A Literature Review of Maintenance Performance Measurement:
Directions for Future Research

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Summary

Today’s manufacturing organizations are required to operate as open operational systems. In such systems, advanced operational manufacturing technologies are blended with modern information systems to integrate and coordinate operational resources, processes, and activities in order to generate a stream of value-added operations aimed at capturing a competitive advantage. With the increasing complexity, scope, and organizational role of operational advanced manufacturing technologies, the maintenance of these technologies is becoming very important to the ability of the organization to compete.

Motivated by the increasing significance of the different facets of maintenance in today’s open system manufacturing organizations, the objective of this research is to systematically examine the literature dealing with the multifacets of maintenance and their organizational and operational levels. Specifically, this literature review focuses on performance measures, measurement, and management of the different aspects of maintenance in an organizational open system context. Based on this investigation, directions for future research are pointed out.

A database of 251 peer-reviewed publications, published between 1979 and 2009, was utilized for the purpose of this research. The published works included contributions from both practitioners and scholars. As a result of this literature review, three-hundred and forty five (345) different measures were found in a total of six hundred and ninety six (696) occurrences. The most utilized measures included several dimensions of maintenance performance, namely technical, economic, safety, and human resources. The least utilized measures group included several key measures, such as training/learning, skills/competences, work incentives, process performance, resources utilization, maintenance capacity, customer satisfaction, employee satisfaction. The results of this literature review also show that most of the reviewed research was based on practical applications.

Based on the content analyzes of the reviewed articles, some relevant issues (themes) related to maintenance performance measures, measurement, and management emerged. The issues listed below represent potential subjects for future research in this important area.

- Effective utilization of maintenance resources
- Total maintenance and information systems support
- Measurement, measures, and the human factor

Based on the findings of this study, it is concluded that this area of research is in need of more future research efforts aimed at solidifying theoretical constructs and practical applications. Findings derived from this investigation have relevant business implications. In this context, understanding the different approaches to maintenance performance measurement and management as utilized in manufacturing organizations is critical to the efforts of these organizations’ performance improvement efforts.
1. Introduction

In the last few decades, manufacturing organizations were forced to shift their business models from closed systems orientations, to more open system orientations. This shift was brought about by drastic competitive forces, which made the customer the focus of organizational, operational and strategic practices. Today’s manufacturing organizations are required to operate as open operational systems. In such systems, advanced operational manufacturing technologies are blended with modern information and communication technologies to integrate and coordinate operational resources, processes, and activities in order to generate a stream of value-added operations aimed at capturing and sustaining a competitive advantage. With the increasing complexity, scope, and organisational role of operational advanced manufacturing technologies, the maintenance of these technologies is becoming very critical to the ability of the organization to compete. In this context, operations management, especially maintenance management is taking on a broader organizational strategic role.

Traditionally, maintenance, with its multifaceted activities, resources, measurement, and management, has been important to manufacturing organizations. However, in recent years, the need to manage the different facets of maintenance more effectively has gained added importance, due to changing operational technologies and the changing organizational role of maintenance. In today’s open system manufacturing organization, maintenance has a broader perspective. In such organizations, the scope of maintenance has shifted from a narrowly-defined operational perspective, to an organizational strategic perspective. Some authors attribute this shift to the utilization of more advanced technologies (Swanson, 1997), increased emphasis on safety, and new environmental legislations (Cooke, 2003). In such operational environment, the role of the maintenance manager is critical. As such, maintenance managers are being called upon to integrate and direct the maintenance efforts to meet organizational strategic goals efficiently and effectively (Alsyouf, 2007; Al-Najjar, 2007). Thus, the need for these managers to receive appropriate formal educational training, which incorporate the different facets of their increasing organizational roles, is becoming more important than ever before (European Round Table, 1999; Shrivastav, 2005).

