Computational Model for Fleet Management Based on Reliability Centered Maintenance

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Abstract

This paper aims to study the computational mapping for evaluation of failure indicators in the transportation segment. The proposal establishes the relationship between the computational tools and the necessity to get reliable information. The results show a significant time reduction and a strong impact on failure reduction.

Keywords: Maintenance, Computational Model, Reliability, Fleet, Road Transportation.

INTRODUCTION

The recent changes occurred in the organizational scene where companies need to remain competitive make essential to take strategic actions that can contribute to an optimized and highly productive organization management. Such productivity depends on high process reliability that would stabilize the process continuity and performance. In this perspective, maintenance management has gain notoriety since maintenance function is a key factor in the pursuit of competitiveness based on both quality and productivity (Karabay and Uzman, 2009; Zhaoyang et al.,2011). Equipment reliability considers the integration of various tools to be ensured. It is essential to predict to the information system in advance the possible failures in the operational system. Additionally, through artificial intelligence (AI), the managerial system has to indicate the probability of failure occurrence without affecting the operation of equipment mainly breakdowns. The transport sector as a fundamental part of the modern world has been increasingly stressed by several demands regarding traffic control, emission performance and equipment life-cycle perspective (Eriksson et al. 1996; Li and Crawford-Brown, 2011). Several areas have been researched for improvements in the sector like the development of Intelligent Transport Systems – ITS- (Repoussis and Tarantilis, 2010) focused on traffic problems and other programs for fleet size and routing problems (Belmonte et al., 2008). The investigation on the maintenance area has mainly been focused on programming and maintenance scheduling or reliability of specific components (Huang and Ming-Jong, 2008; Chan et al., 1997). This work proposes a computational model for failure evaluation on the management of interstate road transport fleet characterized as an operational critical process. The model serves as a support and subsidy to foresight and anticipation of schedule for taking decision in transactional processes with focus on organizations of the segment of road transportation.

METHODS

The investigation uses a case study as the method to develop the requirements and demands treated in the system. The study is based in a company located in the Sao Paulo, Brazil, whose operational process refers to critical operations belonging to the segment of interstate road transport, specifically bus transportation, requiring high reliability in operation and management of the operational processes. Data collection will be carried out from information initially obtained through maintenance historical register. There is a record of equipment failures in the past three years for the overall fleet and components. However, only components with higher propensity to faults and consequent influence on operational breakdown will be considered since they are the main cause of high maintenance costs and loss production. These data will be stored in Reliability Centered Maintenance commercial software and integrated to the communication network. The equipment data must also be obtained from suppliers mainly related to the most critical parts in a stressful environment.

LITERATURE REVIEW

Maintenance activities

Nowadays, maintenance can be divided in four different methods: corrective, preventive, predictive and detective. Corrective Maintenance may be derived from a predictive decision, by managerial decision when is called planned corrective maintenance. Then, unplanned corrective maintenance occurs when it is realized on equipment that is no longer working leading to high costs of equipment downtime and maintenance actions (Backlund and Akersten, 2003). Preventive Maintenance allows maintenance obeying to the pre-established schedule by company. Its target is to reduce failures and costs and improve performance focusing on the reduction of the asset's failure probability (Al-Mishari and Suliman, 2008). Predictive or Condition Based Maintenance aims to perform maintenance just when equipment condition requires it. By monitoring inspections, incipient failures are identified before they become critical which enables an accurate planning for corrective action (Slack et al., 2007). Detective Maintenance searches for hidden failures that are not perceived by equipment's operator or systems, usually related to protection systems or command (Canaday, 2008). To face the increasing demand for equipment reliability and performance, maintenance engineering incorporates criteria that improve reliability and availability by studying failure modes, technical maintenance activities, improvements in the equipment design and computerized control maintenance systems (Duggan et al., 2005). Reliability is understood as the probability that an item will do its function without fails, under specific conditions and during certain time interval (Son et al., 2009). Therefore, reliability engineers aim to identify failures in the critic systems' modules avoiding these occurrences at the operational level (Rausand and Hoyland, 2004). Critic systems are normally related to both performance and safety. A system considered with a high degree of risk needs additional protection to functional and informational failures, including data integrity. In this context, a Road Transport System, due to the probability of human failures occurrence, can use automatic controls that will help in activating system security mechanisms and avoid accidents. In the systems of high-risk degree, some terms are used, such as exhibition; vulnerability; attack; threats and control (Sommerville, 2004). Therefore, when the theme is risk management, the term ALARP (As Low As Reasonably Practicable), i.e., as low as possible, (Fig. 1) is useful and can be seen as a guideline in the adoption of risk reduction controls. As conception, the Interstate Road System is a transport's network classified with a high degree of accidents and it needs to provide a service with high reliability due to transporting of human lives.

