Designing Performance Measures for Asset Management Systems in Asset-Intensive Manufacturing Companies: A Case Study

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Abstract This paper proposes a structural and procedural framework for developing performance measures for engineering asset management systems with an in-depth case study of an international glass manufacturer. The structural framework was built by adapting the Balanced Scorecard method to leading engineering asset management standards. Further, the procedural framework describes how to develop the performance measures systematically, and provides practical guidelines facilitate design process. Asset managers at different levels were brought together to use the proposed structural framework to an build asset management strategy map by linking and mapping all critical objectives in the defined perspectives. Subsequently performance measures are identified for each objective in the asset management strategy map. Finally all selected performance measures are critically reviewed with existing performance measures and qualitative feedback was collected from a senior participant. The results showed that the proposed structural and procedural framework are effective and efficient in helping asset-intensive organisations build their performance measurement systems for asset management.

1 Introduction

Engineering asset management systems (EAMS) are designed and implemented by asset intensive manufacturing organisations to serve their overall business strategy. Therefore asset intensive manufacturing companies heavily rely on their EAMS to

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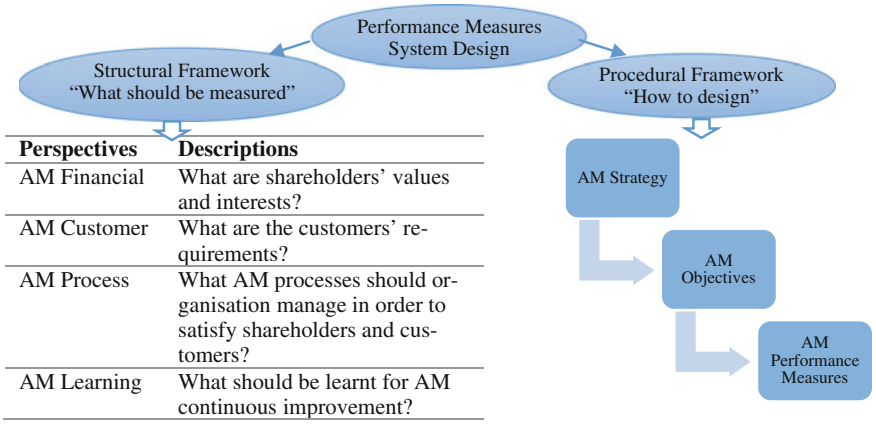
gain core competitive advantages (Woodhouse 2009; Amadi-Echendu et al. 2007; El-Akruti et al. 2013). A performance measurement system (PMS), is a set of individual performance measures (PMs) essential and useful for ensuring the effectiveness and efficiency of EAMS. Designing and applying effective performance measures has been regarded as a challenging and critical issue for asset owning organisations. It is necessary for internal operation management such as process management and incentive designs (Woodhouse 2009), additionally it is required by third party regulators (i.e. government agencies in safety, service and environment), and furthermore it is also recommended and highlighted by several leading industrial standards such as ISO55000 and PAS55 (IAM 2015).

Although there is rapidly growing interests, engineering asset management (EAM) is still in its early stage. Particularly performance measurement research for EAM is very limited. From a practical point of view, industrial organisations rarely apply structured methods to design performance measures and this results in their EAM performance measures evolved to address only a particular part of EAMS. A number of AM excellency frameworks or AM maturity models are accepted and applied by asset-intensive organisations (IAM 2015). These are very useful tools to generally understand how professional the assessed company was in terms of managing their engineering assets. However, these models do not help understand the relationship between organisations actual performance and their maturity model scores (Attwater et al. 2014).

Balanced scorecard by Kaplan and Norton is presently the most widely used performance measurement design approach (Folan and Browne 2005), and it provides effective guidelines to identify strategy-aligned performance measures. However, it only contains generic frameworks aiming for business strategy of whole organisation. Hence it is not most suitable under the specific context of organisations' EAM, for example, EAM is heavily relied on the successful management of various asset risks such as asset safety and reliability. A notable study by Arthur et al. (2014) designed their own top-down strategy map for developing performance measures based on balanced scorecard approach. However, this innovative approach did not address the integrative complexity of EAMS, requiring performance measures design cross perspective. Existing literature also placed extra emphasis on maintenance performance measures rather than the whole concept of systematic EAM, Simoes et al. (2010) conducted a comprehensive review of 345 different measures in use for maintenance management performance. That research provided indications for how to design performance measures but only focused on part of the EAMS. Therefore a refined approach which combines leading thoughts of both EAM and balanced scorecard is necessary. The paper proposed frameworks built on both structural literature review and interviews with experienced asset management practitioners in industry for practical perspectives. Furthermore, the proposed frameworks were tested and refined with an in-depth case study.