Motivated by the increasing significance of the different facets of maintenance management in today’s open system manufacturing organizations, the objective of this research is to systematically examine the literature dealing with the different aspects of modern maintenance activities, measurements and management. Specifically, this literature review focuses on performance measures, measurement, and management of the different aspects of maintenance. For the purpose of this literature review, several electronic databases were utilized. In the process, articles published in the last thirty years are identified, analysed, and classified. This research effort facilitates tracing the evolution of performance measures and measurement, as related to the important maintenance organizational function, and its resources, activities, and practices. As a result of this detailed examination, directions for future research are identified and articulated.

The next section provides a brief background, which explores the nature of the problem under investigation. Section three of this research deals with the research method utilized. The results section highlights some of the uncovered important themes. A summary of the findings and directions for future research is also presented.
2. Background

Due to the changing organizational role of maintenance, and the increasing complexity of manufacturing technologies, maintenance related costs have been on the increase in recent years (Parida & Kumar, 2006). In manufacturing organizations, maintenance related costs are estimated to twenty five percent of overall operating cost (Cross, 1988a; Komonen, 2002). In some industries, such as petrochemical, electrical power, and mining, maintenance related costs may surpass operational cost (Raouf, 1993; De Groote, 1995; Eti, Ogaji, & Probert, 2005; Parida & Kumar, 2006). As such, close attention should be paid to maintenance performance measures, measurement and management, in order to utilize the scarce maintenance resources more effectively, and in the process, improve organizational efficiency and effectiveness.

According to the CEN-European Committee for Standardization (2001), one of the main responsibilities of the maintenance manager is to chart a systematic maintenance strategy, which takes the three main criteria below into account.

- To ensure the availability of the item for the required function, often at optimum costs;
- To consider the safety requirements associated with the item for both maintenance and user personnel, and, where necessary, any impact on the environment;
- To uphold the durability of the item and/or the quality of the product or service provided considering, where necessary, costs.

To achieve the overall maintenance objectives, the following strategic approaches are recommended, as either stand-alone, and/or jointly (CEN, 2001).

- Preventive maintenance approach
  - Scheduled maintenance
  - Predetermined maintenance
  - Condition based maintenance
  - Predictive maintenance
- Corrective maintenance approach
  - Immediate maintenance
  - Deferred maintenance

These maintenance strategic approaches are usually implemented through a well-designed set of tasks, which include: inspection, monitoring, test, check, routine operation, repair, general revision, reconstruction, temporary repair, lubrication, cleaning, diagnosis, malfunction troubleshooting, improvement, adjustment, registration and modification (CEN, 2001; Cabral, 2009).

In performing the different tasks related to maintenance performance management, maintenance managers can utilize many tools, approaches, and models. Based on a literature review of maintenance management, Garg & Deshmukh (2006) identified forty-nine (49) types of models, techniques, systems and policies. Similar to the performance management process of any other organizational dimensions, maintenance performance measures, measurement, and management should provide evidence of whether, or not, the intended results have been achieved (IAEA-International Atomic Energy Agency, 1997).

In order to utilize maintenance performance measurement and management to promote positive organizational change, the maintenance performance management system should be designed to track and improve the different aspects of the maintenance effort. This process should
be guided by the integration of critical success business factors, which are derived from the organizational strategy (Tsang, Jardine, & Kolodny, 1999).

In general, performance measurement can play an important role in focusing people and resources on particular aspects of a business (Waggoner, Neely, & Kennerley, 1999). According to Parida & Kumar (2006), the following are considered important factors, justifying the implementation of a maintenance performance measurement process:

- Measuring value created by the maintenance;
- Justifying investment;
- Revising resource allocations;
- Health safety and environment issues;
- Focus on knowledge management;
- Adapting to new trends in operation and maintenance strategy;
- Organizational structural changes.

Despite the overwhelming benefits gained through effective performance measurement and management, and the fact that organizations using integrated balanced performance management systems tend to outperform their counterparts which do not (Parida & Kumar, 2006), studies have shown that 70% of all maintenance implementation initiatives have failed (Bourne, Neely, Platts, & Mills, 2002; Bourne, 2005). Even worse, in a survey of manufacturing organizations conducted by Cholasuke, Bhardwa, & Antony (2004), only one-third of the organizations, with good maintenance management practices tended to realize the full benefits of their maintenance management initiatives.

