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Research directions for integrating the triple bottom line in maintenance dashboards

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ABSTRACT

Among the activities managed by an organization, the maintenance of the resources it uses considerably affects sustainable performance. In this paper, we propose research on decision support for controlling sustainable performance induced by maintenance processes based on the core principles of decision systems. We discuss their application in maintenance, and underline the weaknesses of current practices in this domain. As we are particularly interested in key performance indicators, dashboards and prognosis approaches, we have reviewed the work on these subjects conducted by different scientific communities. This study allows us to propose a set of founding elements to conduct research on dashboards for sustainable performance in maintenance. Among these elements, we define sustainable value, sustainable signature, and sustainable state of the equipment. We suggest implementing such dashboards in Sustainable Condition-Based Maintenance (SCBM) based on Remaining Sustainable Life (RSL), and we propose a framework to conduct this research using a systemic approach according to the process of dashboard building.

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1. Introduction

Sustainable performance is long-term performance hinged on three dimensions: the social dimension that consists of looking after the welfare of people, the environmental (or ecological) dimension that deals with the planet's health, and the financial dimension aimed at reducing costs and boosting benefits. The concept appeared fifteen years ago under the term “triple bottom line” (Elkington, 1998; Asselot, 2011), and is currently being deployed in corporate operational management.

Among the activities managed by an organization, we are particularly interested in the maintenance of the resources it uses. Maintenance is defined as a combination of all technical and associated administrative activities required to keep equipment, installations and other physical assets in the desired operating condition or restore them to this condition (Muchiri et al., 2011).

It is increasingly recognized that maintenance has a huge impact on economic, environmental and social performance. In Industrial Ecology, maintenance is considered from the perspective of the whole product life cycle. In a holistic or system thinking approach, it leads to the integration of system complexity and a multidisciplinary vision to manage assets as a whole (Iung and Levrat, 2014). Green maintenance attempts to make maintenance more environmentally benign by eliminating all associated waste streams, and consists in the integration of product design, maintenance planning and execution issues aimed at minimizing the negative environmental effect (Ajukumar and Gandhi, 2013). As part of the circular economy, maintenance can first be seen as a means of sustaining the target system throughout its life cycle, then as a key tool to maintain the regeneration potential of the artefacts, and finally as a target system that also needs to be sustainable (Iung and Levrat, 2014). Beyond the artefacts on which maintenance is applied, the target of maintenance activities is to ensure the durability of services provided by these artefacts. This vision places maintenance at the heart of the concepts of “service economy” (Stahel, 1997), “Eco-Efficient Services” (Bartolomeo, 2003), “Product-Service Systems” (Tukker and Tischner, 2004), and of “servitization” (Baines et al., 2009). In these economic models, services are still provided through equipment's use, and so the maintenance is still applied to equipment. But the control of this maintenance activity, as well as dismantling and recycling, becomes the responsibility of providers/manufacturers instead of the customers/users' one.

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Whatever the economic model, life-cycle maintenance consists of managing maintenance activities in an effective way throughout the life cycle of the maintained system. For this, some authors suggest to build maintenance management on three feedback loops in order to adapt maintenance strategies to various changes such as those in the operation conditions and environment (Takata et al., 2004).

In such a context, decisions made and information considered must evolve, and decision support tools must be adapted to suit new needs. As research managers, we propose to conduct research on decision support for sustainable performance in maintenance using a combined holistic/analytical approach. In section 2 we analyze these needs starting with the core principles of decision systems. We discuss their use in maintenance, and underline the weaknesses of current practice in this domain. In section 3 we review the research conducted on key performance indicators (KPIs), dashboards and prognosis approaches for decision support in maintenance. These studies are the starting point of some of the steps in the framework we propose in section 4. This framework is part of the set of founding elements we propose in order to conduct research on dashboards for sustainable performance in maintenance based on a joint holistic and analytical approach. Section 5 concludes the paper and introduces prospects for the implementation of these elements.

2. Current elements and weaknesses of decision systems in maintenance

Maintenance is undertaken in production systems (production of products and services), and as such it inherits their decision-making mechanisms.