2 Proposed Frameworks

There are two fundamental tasks in designing performance measures: (i) understand relevant strategy, and (ii) select aligned AM performance measures (Neely et al. 2005). It is commonly agreed in the literature that at least a structural framework and a procedural framework (Fig. 1) are required for designing performance measurement systems (Folan and Browne 2005). The first framework is a structural framework explaining four perspectives or dimensions for identifying performance measures: asset management financial, asset management customer, asset management processes and asset management learning. All perspectives add risk control elements, which are highlighted in most EAM literature. Additionally AM planning, AM implementing, AM monitoring and AM review "plan-do-check-act" framework from ISO55000 are applied for AM process perspective. And this is necessary given the complexity nature of "asset management process" perspective in the structural framework. The second framework describes a step-by-step "strategy-objective-performance measures" process for designing performance measures for EAMS, and it also contains guidelines for facilitation the design process in the workshop.



Perspectives	Descriptions
AM Financial	What are shareholders' values and interests?
AM Customer	What are the customers' requirements?
AM Process	What AM processes should organisation manage in order to satisfy shareholders and customers?
AM Learning	What should be learnt for AM continuous improvement?

Fig. 1 Frameworks for designing performance measures

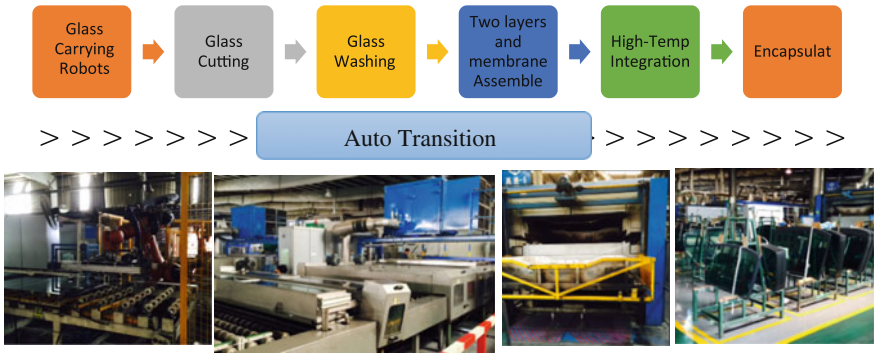


Fig. 2 Glass Inc. production line simplified illustration

3 Case Study

3.1 Background

Glass Inc.[1] is based in China and it has more than 25 years' experience in wide-screen and special glass manufacturing. It has established asset management practice and asset management systems. As nationally and internationally leading organisation in glass manufacturing, it has been accredited by ISO9000 and TS16949 and it is aware of the newly introduced ISO55000. All Glass Inc. production lines (Fig. 2) apply six sigma principles and 5S management practice, therefore Glass Inc. is a representative example to reflect existing industrial practice. Several interviews with asset management practitioners and an action research workshop were conducted for this case study. The interviews aimed at understanding the asset management context of the company. Next the workshop invited asset managers to apply the proposed frameworks to select performance measures from scratch. The aim of this case study was targeted testing the proposed frameworks:

- What are the essential dimensions/perspectives for measuring the activities' results? What are the critical objectives in each perspectives and what are the relationships between objectives?
- What are the steps for designing performance measures for their EAMS, and how to order and implement them?

[1]The name of the company has been changed to protect confidentiality.

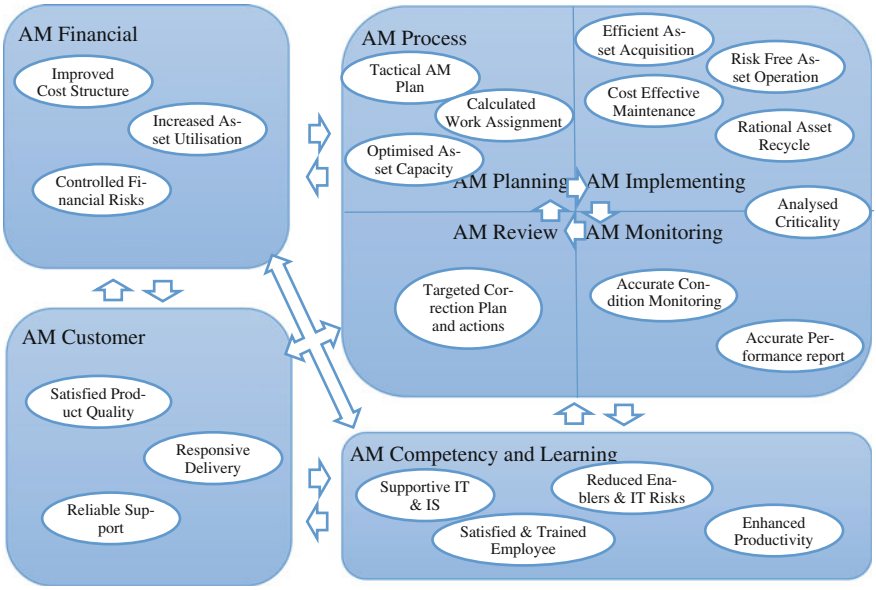


Fig. 3 Glass Inc. asset management strategy map

3.2 Results from Case Study

Interviews with asset managers revealed that Glass Inc. does not have a well defined holistic approach to design performance measures for its EAMS and all its performance measures are evolved separately. For example: safety and quality performance measures are simply issued by requirements from regulators and customers. Using a workshop, we constructed asset management strategy map (Fig. 3) by mapping and linking critical objectives in four perspectives: AM customer, AM financial, AM process and AM learning.