One of the earlier studies on maintenance performance utilizing data from organizations in the UK (1976 – 1987) reported clear productivity improvement in maintenance services (Cross, 1988b). In this study, it was reported that the most significant contributor to the containment of maintenance costs, and the overall improvement was the restructuring of jobs and the re-organization of the maintenance function. Although particular attention was devoted to cost, the use of other maintenance performance measurement dimensions, such us materials, personnel, safety, workload, reliability, organization, planning and scheduling was also stressed.

The shift from a mere budget reporting-based approach, to a more innovative approaches to maintenance performance measures and measurement has also been forthcoming in the maintenance literature (Löfsten, 2000; Liyange & Kumar, 2003; Al-Najjar & Alsyouf, 2004; Oke, 2006a; Oke, 2006b). These innovative approaches include the use of indicators, reference numbers and visual aids, as well as other more elaborated methods such as the Hibi, and the Luck (Pintelon & Van Puyvelde, 1997). More recently, new performance management approaches, such as the Balance Scorecard, and new organizational improvement instruments, have been advocated to improve the performance of the maintenance management process (Garg & Deshmukh, 2006).

3. Method

For the purpose of this research, an exhaustive and systematic search of the literature related to maintenance management and maintenance performance measurement was conducted. The time frame for this literature review was from 1979 to 2009. This literature search was conducted using, among others, the following electronic databases: Emerald, ScienceDirect, InformaWorld, and SpringerLink. In addition, another search was conducted in an attempt to include related books and thesis. In total, two hundred and fifty one (251) articles were reviewed, showing a crescent tendency in the articles time distribution.
The reviewed articles were published in sixty seven journals (67) between the beginning of 1979 and the middle of 2009. Based on this review, only twenty-eight (28) journals published two or more articles during this period. One hundred and twenty one (121) of the articles reviewed, which accounted for forty eight percent (48) of the articles reviewed, were published in the following five (5) journals:

Journal of Quality in Maintenance Engineering (55),
International Journal of Quality & Reliability Management (26),
International Journal of Operations & Production Management (16),
International Journal of Production Economics (14)
Reliability Engineering & System Safety (10)

The *Journal of Quality in Maintenance Engineering* is singled out, as providing the most coverage on the topic investigated in this study (22%) during the period under consideration.

### 4. Results

Based on careful and systematic content analysis of the reviewed articles, it was determined that some of these articles contained some redundant information. Therefore, one hundred and fifty six (156) articles were selected for further analysis. Five percent (5%) of the retained articles did not present measures. On the other hand, seventy percent (70%) of the articles with measures were supported by a model/ framework.

![Figure 1 - Type and occurrences of maintenance performance measures identified](image-url)
As a result of the focused literature review, three-hundred and forty five (345) different measures emerged, with a total of six hundred and ninety six (696) occurrences. Figure 1 reports the main thirty seven (37) measures, with more than two occurrences. It is to be noted that cost, with forty (55) occurrences, was the most used maintenance performance measure (15% of total occurrences within this group of measures). The most utilized measures represented several dimensions of maintenance performance, namely technical, economic, safety, and human resources. The least utilized measures group included several key measures, such as training/learning, skills/competences, work incentives, process performance, resources utilization, maintenance capacity, customer satisfaction, employee satisfaction.

The results of the content analysis also show that most of the reviewed research was derived from practical applications. It’s evident by the fact that there were hundred and thirty seven (137) case studies distributed in thirty two (32) different industries. In this context, the automotive, electrical/electronic, and chemical were the most represented industries.

Based on the focused content analyzes of the reviewed selected articles, three relevant themes related to maintenance performance measures, measurement, and management emerged. These themes represent reach areas for future research.

