grows, there tends to be a technological push combined with the market pull, and the increased number of customer requirements at reduced costs put forward a lot of challenges for the organizations, who need to ensure effective utilization of their resources and ensure at least minimum profits. As the cost of operation needs to be reduced, even the machinery manufacturers tend to make products, which may be subjected to speedy wear and tear possibilities and reduced life cycles and to add more, these plant and machinery need to work under higher stress always.

Most of the construction companies in the United Arab Emirates work with own and rented fleet of plant and machinery. The machinery is of mixed condition, new-to-old to very old. Even though there are various maintenance strategies adopted for the maintenance of these construction machinery, since these machinery are of mixed age and also they are forced to

perform the service under extreme conditions of very hot to very cold, with the temperatures going more than 50 degree centigrade sometimes, unlike Europe or India, the breakdowns of these machinery are inevitable and unavoidable. As the breakdown of plant and machinery is a common unavoidable problem, it is better to manage the breakdowns in an efficient manner. Hence good management tools on breakdown management of construction machinery are always essential. The reasons for failures and breakdowns can be due to the following attributes as mentioned in figure 4.3.

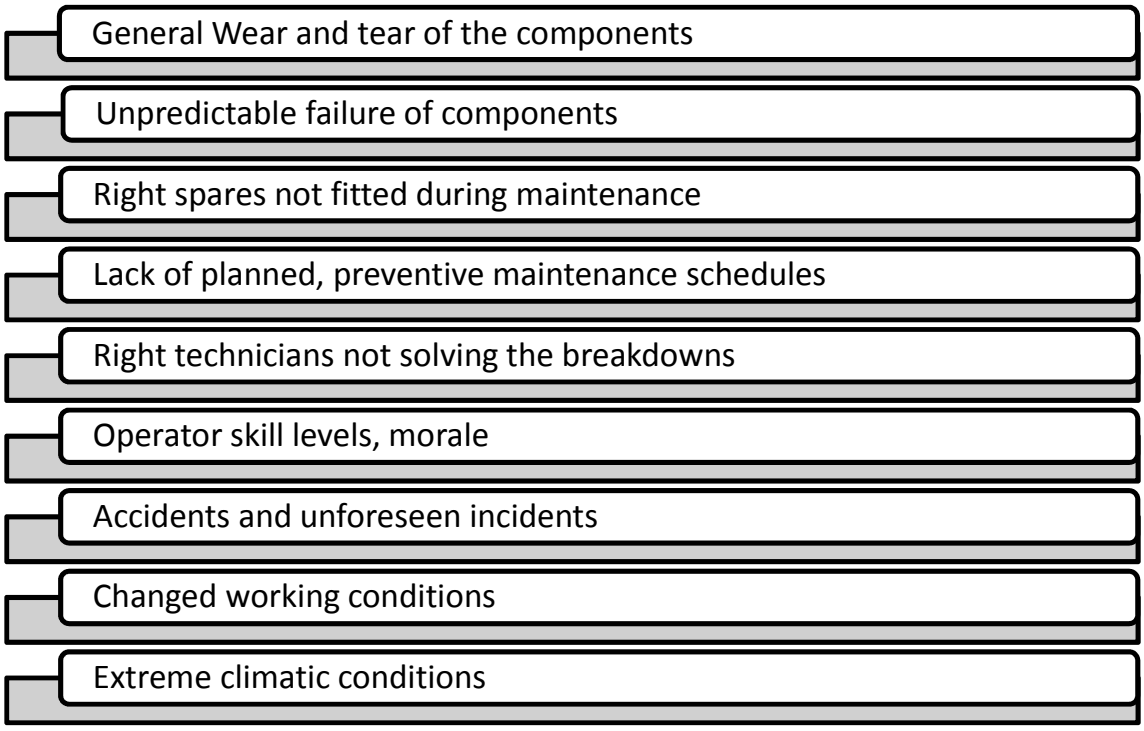

Figure 4.3 Reasons for Failures / Breakdowns on Construction Machinery

Generally in construction industries, all the maintenance systems including preventive maintenance, breakdown maintenance and in the recent times, predictive maintenance techniques like condition based maintenance are followed. Whatever may be the trade or field, breakdown maintenance is always disliked by the end user as it is unproductive. But breakdowns are inevitable. As detailed in table 4.1 all types of maintenance strategies are adopted by the maintenance team for all the ranges of construction machinery from light vehicles up to heavy earth moving machinery.

