Defining Maintenance Performance Indicators for Asset Management Based on ISO 55000 and Balanced Scorecard: A Hydropower Plant Case Study

Renan Favarão da Silva

Department of Mechatronics and Mechanical Systems, University of São Paulo, Avenida Professor Mello de Moraes 2231, São Paulo, SP, 05508-030, Brazil. E-mail: renanfavarao@usp.br

Arthur Henrique de Andrade Melani

Department of Mechatronics and Mechanical Systems, University of São Paulo, Avenida Professor Mello de Moraes 2231, São Paulo, SP, 05508-030, Brazil. E-mail: melani@usp.br

Miguel Angelo de Carvalho Michalski

Department of Mechatronics and Mechanical Systems, University of São Paulo, Avenida Professor Mello de Moraes 2231, São Paulo, SP, 05508-030, Brazil. E-mail: michalski@usp.br

Gilberto Francisco Martha de Souza

Department of Mechatronics and Mechanical Systems, University of São Paulo, Avenida Professor Mello de Moraes 2231, São Paulo, SP, 05508-030, Brazil. E-mail: gfmsouza@usp.br

Silvio Ikuyo Nabeta

Department of Energy and Electrical Automation, University of São Paulo, Av. Prof. Luciano Gualberto, Travessa 3, 158, São Paulo, SP, 05508-010, Brazil. E-mail: nabeta@pea.usp.br

Fernando Hiroyuki Hamaji

EDP Brazil, Gomes de Carvalho 1996, Vila Olímpia, São Paulo, SP, 04547-006, Brazil. E-mail: fernando.hamaji@edpbr.com.br

Asset management coordinates activities to realize value from assets in organizations. Regarding the physical assets, maintenance is an important sector for achieving the organizational goals of companies. Evidence shows that poor maintenance can result in process failures that can put people at risk, lose revenue and make operations unfeasible. Therefore, maintenance performance should be properly monitored and evaluated in an asset management approach. In this context, this paper proposes a method for the determination of maintenance performance indicators (MPIs) for asset management based on international ISO 55000 series and Balanced Scorecard (BSC). The proposed framework comprised three sections: guidelines review, strategy alignment and maintenance indicators definition. The ISO 55000 series and the BSC approach were the guidelines reviewed. ISO 55001 was used to identify the performance evaluation requirements for an asset management system. Three different levels of evaluation are needed to meet the standard: assets, asset management, and asset management system. Then, BSC approach was reviewed to address the asset management level according to its four evaluation perspectives. The MPIs were defined for each of the performance evaluation levels in line with the maintenance strategy studied. A case study was applied to a maintenance sector of a Brazilian hydroelectric power plant. The results obtained showed a consistent method by which organizations can define MPIs that contribute to the achievement of business strategy systematically.

Keywords: Asset management, maintenance, performance, indicators, KPI, ISO 55000, Balanced Scorecard, BSC, hydropower plant.

1. Introduction

All organizations have physical assets that are used to manufacture products and deliver services, and for decades, managers have asked if this has been done efficiently and effectively (Hodkiewicz (2015)). Since these assets allow organizations to achieve strategic objectives and meet the needs of stakeholders, an adequate asset management has become crucial for organizations to remain competitive in the current global market (Ihemegbulem and Baglee (2017)).

According to ISO 55000, asset management is the coordinated activity of an organization to realize value from assets. Achieving value typically involves balancing costs, risks, opportunities, and performance benefits (ISO (2014a)). In other words, value represents the

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concept of a gain being greater than any associated pain as a good value means that the benefit cost ratio is highly attractive and a poor value, obviously, the reverse (Woodhouse (2018)).

The challenges of intense international competition and market globalization have placed pressure on maintenance management for better results. Maintenance is an important sector for achieving the organizational goals of companies regarding the physical assets. In industries, maintenance represents a large percentage of operating costs and face challenges to improve their processes in order to obtain greater equipment availability (Ihemegbulem and Baglee (2017)).