4.1 Effective utilization of maintenance resources

From the perspective of the maintenance manager, maintenance resources are finite, and usually below the level they should be. Production stoppages, breakdowns, power stoppages, shortage in manpower, lack of materials (supply), demand (external) and others business factors, directly or indirectly affect the level of production. Thus, making maintenance scheduling a dynamic process (Paz & Leigh, 1994). As such, the limited capacities and resources have to be shared, rather than competed for (Gits, 1994). Developing a maintenance planning programme is an iterative process that involves different decision makers, who may have conflicting objectives. In deriving these objectives, maintenance managers usually try to achieve multiple, and sometimes, conflicting objectives, such as maximizing throughput, availability, and quality, subject to the constraints on production plans (Labib, 1998). The literature points to the existence of tradeoffs among the different aspects of performance (Silveira & Slack, 2001). Performance measures will not have equal importance for an individual operation, thus they tend to be traded-off against each other (Slack & Lewis, 2008). Therefore, in order to solve conflicting objectives, such as system reliability and profit maximization, an organization must establish appropriate maintenance guidelines that regulate (1) costs associated with performing production activities, (2) costs associated with performing maintenance activities, and (3) the various costs associated with equipments failure and the resulting interruptions to the production plan (Weinstein & Chung, 1999).

When manufacturing organizations choose to compete in the global market, they usually use several competitive priorities, such as cost, quality, flexibility, and other competitive methods, depending of their manufacturing process capabilities. Therefore, their manufacturing equipment availability becomes critical, and their maintenance, as an integral part of manufacturing process, can influence those competitive priorities, and hence the business strategy (Pinjala, Pintelon, & Vereecke, 2006). Therefore, it is fundamental for maintenance managers to be aware of the organizational business strategy. Business strategy, in turn, should drive the maintenance approaches, models and strategies utilized. For instance, if on one hand JIT requires high machine availability, which requires excellent preventive maintenance. On the other hand, total quality management (TQM) requires that machines are in excellent working condition (Chen, 1994). Therefore it is important to have an organizational systematic maintenance strategy.
to guide the strategic as well as the operational utilization of these models and techniques (Jonsson, 1997).

There are many models, techniques, systems and approaches available to support maintenance management of activities and decisions (Garg & Deshmukh, 2006). In this context, several new approaches and strategies/tactics/technologies can be utilized. These included among others, self-maintenance, web-based maintenance, integration of product and maintenance design, proactive maintenance based on intelligent units, life cycle simulation for maintenance strategy planning, model-based maintenance, TPM, RCM, PM, CBM, CM (Takata et al., 2004). Therefore approaching maintenance management strategically and systematically has become essential to make the right choices, especially in capital-intensive industries.

The literature points to strong linkages between business strategy and manufacturing maintenance strategies (Madu, 2000; Pinjala, Pintelon, & Vereecke, 2006; Rosqvist, Laakso, & Reunanen, 2009). Thus, there is a need for a carefully designed and implemented organizational system to manage maintenance and related performance aspects from a strategic perspective. According to Alsyouf (2006), such system should have the following characteristics and abilities.

- Assess the contribution of the maintenance function to the strategic business objectives;
- Identify the weaknesses and strengths of the implemented maintenance strategy;
- Establish a sound foundation for a comprehensive maintenance improvement strategy using quantitative and qualitative data;
- Re-evaluate benchmarking maintenance practice and performance with the best practice within and outside the same industry;
- Track maintenance impact and showing the linkages between operational and financial measures, holistically.

Some of the important factors, which need to be considered in the road toward effective performance maintenance management, are highlighted in the reviewed literature (Tsang, 1998; Kumar, 2006; Parida & Kumar, 2006). They include:

- Measuring value created by the maintenance;
- Justifying investment and maximize asset utilization;
- Revising resource allocations, improving responsiveness;
- Health safety and environmental issues;
- Focus on knowledge management and developing core competences;
- Adapting to new trends in operation and maintenance strategy;
- Organizational structural changes.

In this context, the following considerations are in order.
- Business strategy and maintenance strategy must be consistent and linked with each other?
- Maintenance should maximize equipment/resources availability in order to allow strategy flexibility?
- Links between business strategy and maintenance must be well established and made clear to relevant members of the organization?
- There must be a clear maintenance vision statement specifying what goals to accomplish and how such goals can be measured?