2.1. Decision-making mechanisms in production systems

If we refer to the systems theory, a production system can be divided into three sub-systems (Doumeingts et al., 1998): physical system, decision-making system, and information system.

The global performance of a given production system is highly dependent on interactions between the three sub-systems, and between the production system and its environment (Sénéchal, 2004). These interactions are of major concern in cybernetics (Wiener, 1948), from where comes the second key concept of control: feedback. Decision-making in production systems is part of a control loop where decisions result from comparisons between expected and observed situations. Numerous papers talk about performance in terms of effectiveness and efficiency. Some use the terms without ever defining them precisely (Martorell et al., 2002); others use them synonymously, though clearly linked to different decision-making levels (efficiency associated with internal and operational decisions; effectiveness associated with strategic and external decisions) (Yasin et al., 1999).

In the case of sustainability research, it seems important to us to clearly distinguish these notions and others such as relevance and effectivity. According to (Mentzer and Konrad, 1991), relevance is the connection between the objectives and the means, efficiency is the connection between the means and the results, effectiveness is the connection between the results and the objectives, and effectivity is the connection between the objectives, the means and the results, evaluated in terms of the finality of the system.

We consider that the performance control loop has to balance these four dimensions to obtain a more regular tetrahedron, as shown in Fig. 1.

Knowledge of the observed and expected situations requires the use of two categories of performance indicators, currently named in the safety domain as leading and lagging indicators (Hinze et al., 2013).

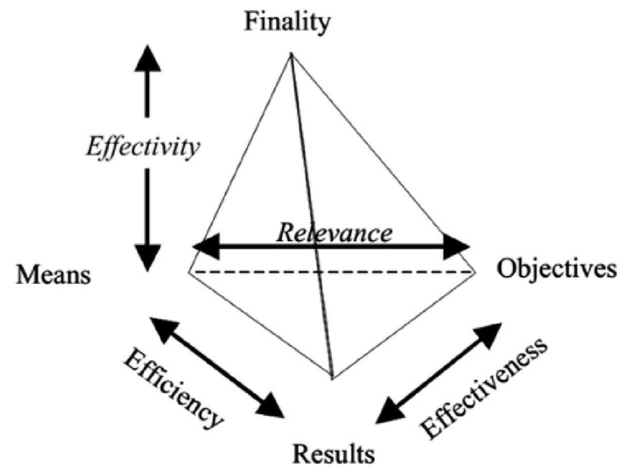

Fig. 1. The performance tetrahedron to balance control production systems.

Lagging indicators are measurements that are linked to the outcome of an observed phenomenon. They can provide data about incidents after the fact, and are the traditional safety metrics used to indicate progress toward compliance with safety rules.

Leading indicators are measures that can be used as predictors of future levels of safety performance. In the literature, Grabowski describes leading indicators as conditions, events or measures that precede an incident and have a predictive value with regard to an accident/incident/unsafe condition (Grabowski et al., 2007).

Finally, this control loop must be developed at every decision level in the production system (strategic, tactical and operational), and must take into account the wide range of criteria set by decision makers and thus be built with the right KPIs.

Decision makers, and notably managers, are often overwhelmed with reports and information churned out from a multitude of organizational information systems. Performance dashboards might offer a remedy to this information overload problem by providing an all-inclusive package for performance management, incorporating various concepts into one manageable solution (Yigitbasioglu and Velcu, 2012).

Here, we are particularly interested in the application of these principles to KPIs implemented in maintenance decision support, found under the term “Maintenance Performance Measurement” (MPM).

Weaknesses in the application of these principles to the traditional Maintenance Performance Measurement (MPM).

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 requirements viewed strategically from an overall business perspective” (Parida and Chattopadhyay, 2007). In this context, we can find some common performance indicators used to reach different maintenance activity objectives at different decision levels. The standard EN 15341 proposes more than seventy indicators on three different levels that are divided into three types: technical, economic and organizational. Only the economic dimension of sustainability is explicitly considered here. The social dimension is indirectly considered through worker safety with the number of personal injuries due to maintenance.

The environmental dimension is considered in a very global way through the concept of “environmental damage”. In their review of the state of the art on maintenance performance metrics, (Kumar et al., 2013) found that for maintenance to contribute to the

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