Table 4.1 Maintenance Strategies on Construction Machinery

Sl. No.	Name of Equipment Group	Preventive Maintenance	Condition Based Maintenance	Breakdown Maintenance
1	Heavy Earthmoving Equipment	Applicable	Applicable	Applicable
2	Material Handling Equipment	Applicable	Applicable	Applicable
3	Cranes	Applicable	Applicable	Applicable
4	Heavy Equipment	Applicable	Applicable	Applicable
5	Heavy Construction Vehicles	Applicable	Applicable	Applicable
6	Concreting Machineries	Applicable	Less Applicable	Applicable
7	Lifting Machineries	Applicable	Less Applicable	Applicable
8	Finishing Machineries	Applicable	Less Applicable	Applicable
9	Commercial Vehicles	Applicable	Applicable	Applicable
10	Light Vehicles	Applicable	Less Applicable	Applicable

- All of the above justify that breakdown maintenance in the construction organizations are inevitable as all of the categories of plant and machinery gets involved with this category of maintenance.
- Nowadays maintenance personnel need to make a strong/convincing cases to seek "rupees/dirhams/dollars" for executing maintenance activities
- Everyone in the construction/ production industry want machinery and plants to work continuously and effectively
- Machinery dependency rate has become increasingly high due to numerous fast-track construction projects in the market which need specialized/ conventional machinery and systems
- Generally in the world and particularly in the United Arab Emirates, there is a tremendous amount of Construction Works progressing and the role of plant and machinery are vital in this area
- Many of the construction organizations have a combination of the old machines working on the obsolete technology and the new systems utilizing the latest technology and the machinery and in a nutshell have plant and machinery of mixed ages like old and some new. These plant and machinery will have to be under a Maintenance Management for serving consistently.
- Whether all the plants and machinery are in very good/good/fair condition, they need to be attended under an effective maintenance system and strategy, so that their working conditions will remain in order and their life expectancy enhanced.

- Proper Maintenance of plant and machinery in the construction industry will significantly reduce the overall operating cost, and will boost the productivity of output
- The typical cost centre approach for maintenance function is on the changing trend, towards profit centre approach in many fields of industries including construction industry

When any failure/breakdown occurs, on the construction machinery, to bring back and to regain its intended serviceability requirements, the breakdown maintenance process has to be flawless and also speed is the essential factor. The supervision of the breakdown maintenance process also will have limitations and may become less as the duration extends due to continuance of the breakdown, which really affects the quality of breakdown maintenance process.

Generally people make a faulty assumption that the cost of the breakdown is the only cost incurred in getting the machinery back into service, but the true cost is considerably higher. The overall costs include, the direct cost of the repair, the on-costs of wages paid to idle operatives, the cost of production affected, cost of alternate plants arranged, cost of regaining the momentum, cost due of loss of goodwill from the clients/customers and the overall cost of loss in production. When these additional costs are added to the breakdown/emergency repair cost in terms of material and labor, the cost of the breakdown becomes substantial.

It also follows the fact that the magnitude of the breakdown repairs and the process duration will be greater, than if the rectification was carried out under controlled conditions, so preventing premature failure even after rectification. Furthermore, if spare parts are not immediately available in the event of an unexpected breakdown, one may face the extra costs of sub-contracting and leasing machinery for production during the extended period of shutdown while the spare parts are manufactured and fitted, thus increasing the cost.

It can, therefore, be stated that normally, unless an item of machinery is so situated that it will not interrupt the intended production, breakdown maintenance is inherently, inefficient on all accounts, creating an indeterminate workload and loss of morale on the maintenance staff and there can be no justification for the continued breakdowns in construction industry.