Subsequently, all participants developed performance measures (Table 1) for each objective and critical objective relationships in the asset management strategy map.

3.3 Comparisons and Feedback

By comparing the performance measures developed by the proposed frameworks with existing performance measures, there are a number of significant improvements. Firstly the proposed frameworks showed a whole picture of asset management so that participants were able to uncover missing areas in performance measurement. For example: there is no performance measures to assess the asset

Table 1 Objectives and issued performance measures

Objectives	Performance measures and descriptions
Improved cost structure	Reduction of cost per unit compared to last year
Increased asset utilisation	Overall equipment effectiveness
Controlled financial risks	Return on investment, daily operation cost, maintenance cost
Satisfied product quality	Quality through test pass ratio, customer return quantity due to quality issue
Responsive delivery	Delivery on time rate
Reliable support	Safety stock
Tactical AM plan	Budget precision rate, capacity gap quantity, planned/unplanned working hours, material in stock days
Optimised asset capacity	Spare/short asset hours
Calculated work assignment	Short of labour hours, spare labour hours
Efficient asset acquisition	Installation on time rate, number of error caused in installation, acquisition cost
Risk free operation	Number of incident, loss caused by incident, unexpected shutdown time, reliability rate,
Cost effective maintenance	Mean time to repair, average maintenance cost
Rational asset recycle	Number of reusable units, resale value, time to recycle
Analysed asset criticality	Maintenance cost for critical (non-critical) assets/loss caused by critical (non-critical) assets
Accurate condition monitoring	Number of faulty positive/negative monitoring
Accurate performance report	Number of performance report errors
Targeted correction plan and actions	Number of initialised/completed improvement projects
Supportive IT & IS	Bespoke IT development time, IT system coverage
Satisfied & trained staff	AM staff turnover ratio, satisfaction ratio, training test pass ratio
Reduced enablers & IT risks	Number/loss of incident caused by staff/IT
Enhanced worker productivity	Worker productivity compared to last year

management plan other than over budget ratio, no performance indicators for measuring criticality management in place as well as asset recycle activities. In addition, some leading indicators have been introduced to assist existing performance measures, for example: Glass Inc. applied "penalty charged by government for pollution" as a measure, and it is agreed to introduce leading indicator "untreated waste" to prevent the penalty. Furthermore, qualitative feedback collected from case study participants also strongly supported the usability and feasibility of the proposed frameworks.

4 Discussions and Conclusions

Folan and Browne (2005) summarised ideal recommendations for both structural and procedural framework, additionally Cocca and Alberti (2010) concluded a set of "good performance measurement system characteristics". The proposed frameworks have been tested in the reported case study in a way complied with these surveyed design criteria. Such as, design with different level of asset managers and design from different perspectives. Performance measurement as an essentially additional and internal element to EAM maturity models, which are conducted by external entities, ensures the effectiveness and efficiency of the ultimate engineering asset performance. Furthermore, strategy aligned performance measures provide reliable data source for future work directions such as quantifying the benefits of asset management (Roda et al. 2015). For asset-intensive manufacturing or production companies, the engineering asset performance directly determines their business performance. Therefore engineering asset management performance measures are important leading indicators of overall business key performance indicators. A common problem with capital-intensive manufacturing organisations is that only maintenance performance measures have been highlighted while other areas (e.g. asset management plan and criticality analysis) of engineering asset management are considered little. This paper proposed and empirically studied a structural framework and a procedural framework for designing performance measures especially for engineering asset management systems in heavy manufacturing industry. These frameworks have been tested and refined by a case study in an international leading vehicle glass manufacturer. The results and feedback from the case study proved great refinement and improvement of proposed frameworks from existing performance measures for collaborated organisation. Therefore the proposed frameworks are feasible and useful in identifying asset management strategy aligned performance measures. The results also indicated that there may be a generic set of performance measures which could potentially work as specific industrial sector guidelines or standardisation. The main future work to test the frameworks using more asset-intensive production organisations particularly for less mature companies. Furthermore, there are many upper level work can be exploited, for example: asset management incentives and target setting based on performance measurement systems.

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