In addition, evidence has shown that failures in the process can be a consequence of poor maintenance. As an aggravating factor, these failures can put people at risk, lose revenue and make operations unviable (Ihemegbulem and Baglee (2017)). Thus, evaluating maintenance performance properly is an essential process for improving maintenance and, consequently, asset management.

With the release of ISO 55000 series for asset management in early 2014, there was a need to investigate how this can improve maintenance management as it is part of the asset management lifecycle. However, there has been little academic review of the subject (Okoh et al. (2015)).

Performance evaluation is one of the elements required for an asset management system in the ISO 55000 series. Nevertheless, these standards only prescribe what needs to be in place, not how these requirements should be fulfilled and many organizations struggle with it (Wijnia and de Croon (2014)).

In this context, this paper proposes a method for determining the maintenance performance indicators (MPIs) for asset management based on international ISO 55000 series and Balanced Scorecard (BSC). The method intends to address the performance evaluation requirements related to performance indicators set out in the ISO 55000 series and to use BSC as a support tool. It is validated through a maintenance case study application in a hydropower plant.

This paper is organized as follows: Section 2 presents a brief description about asset management performance evaluation in the ISO 55000 series context. Section 3 describes the BSC approach for measurement of organizational performance. Section 4 presents the proposed framework for defining MPIs in line with organization strategies. Section 5 applies the method to a hydropower plant case. Finally, Section 6 presents the authors conclusions about the proposed method and study case.

2. Asset Management Performance Evaluation and ISO 55000 Series

The ISO 55000 series, launched in 2014, is the first official international standard in the asset management discipline that has reached global consensus. According to the Global Forum on Maintenance & Asset Management (GFMAN (2016)), the ISO 55000 series describes the benefits of asset management as enabling organizations to realize value from the use of assets in the achievement of their organizational objectives.

The series ISO 55000 contemplates three standards (ISO (2014a), ISO (2014b) and ISO (2014c)) which cover asset management in a broad spectrum. Asset management enables analytical applications to manage an asset during different phases of its life cycle (ISO (2014a)). In this paper, the focus is specifically on the lifecycle maintenance stage of physical assets.

Among the elements that make up an asset management system, the performance evaluation concentrates the monitoring, measurement, analysis and evaluation. According to the ISO (2014b), the organization shall evaluate and report on the asset performance, the asset management performance and the effectiveness of the asset management system. Therefore, performance evaluation takes place at three different levels. The relationship among these performance evaluation levels was represented in Fig. 1.

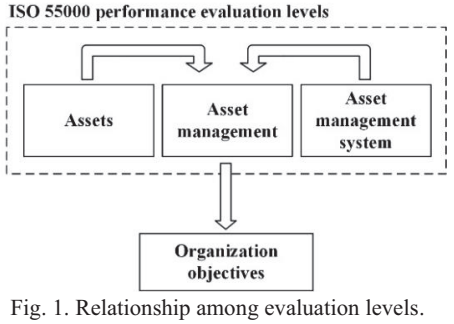

Fig. 1. Relationship among evaluation levels.

The first level is related to the assets and, according to ISO 55000, is often indirect and complex. Asset data management and the transformation of data into information are key to measuring asset performance. For the second level, asset management, it is recommended that asset management performance be assessed against whether asset management objectives have been met, and if not why not (ISO, (2014a)).

Finally, for the asset management system, ISO 55000 recommends that the performance of the asset management system be evaluated against the objectives set specifically for the system itself.

The main purpose of evaluating the system is to determine if it is effective and efficient in supporting the organization's asset management (ISO, (2014a)). The organization shall also conduct internal audits to assess whether the asset management system complies with its requirements (ISO, (2014b)).

As can be seen (Fig. 1.), asset performance level directly impacts asset management. Similarly, the asset management system level also impacts asset management outcomes. Both can positively influence asset management results. Lastly, asset management performance should contribute to the achievement of organizational objectives.