With all the above facts in place it is very much evident that the breakdown maintenance execution process is generally not a likeable and preferred one as it involves cost, human efforts and will not be prudent, if executed in an unplanned, non-sequential manner. The proposed newer methods and tools paves way for better execution of the breakdown maintenance and will help in the long way to reduce the breakdown durations, to improve on the breakdown frequencies and also to create interest amongst the crew to execute the breakdown maintenance effectively.

4.9 Effect of Construction Machinery Breakdowns

The construction machinery failures/breakdowns make friction effect to the smooth construction activities and in effect, affect the overall productivity and efficiency of the construction programme. To make the construction projects run on time and to ensure the projected revenue to the project, the failures/breakdowns of the machinery to be managed with utmost seriousness. Machinery failures which eventually leads to failures in production systems may cause high losses, for instance in the form of lost production time or volume, negative impact on the environment, lost customers and warranty payments (Todinov, 2006). Consistent breakdowns to construction machinery will almost certainly result in delays to the contract, loss of client goodwill, loss of company reputation and risk to safety.

Break down maintenance is an unscheduled activity and has numerous ill effects in countries like UAE, where the projects are always scheduled on a fast track basis. Hence optimization of the breakdown maintenance with better procedures and techniques will surely yield an effective maintenance system for the organizations. Well defined maintenance systems will ensure enhanced and optimal performance of the machinery. The construction plant breakdowns make the project overrun on time and results in subsequent loss of revenue to the project. Figure 4.4 illustrate the effect of unplanned and frequent breakdowns to the organizations. The dissociation effects shown above indicate that all the good and favourable conditions go away from the contractor/organization, if repeated breakdowns on the plant and machinery occur consistently.