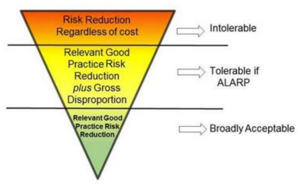

Figure 1 - ALARP (As Low As Reasonably Practicable)
Source: (IEC, 1997)

Data management and information technology

Data warehouse stores data extracted from many operational databases of an organization. It is a central source of data which has been sorted, edited, standardized and integrated in such way that can be used by managers and other professionals for a multiplicity of business analysis, market research and decision support (O'Brien and Marakas, 2005). This resource integrates and consolidates information in many files. It also measures and consolidates data, arranging them for improving query performance. Data warehouse can be considered as a real corporate information factory. Kimball and Ross (2002) specify the main objectives of a data warehouse: a) Providing access to corporate or organizational data; b) Keeping the consistent and reliable data, according to the company criteria; c) Separating and combining the data in order to facilitate any possible business vision; d) Providing means for querying, analyzing, and presenting information; e) Guaranteeing reliable data for publishing; f) Guaranteeing data quality in order to supporting a business reengineering. Data Mart is part of a data warehouse. Although of small capacity, it can be used in a company department with the same characteristics of the data warehouse (Singh, 2001). Generally, a data mart focuses on a unique area of interest or business line that makes his building faster and at a lower cost compared to building an organization data warehouse. The storage volume is challenged daily because there is a large and continuous growth of data available. Thus, data mining enables the "mining" of data in order to generate a true value of the data, turning it into information and knowledge. In this context, data mining can be seen as a method that searches patterns and regularities in a data set using a description logic or mathematical, sometimes complex, and seeking to find patterns, associations, changes, anomalies and statistical structures in the data. Data mining has the following purposes (Elsmari and Navathe, 1994): a) prediction – demonstrates how certain attributes will behave in the future; b) identification – the standardized data are used for identifying the existence of an item, an event or activity; c) classification – data is categorized into different classes and identified based on parameters' combinations; d)resource optimization.

Performance Indicators

The hierarchy of logical steps for each task in the proposed computational model is showed in Fig. 2 and further discussed. The steps aim to analyze questions of technical feasibility and functionality.

- Failure sources and information feedback sources: from the mapping and surveying of company procedures from the people involved in operation and maintenance management it was possible to detect that the main sources of failures are among the operating systems of vehicles control (1), the maintenance operating systems (2) and the external data systems (3) which contains data of electronic system embedded on company vehicles. The occurrences generated from external data systems have not been directly accessed since this system is not part of the conventional network of the company. However, all failures detected in the operating control systems were recorded in the external data and maintenance servers (5 and 6), as well as the registered in the service order for further evaluation;

- Process of collection, treatment and exchange of data: this process (4, 5 and 6) is made twice a day by ETL tool (7) (extraction, transformation and load), assuring that the quality of the imported information is consistent, full, correct, complete, not redundant and according to the decision needs of the company;

- Data storage: after ETL process (7), the data is stored on the server (8) going to data warehouse. The data collected from maintenance transactional systems are stored by dimensions selecting, each one in its dimensional model in the data warehouse (9).