3. Balanced Scorecard (BSC)

The BSC is a performance measurement approach based on a model of four evaluation perspectives: financial, customers, internal processes, and learning and growth. It describes how the business unit creates shareholder value through better customer relationships, driven by excellence in internal processes. Such processes are continually improved by aligning people, systems and cultures (Kaplan and Norton (2006)).

The four perspectives are interconnected by a chain of cause and effect relationships. This relationship is given from the bottom up, that is, perspective (d) contributes to (c), which contributes to (b), and finally to (a), as shown in Fig. 2. In other words, for example, a departmental training program enhances employee skills and contributes to the improvement of internal processes. Better processes contribute to better customer service and can impact greater satisfaction. At its last level, increased revenues and margins depend on customer satisfaction (Kaplan and Norton (2006)).

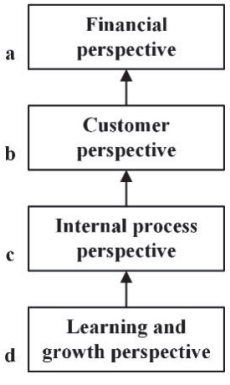

Fig. 2. Cause and effect relationship in BSC.

According to Kaplan and Norton (2003), measurement systems should focus on organizational strategy to make the greatest possible impact. Thus, when designing the BSC, the organization must measure the few critical indicators that represent its strategy for long-term value creation. In this paper, the corporate strategy deployment into lower levels such as maintenance strategy will integrate the proposed method for MPI definition.

Finally, it is noteworthy that BSC does not deal with strategic plans. Its focus is on aligning organizational objectives in different levels of application and linking performance indicators for the four perspectives that relate to those levels. Thus, the BSC does not approach what should be done to achieve these objectives. It describes the strategy into objectives and indicators.

4. Proposed Method

This paper proposes a novel method for the determination of the maintenance performance indicators (MPIs) for asset management using the guidelines from ISO 55000 series and BSC. This framework complies three sections: Guidelines review (I), Strategy alignment (II) and Maintenance indicators (III). The proposed framework was detailed and represented in Fig. 3.

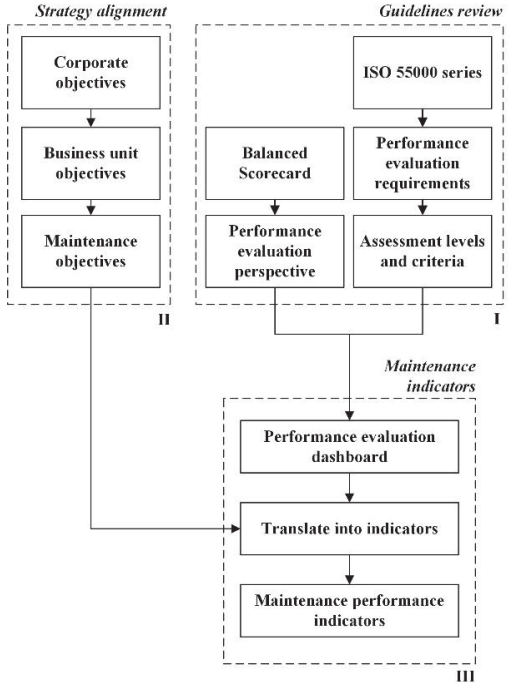

Fig. 3. Proposed framework for MPI definition.

4.1 *Guidelines review*

The proposed method starts with the review of two important guidelines in the first section (I): ISO 55000 series for asset management due to its recently importance for maintenance and the BSC approach for performance measurement. Both were integrated to develop a maintenance performance dashboard.

According to the performance evaluation in ISO 55000 standard, the organization should evaluate the performance of its assets, its asset management and its asset management system (ISO (2014a)). As requirements of ISO 55001, the evaluation shall focus on asset performance, financial and non-financial performance of asset management and the effectiveness and compliance of the asset management system (ISO (2014b)). Thus, the ISO 55000 series specifies three assessment levels and their criteria for performance evaluation which will be used for MPI dashboard.