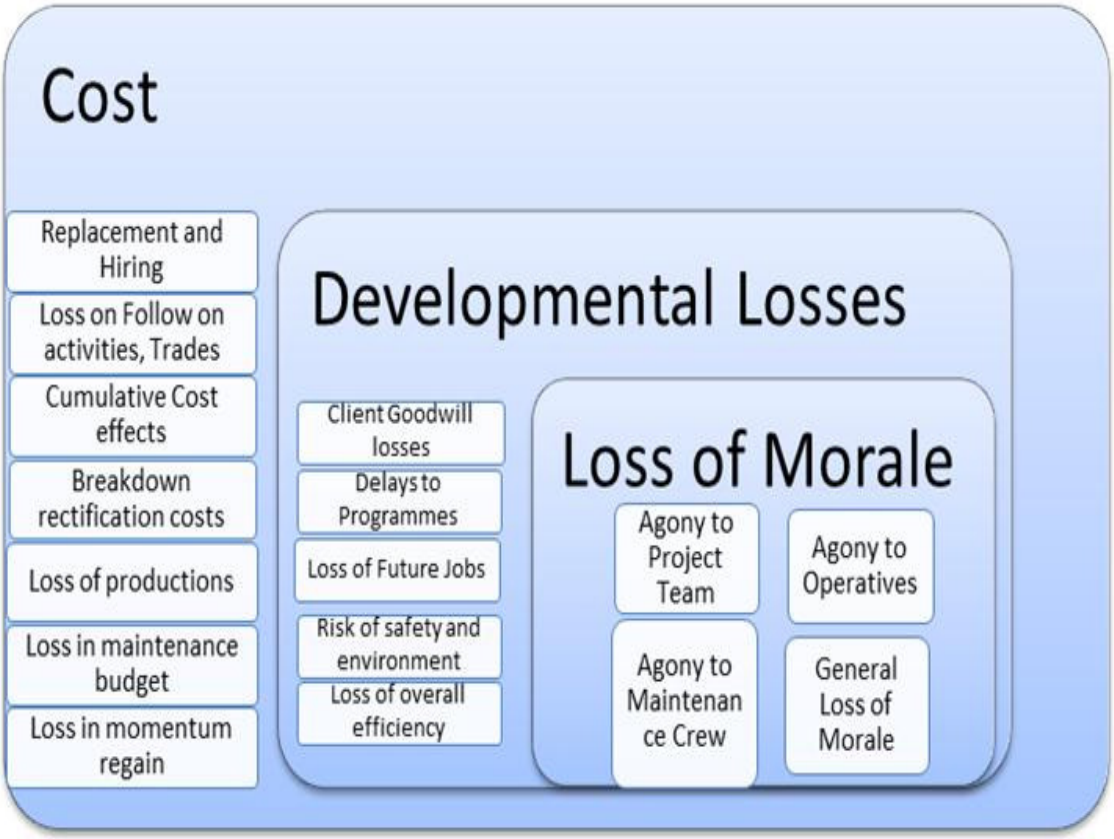

Figure 4.4 Results of Unplanned Breakdowns to Construction Machinery

4.10 Quality Attributes of Breakdowns

The breakdowns happen due to following attributes which are generally the lack of standard workings and requirements not prevailing with the machinery management team. As illustrated in figure 4.5, attributes include general wear and tear of the machine components, right spare parts and non-standard spares and components fitted to the machinery during preventive and corrective maintenance, right technicians not deployed for attending to the specific breakdowns, un planned failures making the situation busy and chaotic leading to haphazard working, sudden and unforeseen accidents and incidents happening at the job sites creating war like situation wherein the remedial repairs to be taken care immediately, the countries like United Arab Emirates where very hot, humid, very cold, dry and all these kinds of climates are prevailing to which the machinery and as well the operatives need to be adopted, shifting of machinery from project to project makes a situation of changed environment to the machinery and it needs to get set with the newer environments, most

importantly failures in preventive maintenance and lack of planning in preventive maintenance which itself leads to the failures. All these quality imperfect attributes makes the breakdowns to be very much unplanned and the relative activities performed after occurrence of these attributes are always haphazard.