4.2 Total maintenance and information systems support

The literature reviewed has underscored the relevance of certain tools and techniques in relation to organizational maintenance and its role (Goh & Guan-How, 1995; Ben-Daya &
Duffuaa, 1995). In the past, reactive maintenance approaches have resulted in consistent but not necessarily effective performance maintenance results (Azadivar & Shu, 1999). However, more recently, new maintenance approaches along with business integration at all levels and across all disciplines has been advocated as important factors to manufacturing competitiveness (Bamber, Sharp, & Castka, 2004). As such, total productive maintenance (TPM) can drive and facilitate an integrated manufacturing management system capable of supporting the different operational sub-systems. This integrated maintenance management approach within a manufacturing environment, places the maintenance function at the heart of the manufacturing system.

Integration can be facilitated by overlapping practices related to manufacturing initiatives, such as JIT and TQM with TPM (Miyake, Enkawa, & Fleury, 1995; Cua, Mckone, & Schroeder, 2001). Significant support was found for a positive correlation between TPM and business performance. Thus, showing that business performance of firms with TPM was significantly superior to the non-TPM firms (Brah & Chong, 2004). In this context, the role of an integrated information system is critical in order to ensure the availability of data needed for true reliability-based maintenance schedule optimization (Sherwin & Jonsson, 1995). Information sharing practices, information attributes, information technology use, collaborative foundation, time-related issues, processes and activities are all considered as critical elements of information integration (Uusipaavalniemi & Juga, 2009).

Information technology (IT) can be beneficial in reducing costs, and assisting in providing services, which were infeasible before (Concetti, Cuccioletta, Fedele, & Mercuri, 2009). IT can also be expensive and wasteful both in terms of time and money. It is therefore essential that the software design of the maintenance performance management system incorporate the culture and resources of the organization for which it is intended (Davies, 1990; Pinjala, Pintelon, & Vereecke, 2006; Hwang, Tien, & Shu, 2007; Kans, 2008).

The literature reviewed presented computerized maintenance management systems that included many of the features needed to support the maintenance management and performance measurement system (Labib, 1998; Labib, 2004). However, typical software usually does not support important features, such as failure reports, which are specific to production functions. Also, the suitable maintenance management software support tends to depend on the maintenance strategy used (Kans & Ingwald, 2008). Manufacturing organizations, especially small and medium-sized enterprises would benefit from having easy-to-use tools and methods for determining their maintenance management information technologies needs to be able in order to choose the relatively best solution available off-the shelf (Kans, 2008).

A common database can be an important instrument for decision-making in maintenance (Kans & Ingwald, 2008). Since it includes data from several relevant operational organizational areas, it can form a basis for a quick overview of the current situation. Applying the common database methodology makes it possible to store and access a more current view of activities related to operations. Us it tends to enhance decision-making related to maintenance, as all data is integrated (Uusipaavalniemi & Juga, 2009). Furthermore, since it gives easy access to relevant on real time and on-demand data, it enables the detection of deviations at an early stage, thereby avoiding unnecessary costs. The backward data identification process ensures that the data-set supports relevant performance measures for maintenance monitoring and follow-up (Kans & Ingwald, 2008).

In this context the following concerns are relevant:

- Maintenance performance measurement systems should be integrated in the organizational performance measurement system?
- Maintenance information systems should be tailored to manufacturing processes.
4.3 Measurement, measures, and human factor management

Maintenance is a logistic organizational function, which is typically integrated into a production process. Therefore, its efficiency and effectiveness tend to be difficult to measure in absolute value. Consequently, performance measures have been defined in relative terms (values), in form of ratios of economic, technical or organizational measures (De Groote, 1995).