- OLAP (On-Line Analytical Processing): data is already available in the data warehouse (9); company managers (10) can start strategic modeling for decision making through graph consultations or custom reports molded to specific needs;

- Feedback process: after analytical measurements in OLAP layer (9), it is expected strategic decisions are taken safely, guaranteeing the quality of improvement actions in the system.

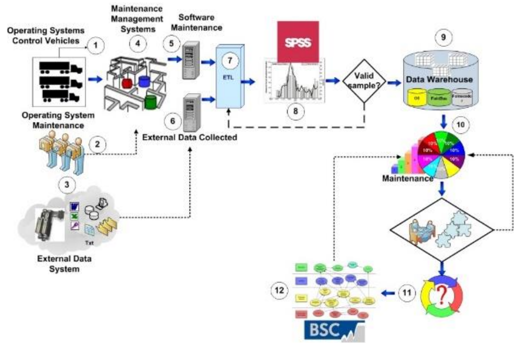

Figure 2 - Hierarchy of logical steps for each task in the proposed computational model
Source: (Authors, 2015)

It can be noted that the environment described allowed the understanding of the information cycle generated by the company as well as facilitated the view and execution of possible tests by analytical processes and necessary decisions. It is estimated, for this particular case, a break of half-day for updating information on analytic environment, thus attending the expectations of managers involved in decision-making. The concept of Strategic Indicators of Confidence (SIC) comes from the definition and study of Kaplan and Norton (2001) who have used the methodology of BSC (Balanced Scorecard) as the main factor for searching the called key Performance Indicators (KPI). It must be emphasized that the strategic indicators treated here were evaluated and adjusted to the case study. As showed in Figure 1, the indicators establish the technological parameters to factors related to the acquisition, implantation, expansion and search for modernization of the existing systems. From the maintenance point of view, the strategies related to equipment maintainability and reliability are defined.

The strategic indicators suggested in the model and extracted from this case study are:

- Indicator of the Nature of the Fault (1): this indicator is related to the intersection of nature and failures occurred in the equipment. It can be highlighted here the frequency indexes (here classified as probable, frequent, occasional, unbelievable), the degree of severity (negligible, low, marginal, critical and catastrophic) and the level of tolerance (undesirable, tolerable and negligible).

- Indicator of Fault Type (2): this indicator is related to the kind of failure occurred in equipment measured by mode (mechanical, electrical, structural and human failure), by failure type (ductile, fragile, fatigue, thermal fatigue, mechanical fatigue, electrical fatigue, corrosion, abrasion, pressure, twist, magnetic, overload, voltage, knowledge, attention, deterioration);

- Occurrence Indicator (3): refer to items like service order number, kind of service performed (corrective, preventive, predictive, executor, date and time of service execution;

- Indicator of Type of Stop (4): this indicator treats the types of stops (repair, test, calibration, alignment, lubrication, adjustment, caster, review, test, exchange, washing, calibration, etc.).

- Indicator of Fault Diagnostic (5): identifies symptoms of fault diagnostic related to: overheating, electric pane, high power, motor abnormal noise, viscosity, wheel abnormal noise, smoke, pigmentation, coloring, improper signaling, fairing abnormal noise, escape of electrical charge, trepidation abnormal, loss of pressure, oil odor, etc.; includes type of risk: chemical, physical, biological, ergonomic, electrical, mechanical, etc.

- Indicator of Line/Region (6): in this item the granularity of data related to line number, origin, destination, region, and distance between origin and destination;

- Indicators Products x Resources (7): this indicator rescues the groups of products: air conditioning, cooling system, gearboxes, chassis, differential, steering wheel, brakes, bodywork, cleaning, engine, tires and suspension in relation to products like: gas charge, air filter, fitting, crosshead lever, radiator cap, air balloon, steering lever shaft, etc.

- Time Indicator (8): this indicator is validated by the variable time defined as: year, semester, quarter, bimester, month, fortnight, week, days, hours and minutes; other variables are hours of downtime, hours in service, hours of waiting, hours of preventive maintenance, availability, hour of occurrence, etc.

