Breakdown Maintenance Management (BMM) Model for Construction Machinery – United Arab Emirates Perspective

THESIS

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By

P B AHAMED MOHIDEEN

Under the Supervision of

Prof. M. Ramachandran

and Co-Supervision of

Dr. Calvin Sophistus King, Ph.D

BITS Pilani

Pilani Dubai Goa Hyderabad

BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI

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CHAPTER 8: CONCLUSIONS AND FUTURE RESEARCH

8.1 Conclusions:

- Breakdown maintenance questionnaire survey was conducted in the United Arab Emirates with 72 persons hailing from various constructions machinery management areas, the survey results indicated that if there is a proper system of approach designed to manage nearly all the construction plant and machinery failures/breakdowns, it will lead to better results in the breakdown maintenance management.
- Maintenance costs are a major part of the total operating costs of all manufacturing or production plants and varies between 15 and 60 % to the cost of the goods produced
- The wear and tear rates of the machinery are likely to be very high due to extreme conditions prevailing at construction sites in the United Arab Emirates.
- According to the Third Quarter 2011 Information Handling Services (IHS) Global Insight, the outlook for 2015 global construction spending will be increasing at a compound annual growth rate of 4.7 %, while the outlook beyond 2015 projects for a return to moderately strong growth, in the future years. The CAGR for UAE has been estimated around 20% for the years 2012 to 2013.
- The true cost of breakdowns is considerably high which 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.
- At least 14 % of the Return on investment (ROI) potential improvements are directly related to the maintenance functions as a lost profit which is due to unplanned stoppages and bad quality end products caused by maintenance-related problems
- The selected machinery included, Wheel Loaders, Skid Steer Loaders, Back Hoe Loaders, Dumpers, Mobile Cranes, Forklifts, Compressors, Generators and Roller Compactors and accounts to 180 from the list of 779 machinery of the target company.
- A total of 876 breakdowns from the five year record of the breakdown maintenance data from the selected plant and machinery have been analyzed for breakdown maintenance studies.

- This task of identification of the selection of the machinery is done with a) Failure costs – Cumulative Consequential Cost Impact Analysis b) Critical Construction Machinery Analysis c) Breakdown Impact Effect of Selected Machinery methods.
- The total cumulative loss to the project due to failures/ breakdowns is calculated as per for the formula: **T_P = T_a (Trade Cost) + T_b (Materials Wastage / Activities Lost) + T_c (Machinery / Vehicle Idle Cost) + T_d (Other Time Losses); $T_P = T_a + T_b + T_c + T_d$**
- Total Losses to the Machinery Department is calculated as per the formula, **T_E = T_f (Revenue lost from machinery) + T_g (Replacement Machinery costs) + T_h (Breakdown Rectification Costs); $T_E = T_f + T_g + T_h$**
- 61 % of the breakdowns of all these machinery are falling in the range between 7 to 10 hours or more.
- The cumulative cost per hour breakdown for the machineries, dumper and wheel loader, are AED 6,338/-per hour and AED3,898/- per hour respectively
- Wheel loader with highest breakdown ratio is identified as the most critical machine followed by mobile cranes, back hoe loaders and dumpers in the ranking.
- This critical machinery group of Dumper and Wheel Loader is contributing to 95%, 70.4%, 87%, 81.7% and 58.3% respectively for the years 2007 to 2011 in the earthmoving group of machinery.
- The engine, clutch, gear box of Dumper, have the reliability values of 99.99 % as the cost of even smaller percentages of breakdowns affects the organization's maintenance performance
- Mean time between failures for Dumper which is the frequency of breakdowns is high with engine, clutch, gear box, propeller shaft, and electrical.
- Mean time to repair on Dumpers is high with engine, differentials and hydraulics components.
- The engine, wheels, hydraulic and electrical of Wheel Loaders have the reliability values of 99.96 % and less wherein the wheels have a value of 99.80 and less
- Mean time between failures for Wheel Loaders for engine, electrical, hydraulic, wheel assembly, propeller shaft, and axle assembly is high.
- Mean time to repair on Wheel Loaders is high with engine, transmission, differentials and axle drives components

- The order of frequency of breakdowns on both the machinery varied generally while wheel loader accounted for more frequent failures on the wheel assembly where the dumper had more frequent failures accounted on the engine side.
- The limitation of breakdown maintenance is that most of the repairs are poorly planned, and the concentration is always reactive, that is, only to attend to the obvious symptoms of failure and not on the root cause.
- In spite of being a small percentage of breakdowns of 2 to 3%, the revenue lost due to these breakdowns/failures to the construction process is fairly high as the inter dependency rate of machinery is always high and the loss of production hours results in multifold losses to the target company.
- 15 critical codes namely AA1, AA3, AA4, AA5, AA11, CC1, CC2, CC8, DD1, DD4, DD10, EE1, EE16, JJ3 and LL6 were identified for the Dumper through Pareto Analysis methods.
- 11 critical codes namely AA1, AA2, AA3, DD4, DD10, DD11, DD12, EE1, EE16, GG7 and LL6 were identified for the Wheel Loader through Pareto Analysis methods.
- The focused critical code management approach will help to overcome 80 % of the breakdowns which are generally caused by the critical codes.
- The Breakdown Main Codes, 62 in number, which were the causes for various breakdowns of the components of wheel loaders and dumpers, have been reduced to 27 in number with the Pareto Analysis.
- The severity ratings identified for the breakdown sub codes through FMEA: A38 – 67 % ; A43 – 83.3 % ; A37 – 88 % ; L13 – 92 % ; L05 – 63 % ; and J14 – 80 %
- The total numbers of Breakdown Main Codes (BMC) identified - 107
- The number of Breakdown Sub Codes (BSC) identified - 162
- The numbers of Breakdown Symptom Codes (BSyC) - 119
- The numbers of Breakdown Reason Codes (BRC) - 195
- Each BRC is associated with a Breakdown Maintenance Protocol (BMP) and there are 195 Protocols
- There are 27 resources listed in the Protocol Resource Sheet to manage the breakdowns effectively
- The BMM Model which is the combination of three sub models (Failure Analyzer Model, BMP Identifier Model and the BMM Analyzer Model) and is together termed as the BMM Model.