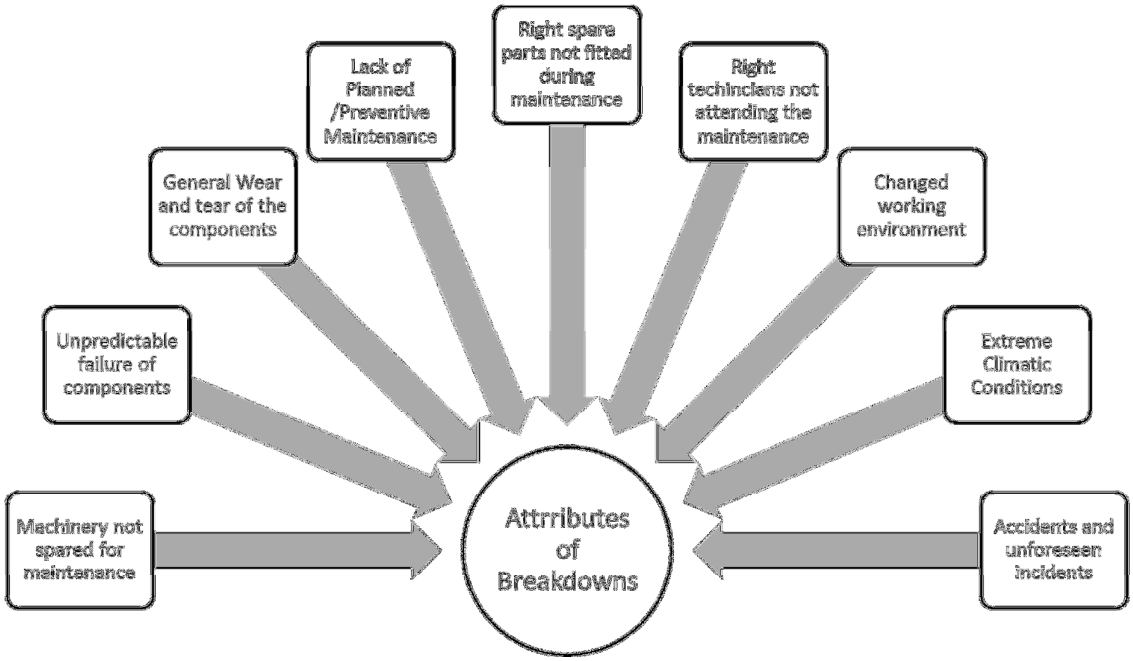

Figure 4.5 Quality Attributes of Breakdowns

4.11 Newer developments and focus approaches in breakdown maintenance management

Figure 4.6 illustrates the newer developments in the breakdown maintenance management include a) Decision support tools and failure hazard studies like CEA tools, failure modes and effects analyses (FMEA) and expert systems b) Flow process analysis tools like fault tree methods (FTA) to find out route causes c) Improved maintenance techniques, such as condition monitoring and breakdown models d) Selecting the machinery which have the designs with a much greater emphasis on reliability and maintainability, e) Effective creation of organizational thinking, ensuring participation, team working and flexibility, f) Improvising the interest on breakdown maintenance performance by the crew, by adopting easier approach towards execution method.