Company Profile Study

The company studied in this work belongs to the segment of interstate road transport for collective passenger. It belongs to a huge commercial group that has been presented in the Brazilian market for the last fifty years. The company headquarters is located in the northern region of Sao Paulo city next to the main roads, which is a competitive differentiator factor on easily and availability of vehicles. It serves most cities in the countryside of São Paulo State and São Paulo city with a fleet of 1,235 buses. Providing customer comfort is one of its fleet characteristics; the fleet is all equipped with modern sound and video equipment, as well as air conditioning, besides regular investment in the acquisition of new vehicles. The company used to renew its fleet every two years, worrying about safety and maintenance of their buses. Maintenance stops are programmed every 15,000 Km for new vehicles and every 8,000 Km for used vehicles (out of manufactures warranty). Maintenance is considered the most important and well-equipped sector with high investment approximately about U$10 million on components, parts, automation and fleet maintenance management. The company's philosophy is submitting all buses to an overall revision after finishing travel. Nowadays, the company possesses over ninety employees for managing organization maintenance; these employees are categorized from mechanical engineers to mechanical operators trained at the bus manufacturers. The buses run an average of 900 Km daily serving thousands of people. Although the company worries about service quality, there are many maintenance services programmed by service orders handily made which are transcribed to electronic sheets. Such activity can generate errors and delays in the decision making process. Some vehicles manufactured between 2008 and 2010 already have fault detection technology (Fieldbus). However, it is possible to collect statistic data of failures and incidents from source, read through the software installed in Fieldbus Pattern and with language based on eXtensible Markup Language (XML) technologies. These data will be sent to central databases and maintenance later and there it will be analyzed through distribution analysis and correlation in proper software. Then it will be possible to map and create an adequate environment for reliability analysis, identifying failure mechanisms present on installations and possible statistical trends.

Gains and Improvement

Several studies have been focused on the diagnostic of specific parts or components (Wang and Li, 2004; Li et al., 2006). Some others have discussed only technical aspects of the diagnosis control in a fleet (Sawicki and Zak, 2009) not observing those aspects from the strategic management point of view. In our study, the strategic mapping was generated from the results obtained in many meetings with the company's board and its administrative and technical staff for mapping the future targets to be taken as practicable from next year onward. Fig. 3 shows the strategic map as mentioned here based on Balance Scorecard. The referred mapping is structured by the managers of the company according to four perspectives: financial, market, internal processes and people. Regarding finances, five aspects are taken into consideration: to pursue goals of results (increased sales, growth and profit); to stabilize financial situation and generate cash flow; to generate net profit of 6% per month and reserve a part to expansion; to eliminate corrective maintenance waste; and to search for sources of funding for growing and expanding into new markets. Directing to maintenance subject, company managers found many problems related to the inexistence of systems that could signal the true operational situation and which could integrate all types of information. From the market perspective, managers described seven important parameters as: developing fault prevention model; developing service models; finding new partners; building corporate image; building an expansion plan; improving fleet management and routes; working new business; studying related markets. These parameters are intrinsically connected; all the problems which company has faced lately bringing negative consequences are directly linked to maintenance inconsistency. Then, for improving its market image the development of a new model of fault prevention was started. In this sense, new models have been developed with investments of U$ 4 million in technical support and information systems to avoid failures. Regarding the internal processes, the managers have begun working about: mitigating corrective maintenance; consolidating computing tools; organizing financial and administrative areas; structuring performance indicators; implementing management information; implementing customer service; valuating the human resource management; and organizing the workshop and maintenance department for minimizing costs and maximizing performance;. Prior to the implementation of the computational model, data were fully dispersed, i.e., there was no integration in information which demanded excessive time form managers to analyze the problems and, as consequence, there were several delays on decision-making, as schematized in the schema of Figure 4 and also in the graphic of Figure 5.