In the past, operating ratios were considered to be adequate indicators of maintenance performance. In this context, most commonly used ratios include maintenance cost ratio to the plant area, maintenance cost ratio to the number of people directly employed, and maintenance cost ratio to the number of units produced. The limitation of these ratios is that they were dependent on each specific plant for which they were developed. Specific characteristics for each industry have been identified by literature as constraints to the development of maintenance management system, namely the information systems support (Oelsner, 1979), extent of centralization of the maintenance departments (Ikhwan & Burney, 1994), technical complexity (Swanson, 1997). Thus, it is difficult to compare ratios of different plants or, for that matter, different organizations. In this context, meaningful comparisons of maintenance performance efficiency between various plants can not be carried out in the absence of maintenance performance efficiency standards (Raouf, 1993; Yam, Tse, Ling, & Fung, 2000; Ahrén & Parida, 2009).

Benchmarking is critical toward achieving world-class maintenance performance levels (Chen, 1994; Raouf & Ben-Daya, 1995; Madu, 2000). It is to be noted that although benchmarking is one of the key elements for the continuous improvement process (Ahrén & Parida, 2009), only seventeen of the analyzed papers (11%), presented or even referred to benchmarking techniques in associations with maintenance performance measurement.

The implementation of quality improvement programs, modern information systems, continuous improvement programs, and the evolution of performance measurement systems, tended to promote the recent proliferation of maintenance performance measures and measurement (Cua, Mckone, & Schroeder, 2001; Bamber, Sharp, & Castka, 2004; Seth & Tripathi, 2006). Due to the increase in the number and type of measures, new approaches for maintenance performance measures and measurement are needed (Kumar, 2006).

The literature has presented several approaches to a better systematization and utilization of maintenance performance measures. Traditional approaches tend to establish a hierarchy with two sets of indicators, namely (i) key indicators, to be evaluated periodically, and (ii) detailed indicators, which are only used for searching for the causes of deviations observed in the key indicators (Martorell et al., 1999).

However, more recent innovative approaches tends to present a more balanced view of maintenance performance measures, namely, equipment related performance, task related performance, cost related performance, immediate customer impact related performance, and learning and growth related performance (Kutucuoglu, Hamali, Irani, & Sharp, 2001).

The CEN (2007), through the framework of the EN 15341 standard, presented the maintenance performance measures’ classification in terms of economic, technical, and organizational indicators. More recently, Cabral (2009) classified economical and technical measures in four groups, namely time related factors, human effort related factors, number of events, and cost related factors.

Qualified and well-trained machine operators and maintenance technicians are the driving force behind any effective maintenance measurement system. They collect the information (especially in small extent automated factories with no automatic data collection), and they report
occurrences (Nakajima, 1988). Most of the maintenance tasks are handled directly by operators instead of the on-site maintenance team. Thus, flexible, co-operative and a shared responsibility approach among production and maintenance personnel is required to promote operator ownership and free up maintenance personnel to perform more technically challenging maintenance works (Yam, Tse, Ling, & Fung, 2000).

The human factor presented by maintenance technicians and other related staff is the backbone of the maintenance system in any organization. As such, the effectiveness of the different facets of the performance system is very much dependent on the competency, training, and motivation of the overall human factor in charge of the maintenance system (Ljungberg, 1998). In this context, factors such as, years of relevant working experience on the machine, personal disposition, operator reliability, work environment, motivational management, training and continuing education, are all relevant factors which tend to impact the effectiveness of the performance of the maintenance system (Cabahug, Edwards, & Nicholas, 2004). Operators are in direct contact with maintenance, and are generally able to judge the quality of the service they receive.

The close cooperation and coordination between the maintenance technicians and machine operators is very critical, as it influences service quality and, in turn, the extent of satisfaction with the rendered services. In this context, repeated visits to repair equipment for the same problem result in operator dissatisfaction (Ardalan, Hammesfahr, & James, 1992). As in all quality management programmes, employee participation is critical for success. The attitude, conduct and personality of maintenance personnel are critical to the effectiveness of the maintenance effort (Goh & Guan-How, 1995; Arca & Prado, 2008).

