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Maintenance decision support for sustainable performance: problems and research directions at the crossroads of health management and eco-design

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Abstract: Despite companies progressively taking sustainable performance into account through various governmental incentives and policies, most still have their own strategic, tactical or operational targets based essentially on economic criteria (turnover, productivity, inventory valuation...). Since the 2000s, the scientific community has been more particularly interested in sustainable operations management, but little research addresses the three dimensions together: economic, social and environmental. Although product and production system maintenance has a significant impact on economic, environmental and social performance, and therefore sustainability, it is no exception. In this paper, we investigate research in the field of maintenance decision support to highlight the gaps we consider to be among the causes of the partial control of sustainable performance in this domain. We then show that some solutions could take inspiration from prognostic and health management, as well as eco-design practices. This investigation led us to establish lines of research for the control of sustainable performance in maintenance.

Keywords: Maintenance, sustainability, decision support, prognostic, health management, eco-design.

1. INTRODUCTION

Sustainable performance is long-term performance hinged on three dimensions: social, environmental (or ecological), and financial. Company performance should be measured and assessed in relation to these three dimensions, as proposed by the Brundtland Commission almost Thirty years ago (WCED, 1987). However, strategic, tactical, and in particular operational targets of companies are still based essentially on economic criteria (turnover, productivity, inventory valuation...).

It is now recognised that sustainability can only be obtained through a holistic approach, as well as the life cycle analysis of both products and services. In this context, the maintenance stage is known to have a significant impact on economic, environmental and social performance, and therefore sustainability. Here we consider maintenance for sustainable performance as a subset of the broader sustainable operations management (SOM) that requires efforts in modelling and analysis (Gunasekaran et al., 2014). Although this subject has attracted much attention from both researchers and practitioners over the past 6–8 years, a limited number of these studies integrate both economic and environmental implications or focus on a trade-off between profitability, competitiveness and environmental dimensions. Moreover, very few of these studies include socio-economic aspects of which the most advanced domain is eco-design. We therefore propose taking inspiration from this domain as well as prognostic and health management, one of the more advanced maintenance approach, to resolve the weaknesses we have identified.

2. WEAKNESSES IN MAINTENANCE DECISION SUPPORT FOR THE ASSESSMENT OF SUSTAINABLE PERFORMANCE

2.1 Relevance and reliability of performance indicators in maintenance

Maintenance Performance Measurement (MPM) is defined as "the multidisciplinary process of measuring and justifying the value created by maintenance investment, and taking care of the organization's stockholder's requirements viewed strategically from the overall business perspective" (Parida, 2006). In this context, we can find some standard performance indicators used to attain different maintenance activity objectives at different decision levels. Standard EN 15341 proposes more than seventy Performance Indicators (PI) covering three different levels and divided into three categories: technical, economic and organizational. Only the economic dimension of sustainability is explicitly considered in this standard. The social dimension is indirectly considered through worker safety with the PI "number of injuries for people due to maintenance". The environmental dimension is considered very globally with the concept of "environmental damage".

In their state of the art on maintenance performance metrics, (Kumar et al., 1993) found that for maintenance to contribute to the company's strategic objectives, Key Performance Indicators (KPI) must allow challenges related to productivity and efficiency to be met. In a quest for sustainable

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performance, these two objectives seem questionable to us for several reasons.

Firstly, with the succession of economic crises, industrialists have experienced a decrease in activity, which implies a reduction in the use of their manufacturing systems, most of which were designed to produce at a maximum rate and not to produce less for long periods. A useless quantity of energy is therefore consumed to supply unused equipment. From a sustainability point of view, maximizing the productive capacity is less efficient than optimizing utilization rates, which can be obtained by reconciling maintenance and production scheduling (Sénéchal et al., 2015).

Secondly, we consider there are some risks in using availability and the associated KPIs commonly used in RAMS (reliability and maintainability). However, these are the main preoccupation of maintenance managers and many authors consider them as “raw materials” for creating more complex indicators. Availability can be viewed in several ways that might be a source of confusion: instantaneous, average, steady, inherent, achieved, or operational availability. For example, some standards consider average availability when failure and maintainability rates are constant, and do not include operating downtimes, logistics downtimes, and preventive maintenance downtimes (NF X 60-500). However, some authors consider the entire time between failures (Sourisse et Klaye 1999), (Zwingelstein 2009). To rely blindly on this indicator could also lead to serious decision-making errors.

The third reason is the way in which such indicators are economically weighted. For instance, the unavailability of a production tool can generate costs due to lost production (touch-ups, scrap, material losses...), trade costs (discounts, late fees...), subcontracting costs, depreciation, or even the deterioration of the company’s brand image. The temporal and causal distance between maintenance activities and such consequences make it very difficult to account for these indirect costs. This is amplified by the budgets to which the corresponding expenses are allocated, as the budget is supposed to be the image of where costs appear, not where they come from. The evolution of total maintenance costs over time and the proportion of direct and indirect costs for a given device are mainly due to the evolution of its wear and tear. Various maintenance actions can lead to various changes in the long-term average yield, giving the shares a different economic relevance according to the date on which it is calculated.

The latter weakness of common MPM affects social, environmental and economic assessments, and even more so if we consider the time scale of environmental and social phenomena.

As we showed at the beginning of this section, availability is questionable with regard to the associated definitions and calculation modes. It is nevertheless the variable that most research aims to maximize.

2.2 The quest for availability, blindly considered as the best guarantee of performance

The majority of research in information science, and more particularly automatic control, aims to act on phenomena that may influence equipment availability, in a preventive or corrective way, including:

- Improving equipment reliability (Weber et al., 2012; Noyes 2002),
- Understanding non-performance causes (Cauffiez et al., 2005),
- Preventing failures (Deloux et al., 2010; Medina-Oliva et al., 2012),
- Reducing repair time (Le Mortellec et al., 2012),
- Overcoming unavailability (Monnin et al., 2012).

Such research could potentially, but not always, contribute to improving economic performance (higher productivity can result in an increase in company turnover...), environmental performance (fewer failures so lower environmental impact...), and even social performance (more operator confidence in his/her equipment, better working conditions...). However, none of the studies reviewed formally or exhaustively establish a link between these goals and performance categories. This seems particularly problematic considering that this link is not always as straightforward as one would tend to believe.

If we take the case of economic performance and look at the question of the link between the reduction in Mean Time to Repair (MTTR) associated with an increase in Mean Time Between Failures (MTBF) of equipment and the evolution of company turnover, we can see that it is heavily influenced by parameters that are external to the way the equipment is used and maintained: the share of fixed costs in the total expenses incurred by the company, its trade policy, the profit margin, or even the market's ability to absorb manufactured equipment. In addition, considerable and sometimes very expensive efforts devoted to avoiding failures in the context of preventive maintenance may be a source of losses for the company in some situations.

Similar observations can be made in the environmental field. For example, we can question the positive environmental consequences of a maintenance decision that helps prevent equipment failure that does not generate pollution or overuse of natural resources, but that requires urgent delivery of spare parts located several hundred kilometres away by road…

Maintenance decision support for sustainable performance should therefore consider several decision criteria at each decision level: strategic, tactical and operational.

2.3 Partial consideration of multi-criteria and multi-level dimensions

Even without considering the three dimensions of sustainable performance, numerous criteria must be taken into account in maintenance decisions. Decision makers must therefore summarize these considerations, more or less formally. We observed several studies aimed at formally defining multi-criteria decision-making in maintenance. Some authors have used an AHP (Analytical Hierarchy Process) complete aggregation method to compare five maintenance policies