Many of the variables raised by the new system were minimized and studied; for example, the function of time decision in the past because of information dispersion was too long and with the new computational model has a 40% gain in failure response velocity and real-time decision making. The information in this new computational model is faster because now the involved employees are already alerted and know how to interpret occurrences, how to act, everything is monitored. Another important variable included in the system and possible to measure is the maintenance cost factor, which the company previously could not measure due to lack of information. The implementation schedule of the vehicles was also improved, anticipating parts which could delay the journey of passengers; this variable has a major impact, causing the driver and passengers have a trip properly scheduled and the bus route fully monitored by the transponder, a device that transmits the vehicle situation. The events from the first six months before the implementation of the computational model were high, averaging 800 per month; nowadays it is around 635 per month, with a tendency to reduce to 200 per month as shown in tendency studies. Another variable that has a big impact from the computational model was the on-hour stops, usually caused by parts that broke on the way of travel, causing delays and exorbitant expenses. There was a reduction of 35% compared to the past, as proved in failure studies. The same happened with the waiting hours that generated losses of customers, achieving a 25% improvement as measured by the call center system of the company in the first half of 2010. The services that were once done through reports, generating misinformation, are now made at computer terminals that are interconnected by a network in which everyone has access to the information. Today, people who are involved in maintenance are able to visualize with accuracy the nature of the fault following a language standard with no individual understanding.

Figure 3 - Mapping the future targets
Source: (Authors, 2016)

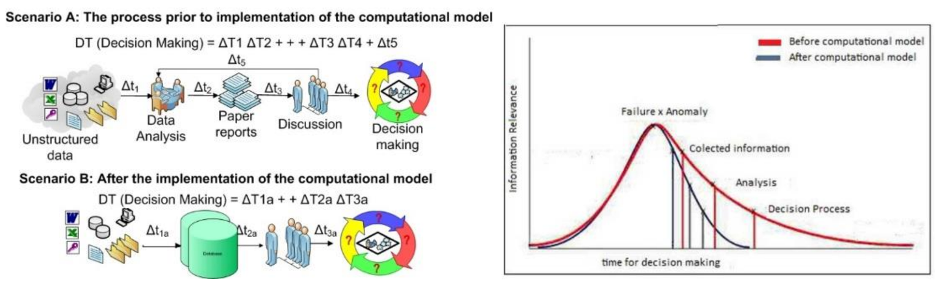

Figure 4 and 5 - Several delays on decision-making and Graphics
Source: (Authors, 2016)

Conclusions

This work presented a study of the development of a computational model for fleet management based on reliability-centered maintenance. The base for the model was the real operation of an interstate road transportation company that have supplied the data and participated on the several steps for the model building.

The obtained results have brought significant gains related to both operational and managerial issues like factors related to procedures and business fleet management, particularly in an organization linked to interstate road transport. The significant time reduction in the decision-making process is an important result that deserves to be emphasized. The reduction of the information extraction time, the data unification in unique and reliable basis, the decreasing of paper flow on the decision-making process and the dissemination of information to other areas of the organization have strengthened operation and maintenance systems and the strategy itself.

Regarding the strategic question it was evident that the computational model proposed integrated with strategic mapping methodology was worthy since with the implementation of the strategic map it was possible to diagnose failures and anomalies. Regarding the studied company, the managers were concerned about waste caused by corrective maintenance. The approach of reliability-centered maintenance with the statistically proved indicators have showed the evidences of waste in the overall organization. Regarding the internal processes, this study affected the company managers because they recognized the possibility of consolidating tools that can support their decisions, as well as the implementation of management information system. The new computational model provides strategic mobility to the company to simulate and predict failure trends and modeling of new scenarios. The easily of analyses and simulation is considered a significant result for synthetic or analytical data samples. The computational tool brings a broad business intelligence layer, facilitating consultation and simulation generated by OLAP queries, facilitating access to key performance indicators of the company. Therefore, the proposed aims were achieved and the use of computational resources corroborated by case study becomes competitive advantage to the business in the studied business environment.

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