Maintenance human resources have been playing an increasing role in relation to operational environment safety (Rankin, Hibit, Allen, & Sargent, 2000; Patankar & Taylor, 2000). Maintenance resource management addresses the issues related to organization, communication, problem solving, and decision making (Taylor, 2000). Maintenance and safety are sometimes treated as separate and independent sets of activities (Raouf, 2004). However, part of the accidents in manufacturing environments are caused by poor maintenance (Raouf, 2004). An integrated approach is the appropriate approach for optimizing plant capacity, as safety and maintenance are not mutually exclusive functions (Raouf, 2004; Liyanage, 2007).

If an organization stresses teamwork (like in the case of those who use TPM), the remuneration structure should promote cooperation rather than undermine it (Bullinger & Menral, 2002). A wide variety of remuneration programmes, which take into account factors, other than rank, experience and length-of-service exist. This programmes are been used in modern, innovative organizations. Some organizations use pay-for-skill programmes to develop multi-skilled employees, pay-for-performance, promote goal-sharing programmes, and provide bonuses that are linked to group performance (Bullinger & Menral, 2002; Eti, Ogaji, & Probert, 2006). However, offering the “right” rewards alone is unlikely to produce sustained empowerment. The power of such methods to maintain commitment declines with use (Eti, Ogaji, & Probert, 2006). Today’s privileges become tomorrow’s rights. Involvement and autonomy are the main motivations that activate the human mind and drive human effort (Eti, Ogaji, & Probert, 2006).

In this context the following research concerns are relevant:
- Should the operators training process include maintenance techniques?
- Should maintenance technicians training include manufacturing process know-how?
- Should the maintenance technicians’ compensation system be based on organizational strategic objectives?
5. Conclusion

This literature review examined issues relevant to the different facets of maintenance activities, resources, measures and measurement in manufacturing organizations. Based on this literature review, which examined relevant articles published from 1979 to 2009, a trend toward moving from the maintenance performance measurement and measures based on a mere budget reporting, to complete and integrated systems with operational and strategic roles was identified.

The historical evolution of maintenance and its organizational role shows a clear path toward the integration of maintenance management. This evolution as it progressed from reactive, preventive, and predictive to a more holistic/process oriented organizational perspective (Alsyouf, 2007). This path is also marked by a first, second, third and recent generation maintenance milestones (Arunraj & Maiti, 2007).

Based on this review, the high levels of equipment availability may not be attributed only to maintenance practices. That availability can be attributed to some practices, which are also leads to the success of other continuous improvement techniques, such JIT and TQM. These practices include, among other management commitment, worker training, worker empowerment and a philosophy.

This literature review also stresses the evolution of the maintenance function in the context of the evolving manufacturing organization. As such, it underscores the consistency between the organization and its view on maintenance. In this context, closed system organizations tend to view maintenance as a cost of doing business, or a necessary evil. These manufacturing organizations viewed the maintenance as a stand-alone operational function, they tend to have a transactional processing system (TPS) informational perspective, they used internal benchmarking, they focused on operational objectives and goals, and they use stand-alone operational technologies.

Open system organizations tend to view maintenance as a strategic competitive resource. This view is consistent with maintenance measures used and information systems utilized to gather needed data. The changing complexity of manufacturing technologies is also evident in the evolution of the maintenance function and its role in today’s manufacturing organizations. These manufacturing organizations view the maintenance, as integrated strategic organizational system. They tend to utilize DSS/Database informational perspective. They also tend to use competitive benchmarking. Such organizations tend to focus on strategic and value-added objectives and goals. Finally, they tend to utilize integrated advanced manufacturing technologies.

Based on this literature review the following relevant issues are put forts for future research considerations.
- Integration of activities, resources, models and human factor;
- Simplification of procedures;
- Competitive benchmarking;
- The role of modern information systems;
- Performance measurement and improvement;
- Strategic, systematic perspective.

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i Hibi – A method computes an integrated efficiency ratio and compares it with a time control scale.

Luck – A graphical method where 4 aspects of maintenance are distributed along the sides of a square, and the global performance is the interception point of the two lines connecting the 4 opposite sides of the square.