The BSC approach for performance evaluation has been integrated to address the criteria for the second evaluation level of the ISO 55000 series. The BSC balances financial indicators with non-financial indicators from three other perspectives: customer, internal process, and learning and growth (Kaplan and Norton (2003)). Therefore, the asset management evaluation level was structured according to the BSC approach and meeting the financial and non-financial valuation as requirements of ISO 55001.

4.2 *Strategy alignment*

The Strategy alignment section (II) consists of parallel activities for the understanding of the corporation in analysis. It aims to support researchers and those involved in performance evaluation in aligning corporation's strategic objectives with the objectives of business union and, subsequently, with the objectives of maintenance.

According to Kaplan and Norton (2006), one of eight types of corporate alignment is the alignment of corporation and business units. It is characterized by the unfolding of corporate priorities into business unit strategies. In this paper, the method proposes to unfold these business unit strategies at a lower level (e.g. department level of a business unit) with another alignment. Since the objectives of maintenance department are aligned with the expected results of the business unit as well as the organization, it will be possible to translate then into MPIs.

4.3 *Maintenance indicators*

In the Maintenance indicators section (III), the proposed framework fills the dashboard defining the MPIs as it translates the maintenance objectives. Therefore, these indicators will be able to measure maintenance performance while aligning with the interests of the business unit and the corporation.

5. Case Study

In this paper, the proposed method was applied to a 198 MW installed hydroelectric power plant composed of 4 Kaplan turbine generating units. Hydroelectric plants are of great importance in Brazil as over 65% of the electricity is generated by hydroelectric plants (Brazil (2018)). This plant in specifically has been undergoing studies and suggestions for asset management improvements. Its maintenance department is centralized and serves the entire plant.

During the Guidelines review phase (I), the ISO 55000 series and the BSC approach were used to define the levels and perspectives for maintenance performance evaluation. This approach aimed to address ISO 55001 requirements related to performance evaluation indicators for asset management while integrating BSC perspectives for the asset management level. The levels of evaluation were appropriated to the context of the case study in order to enable this application, as shown in Table 1.

Table 1. Levels and perspectives for evaluation.

	Levels	**Application**	**Perspective**
I	Asset	Critical equipment and systems	Performance
II	Asset management	Maintenance management	Financial Customer Internal process Learning and growth
III	Asset management system	Risk management systems	Effectiveness Compliance

In this article, the asset level was applied only to critical equipment and systems. For the asset management level, because this paper is only addressing the asset lifecycle maintenance stage, it was equivalent to maintenance management. Finally, for the third level, the organization should have an asset management system, which is not currently in place. Thus, the risk management (rm) system and its interfaces with maintenance was considered for the application.

Subsequently, the strategy alignment phase (II) was initiated to support the identification of applicable performance indicators (MPIs) for each level and perspective of the Table 1. As

planned in section II, this was accomplished by unfolding corporate and business unit objectives at maintenance level. Thus, the proposed indicators for maintenance performance evaluation will be aligned with the company's main objectives. In other words, MPIs will monitor what really affects the achievement of strategic objectives while helping to clarify how maintenance contributes to it.

In this paper, the annual integrated reports of the organization were used to study the corporate strategy and its objectives of the case study. This approach was used by Silva et al. (2019) when identifying criteria that were aligned with corporate objectives for a maintenance criticality analysis of systems and equipment. From these documents, it is possible to identify corporate and business unit objectives and unfold maintenance objectives in line to them.

Clearly, an integrated report from a multinational company has hundreds of objectives, indicators and outcomes discussed. The corporation of this case study has structured its value generation under six different types of capital: infrastructure (if), financial (f), social (s), human (h), natural (n) and intellectual (it). For this application, at least one corporate or business unit objective of each capital was selected to define aligned maintenance indicators, as shown in Table 2.

Table 2. Unfolding corporate and business unit objectives into maintenance performance indicators.