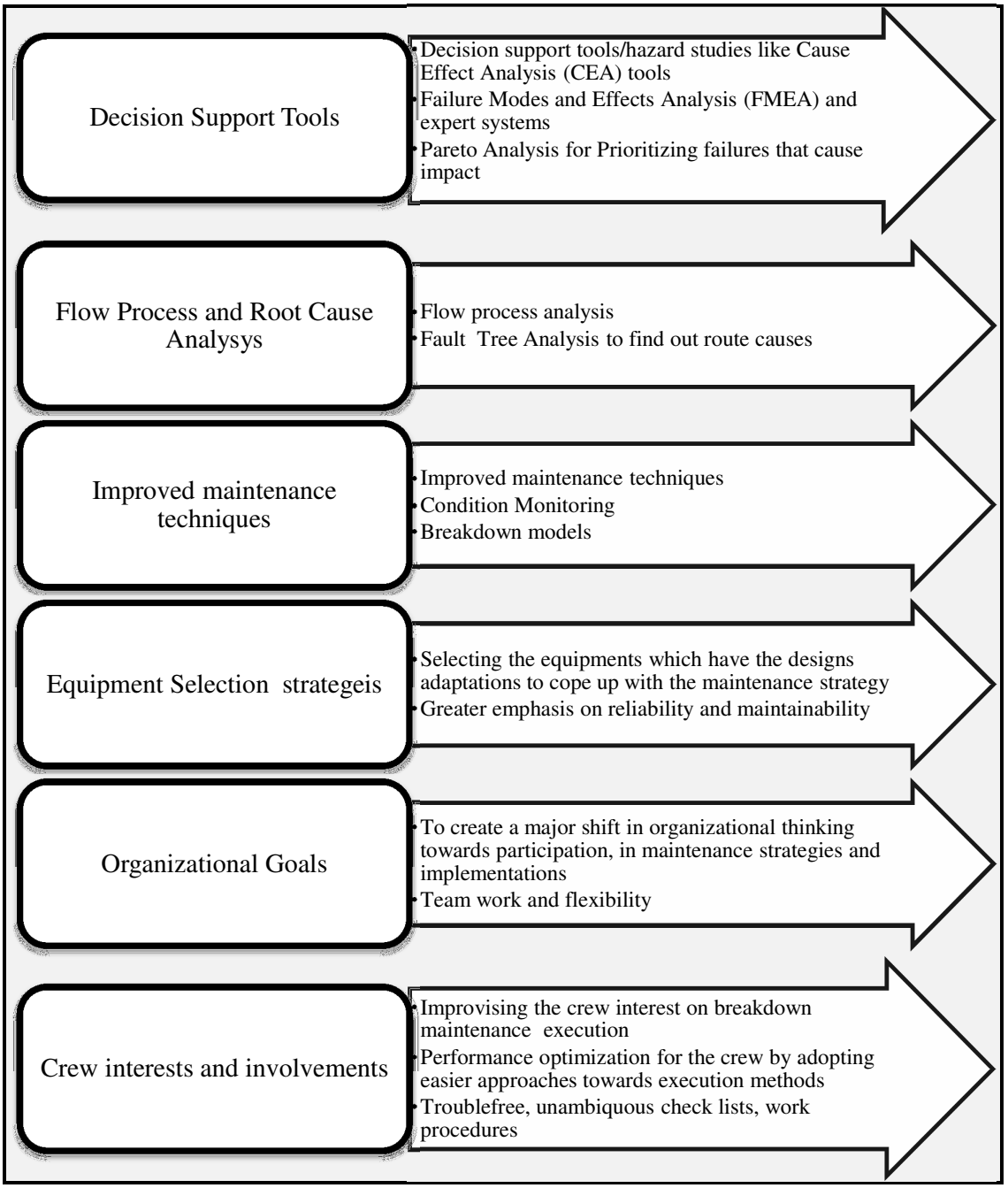

Figure 4.6 – Newer Developments in Maintenance Strategies

A major challenge, faced by construction industry maintenance personnel nowadays is to learn what these techniques are, and also to decide upon which are really worthwhile to be implemented in their own organizations. If the right choices and strategies are implemented, it is possible to improve the asset performance and at the same time, reduce the cost of maintenance and can be summarized as follows:

- To select the most appropriate techniques to deal with each type of failure process in order to fulfil all the expectations of the owners of the assets, the users of the assets and of society as a whole.
- To make the techniques to be more innovative and to remove the concept of ambiguity and fear amongst maintenance crew by way of its easy approach and clear directives
- In the most cost effective and enduring manner with the active support and cooperation of all the people involved including the operatives, end users and so on.
- To provide generalized approach/method which can provide ready-made solution and act as a model tool which can be easily applied by the crew
- To remove the grey areas and ambiguities when approaching and executing repair on a failed system/component/process
- To have determination and deterrent free execution on breakdown maintenance through right protocols

4.12 Machinery Breakdown Maintenance Management – A Conventional Flow Process

The contemporary business environment has raised the strategic importance of the maintenance function in various organizations which have significant investment in physical assets (Albert H.C. Tsang, 2002). As construction industry largely depends on the physical assets namely the plant and machinery, the strategic dimensions of maintenance management including organization, work structuring, maintenance methodology and support systems are always part of newer strategies in maintenance. In the past, many authors have investigated and proposed numerous models to improve the plant's performance based on predictive maintenance. Very few the authors have examined the effect of break down maintenance on the construction plant. No detailed algorithms for breakdown maintenance in construction plant or models based on the data/records of break down maintenance have been reported in the literature.

The real-time reporting of the plant history is examined to understand and determine the factors affecting the breakdown process, overcoming these factors to manage the breakdowns effectively. Based on the study, Breakdown Main Codes (BMC) & Breakdown Sub Codes (BSC) are identified. These BMCs and BSCs are subsequently used to develop further codes

namely Breakdown Symptom Codes (BSyC) and Breakdown Reason Codes (BRC). The dedicated crew/groups of Breakdown maintenance working in the system, can utilize these BSyC and BRC to identify the correct route cause of failures and execute the break downs effectively with minimum recovery time.

The flow process of a typical construction breakdown is shown in figure 4.7. The malfunctions / failures or breakdowns occurring on construction machinery at the site/project will be firstly attended by the machinery operator who is regularly in close proximity with the machinery. He tries to identify the cause of the failure and with his limited knowledge tries to solve the general issues like fuel shortage, tire puncture and hose cuts, provided he is given the minimum repair tools. If it is beyond the level of recognition of his knowledge base, the information/complaint on the failures is informed to the maintenance crew. The maintenance crew upon arrival starts the trouble shooting process to ascertain the cause of the breakdown/failure.

This is a cumbersome process as it involves all the associated field knowledge and the right mechanic in place to ascertain the cause of the failure. Subsequent to trouble shooting further requirement will be to find out the conditions of the component/spare which has been affected, which is the cause of the breakdown. The components/spare should be sent for repair to in-house/outside workshops or to be procured from stores/market and here the role of inventory/stores department takes effect. The method of rectification is generally based on the knowledge levels of technicians and each maintenance crew will have their own ways of utilizing the technical ideas. Further process involves fixing the repaired component/spare part and making the resumption of the functioning of the machinery. This is generally a conventional cycle and if the repairs are beyond the levels of the maintenance crew knowledge, it is sent to the manufacturer/specialist agency for getting the repairs performed.. For companies which does not have such facilities need to depend on the external service providers only for all this activities which will be consuming lots of time and money.