- The results analysis of breakdowns executed with BMM Model includes 7 broad areas namely, entry of the breakdowns in a systematic manner, registration of the breakdown for the records, fault finding and diagnosis of the failure/breakdown to ascertain the cause of the failure, actual execution of the breakdown maintenance, inspection of the breakdown works, analysis of the breakdowns/failures, and records entry. There are 27 attributes with the 7 broad areas which the present breakdown maintenance are analyzed.
- In the call entry segment, most of the savings was achieved in the first fault enquiry and the response time for the calls. This was possible since breakdown codes and ruler were practiced by all the crew members and identification of the faults was easy. About 10 to 15% improvements were achieved in this area.
- In the Fault finding and diagnosis segment, the operator or the end user of the machinery was easy to locate the problems, since the BMP Ruler has been practiced by all the team members. The root cause identification of the failure was easy with the BMP Ruler and this made the job easy for them and resulted in reduction of time. About 50% average improvements were achieved in this area.
- On the Execution of the breakdowns, the achievements were substantial up to 58%. This was possible with the BMM Model, as the resources requirement for each of the breakdowns, the decision making requirements on shifting of various resources and other aspects required for the effective execution was in place.

8.2 Research Contribution

- The construction machinery which is always working in mixed environmental conditions in the UAE was selected for the analysis.
- Primary data on breakdown maintenance which has been carried out on to the construction machinery in a representative construction industry for the period 2007-2011 was studied and analyzed.
- A survey was conducted with the employees at different levels in various construction and related companies to identify the needs of breakdown maintenance management to construction machinery in the region.
- Cumulative consequential cost impact analysis, breakdown ratio analysis and breakdown percentage analysis is performed to identify the critical machinery that contributes to majority of breakdowns in the representative construction industry.

- The costs to the project and to the maintenance departments were analyzed through application of this model to the selected machinery of the target company and the critical machinery in the system were identified.
- Reliability and availability studies were performed for the selected construction machinery from the failure data and the values of Reliability, Availability, Failure Rate (λ), Mean Time Between Failures (MTBF) and Mean Time To Repair (MTTR) were identified.
- Cause Effect Analysis (CEA) diagrams were drawn for the system failures in the critical machinery for the period 2007-2011 were analyzed and the basic causes were identified.
- The Root Cause Analysis (RCA) was performed to arrive at codes called as Breakdown Main Codes (BMC) and Breakdown Sub Codes (BSC).
- Pareto analysis using charts was done on the BMC and BSC to further find out the significant codes responsible for 80% of the breakdowns.
- Failure Mode Effect Analysis (FEMA) was performed to the BMC and BSC to ascertain the impact of these on to the system/component failures and BSC's with the highest impact ranking were identified.
- Fault Tree Analysis (FTA) was performed with the identified BSC's to further identify the symptoms and reasons for the failures. These were termed as Breakdown Symptom Codes (BSyC) and Breakdown Reason Codes (BRC).
- Based on the principles of Medical Protocols, The Breakdown Maintenance Protocol (BMP) to be followed for each failure based on BMC, BSC, BSyC and BRC was developed for the construction machinery breakdowns.
- A BMP ruler (with multiple rings) was constructed to enable easy identification of root causes through multilevel relationship ruler.
- The BMP Resource sheet and BMP Method of Rectification Sheets were developed to be used with the BMP Ruler.
- A new model called Breakdown Maintenance Management (BMM) based on these studies is formulated.
- A comparative study of breakdown maintenance in the representative construction industry chosen before and after BMM is also carried out and reported.
- The crew involvement has been paramount in this process as everyone contributes to the effective solution for the failures and breakdowns.

8.3 Suggestions for future research

The present research has been restricted only to the level of earth moving machineries in the construction industry. There is always good scope for doing further research on to other machinery.

The contribution of this considered machinery to the overall machinery mix in the construction industry is about 30 to 35 % and hence a similar research on the breakdown codes and a BMP simulation for other machinery which contribute to balance 65 % can be very useful in the future.

The dewatering industry, carpentry and wood working industry, cut and bend industry for the steel rebar works, the heavy earthwork and infra-structure machines, the road works machines are all related industries and machinery base to the construction industry and every field utilizes a different mix of plant and machinery and a similar research can be done on each of the field which are independent.

The developed methodology at present is discussed on analytical approach only and systemization of the same with IT tools with handheld devices given to individual users will facilitate further improvement on this methodology.

The community maintenance models can be developed from the basis of this study, to manage and execute various maintenance areas including total city plumbing maintenance, city electrical maintenance etc.