	Corporate and business unit objectives	**Maintenance objectives**	**Maintenance performance indicator**	**Level**	**Perspective**	**MPI Code**
if	Improve availability in power generation	Ensure equipment is available and reliable for operation	Reliability	I	Performance	I a
			Asset Health Index	I	Performance	I b
		Reduce recurring failures	Compliance with root cause analysis	II	Internal process	II a
f	Grow net income for the year	Meet the expected budget for maintenance department	Budgeted versus incurred maintenance cost	II	Financial	II b
		Invest capital in projects with better rate of return	Return on investment	II	Financial	II c
s	Meet expectations for customer satisfaction	Contribute to addressing customer demands and needs	Maintenance emergency downtime	II	Customer	II d
			Compliance with actions regarding maintenance of customer satisfaction plan	II	Customer	II e
h	Strengthen the organization's health and safety culture	Engage maintenance with the organization's health and safety culture	Compliance with health and safety training	II	Learning and growth	II f
h	Develop our people	Identify technical knowledge and skills to be developed in maintenance	Compliance with the technical knowledge and skills development plan	II	Learning growth	II g
n	Prevent and mitigate negative environmental impacts on power generation	Prevent and mitigate negative environmental impacts on maintenance activities	Number of environmental improvements in maintenance	II	Internal process	II h
			Compliance with actions regarding maintenance of environmental plan	II	Internal process	II i
it	Boost business strategy and long-term sustainability through innovation	Boost maintenance results through innovation	Number of maintenance research and development projects	II	Internal process	II j
rm	Risk governance through the risk management system	Physical asset risk governance through the risk management system	Number of open nonconformities for maintenance	III	Compliance	III a
			New controls to mitigate existing risks related to physical assets	III	Effectiveness	III b
			Number of incidents related to maintenance	III	Effectiveness	III c

The alignment of the maintenance with business unit is important for translating the maintenance objectives into performance indicators at different levels and perspective. In Table 2, the selected corporate or business unit objectives are presented and unfolded in maintenance objectives. These objectives have been translated into aligned maintenance performance indicators for different levels and perspective of evaluation which is the main step proposed in the maintenance indicator phase (III).

It can be observed that a strategic objective can unfold into more than one MPI. Moreover, this process of defining maintenance indicators is no longer arbitrary. Following the proposed method, the MPIs will be obtained through the strategic alignment of maintenance with corporate and business unit objectives and by translating these objectives into indicators to be monitored systematically.

Finally, the MPIs can be organized into a performance dashboard for better tracking and analysis. It can contain the values (val.) for each indicator by month, for example, and the compiled result year to date (ytd). Moreover, besides the MPIs itself, the organization should define the goal for each indicator. In Table 3, it is presented a proposed dashboard model with some indicators previously obtained. The calculations and descriptions that demonstrate these indicators are presented in Table 4.

Table 3. A proposed dashboard for monitoring MPIs.

	I. Asset		**II. Asset management**								**III. Asset management system**			
	Critical equipment and systems		Maintenance management								Management systems			
	Performance		Financial		Customer		Internal process		Learning and growth		Effectiveness		Compliance	
	I b		II b		II d		II i		II g		III b		III a	
	val.	goal	val.	goal	val.	goal	val.	goal	val.	goal	val.	goal	val.	goal
jan.	93%	95%	103%	100%	0,83%	1%	80%	100%	35%	100%	0	2	3	0
feb.	92%	95%	97%	100%	0,90%	1%	85%	100%	55%	100%	1	2	3	0
mar.	95%	95%	95%	100%	0,22%	1%	87%	100%	65%	100%	1	2	1	0
apr.	87%	95%	100%	100%	0%	1%	88%	100%	65%	100%	3	2	1	0
may	...	95%	...	100%	...	1%	...	100%	...	100%	...	2	...	0
jun.	...	95%	...	100%	...	1%	...	100%	...	100%	...	2	...	0
jul.	...	95%	...	100%	...	1%	...	100%	...	100%	...	2	...	0
aug.	...	95%	...	100%	...	1%	...	100%	...	100%	...	2	...	0
sep.	...	95%	...	100%	...	1%	...	100%	...	100%	...	2	...	0
oct.	...	95%	...	100%	...	1%	...	100%	...	100%	...	2	...	0
nov.	...	95%	...	100%	...	1%	...	100%	...	100%	...	2	...	0
dec.	...	95%	...	100%	...	1%	...	100%	...	100%	...	2	...	0
ytd	91,8%	95%	98,7%	100%	0,49%	1%	88%	100%	65%	100%	5	24	1	0