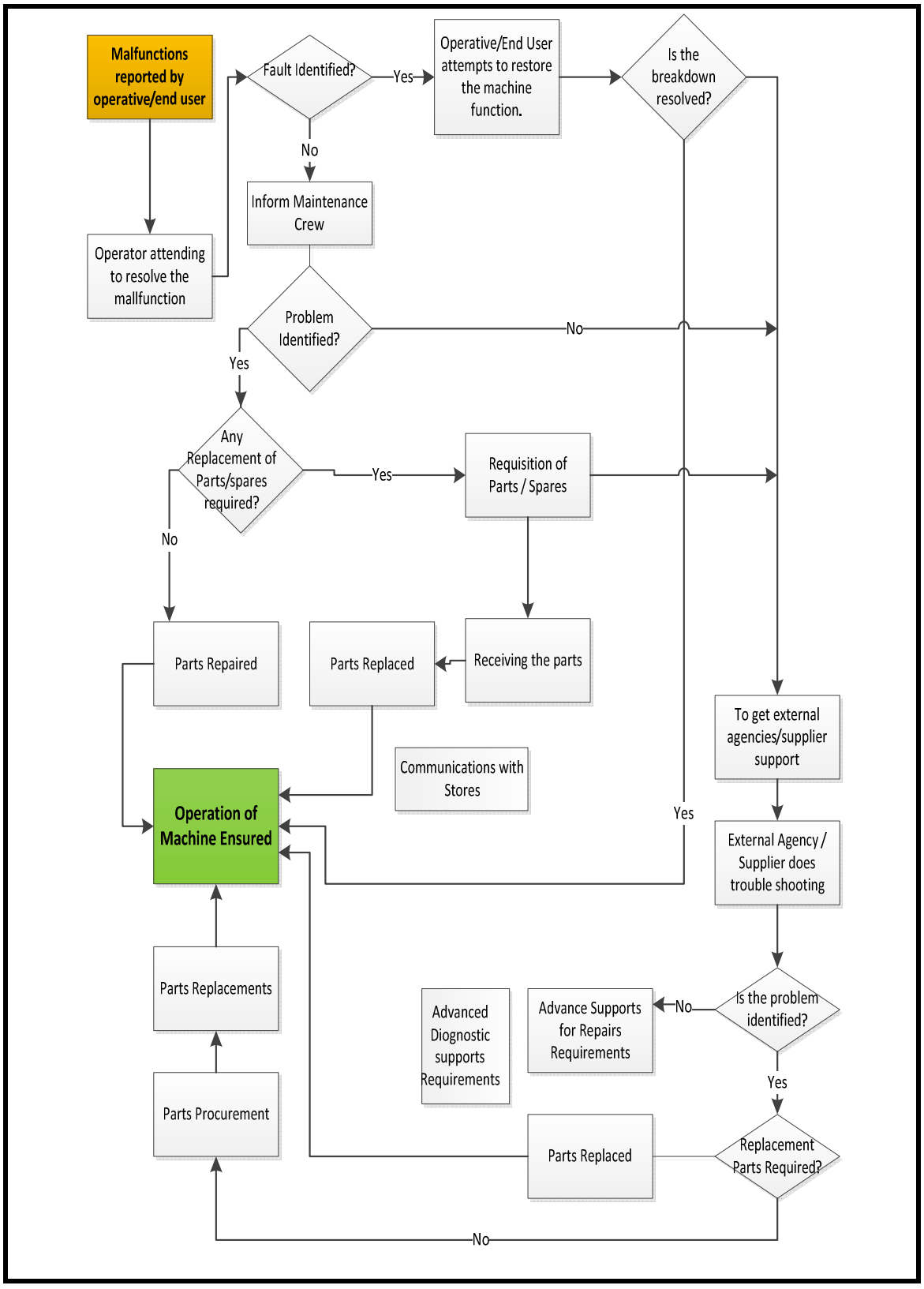

Figure 4.7 Conventional Flow Process of Breakdown Maintenance Execution