It should be noted that the number of indicators and the best template for the performance dashboard depends on the context of the organization. In some organizations, because of the number of indicators, it is more interesting to design individual dashboards for each level of evaluation or even perspectives (e.g. one individual dashboard for asset management level of performance evaluation).

Table 4. Description of proposed MPIs of the dashboard.

Level	Perspective	Code	MPI	Description	Calculation
I. Asset	Performance	I b	Asset Health Index	The proportion of monitored physical asset in normal condition (%)	$= \frac{number\ of\ asset\ in\ normal\ condition}{total\ number\ of\ assets}$
II. Asset management	Financial	II b	Budgeted versus realized maintenance cost	The proportion of budgeted costs that were incurred (%)	$= \frac{maintenance\ budgeted\ costs}{maintenance\ incurred\ costs}$
II. Asset management	Customer	II d	Maintenance emergency downtime	The proportion of hours due to maintenance emergency downtime (%)	$= \frac{hours\ of\ maintenance\ emergency\ downtime}{total\ planned\ hours}$
II. Asset management	Internal process	II i	Compliance with actions regarding maintenance of environmental plan	The proportion of completed action regarding maintenance in the environmental plan (%)	$= \frac{number\ of\ completed\ maintenance\ actions}{total\ number\ of\ maintenance\ actions}$
II. Asset management	Learning and growth	II g	Compliance with the technical knowledge and skills development plan	The proportion of completed technical knowledge and skills development plan (%)	$= \frac{number\ of\ completed\ actions\ of\ development}{total\ actions\ of\ development\ plan}$
III. Asset management system	Effectiveness	III b	New controls to mitigate existing risks related to physical assets	Sum of new controls measures to mitigate existing risks related to physical assets (un.)	$= \sum new\ controls\ measures\ to\ mitigate\ risks$
III. Asset management system	Compliance	III a	Number of open nonconformities for maintenance	Sum of not completed nonconformities for maintenance (un.)	$= \sum not\ completed\ nonconformities\ for\ maitenance$

6. Conclusions

Performance evaluation is an essential process in asset management. Through its results, leaders can analyze what is not performing as expected and initiate an improvement process. Since maintenance has major impacts on asset management, a method for addressing the evaluation of its performance based on the guidelines of the ISO 55000 series and the BSC approach is relevant for practitioners in the field.

Therefore, the present work proposed a novel method for the MPIs determination based on ISO 55000 series and BSC approach. For that, a three-section method was developed and applied with a hydropower plant case study. The method aims to develop indicators for maintenance performance evaluation in line with the objectives of the business unit and the corporation. As a result, the MPIs can contribute to improved maintenance management as leaders can track goals and results from different perspectives and levels.

The study case application showed the proposed method to be a consistent tool for MPI determination. It was able to consider the guidelines of the ISO 55000 series and of the BSC approach in defining the performance evaluation perspectives and the alignment with the organizational strategy in defining the indicators. Besides, with the application of the method, the choice of performance indicators is no longer arbitrary.

It is noteworthy that although the method was applied to maintenance stage of the asset's lifecycle, this framework is suggested to be extended to other lifecycle stages as well. The performance evaluation will be necessary in all stages of asset management once it is an element of the asset management system and a requirement of ISO 55001.

Finally, the method and results of this work are expected to contribute to maintenance and asset management research aiming to increase value creation from maintenance in the organization.

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