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Sustainability performance indicators at shop floor level in large manufacturing companies

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Abstract

This article investigates sustainability in the performance measurement systems of Swedish manufacturing companies. It builds on a previous study that documents relatively few direct environmental indicators at shop floor level, which raises questions about possible indirect links between existing indicators and the environment that could be used to improve the environmental aspect of company´s sustainability ambitions. A method for identifying and categorizing indirect links to sustainability issues was defined and used. The results suggest that at shop floor level 90% of the indicators have at least an indirect relation to one or more of the sustainability dimensions economy, environment and social, of which 26% are at least indirectly related to the environmental dimension. Despite the many indirect connections, participating companies perceive a need to improve sustainability indicators and some ideas are suggested.

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Keywords: Performance Measurement System; Sustainability; Sustainability Performance Indicator; Environmental management

1. Introduction

The field of Performance Management has evolved from revolving around financially-focused and static performance measures to strategic systems with a balanced approach in regards to measuring and managing performance [1]. Following the unparalleled spread of the Balanced Scorecard [2], manufacturing organizations today measure and manage performance from multiple aspects, such as customer, internal processes, learning and development, cost and revenue, quality, delivery, sustainability, safety and reliability.

The adoption of Performance Measurement Systems (PMSs) in the Swedish manufacturing industry seems to be almost 100%, at least among medium and large companies [3]. The Swedish industrial application and the wide spread of PMS is tightly connected to the adoptions of Toyota inspired lean manufacturing strategies and production system models [4], with focus on time efficiency and reducing lead time [5]. This includes using performance indicators (PIs) to align the operation to the company's strategic objectives and managing the daily operation to meet customer demands and other requirements.

In response to the growing sustainability concerns, manufacturing companies have to formulate measures to evaluate sustainable manufacturing performance, aiming at integration of sustainability aspects [6]. Many scholars have explored the mutual goals and tools of lean production on the one hand and sustainability on the other in order to gain a

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better understanding of the compatibility and impact of lean and green initiatives [7], [8]. Integration of sustainability management and operations management is seen as a way forward but is possibly hindered by a lack of sustainability metrics [9]. Although literature on sustainability is extensive and growing, and the companies' interest and focus on sustainability is generally increasing, the major body of knowledge concerns sustainability indicators and reporting at corporate level [10], [11], while few studies have empirically studied how sustainability is integrated at shop floor level in manufacturing operations.

The purpose of this article is to investigate sustainability aspects of the PMS at shop floor level in manufacturing companies. In the earlier study presented by Landström et al [3], a methodology for PMS present state analysis in large companies was introduced and thus provided a foundation for improving PMSs. With respect to sustainability, few indicators were documented as related to the environment, which in part is explained by the fact that the "documentation scope" was limited to indicators related to "production operation and the production support functions: quality, maintenance and internal logistics", found at work center or work unit level, see figure 1. For overall reporting purposes, and at site level, Landström et al. [3] found more indicators related to the environment. This raises the following research questions which will be explored in this article:

1. Which indicators at shop floor level in manufacturing have direct or indirect connections to the environment and sustainability?
2. Do the indicators identified make it possible for the companies to track and improve their goals related to sustainability? If not, which additional indicators are needed at shop floor level?

Since the research questions are related and their respective answers interdependent, they will be explored and discussed together. As society is not yet sustainable, it is assumed that there is a need for more, alternative, sustainability indicators [12] at shop floor level as well as on other levels.

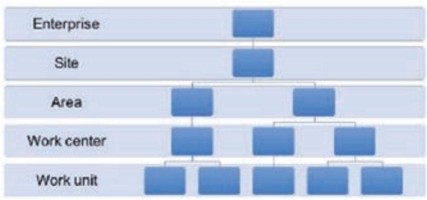

Fig. 1. Hierarchical levels according to ISO 22400-2:2014

2. Research Design

Research presented in this paper is mainly based on empirical data collection from seven large global manufacturing companies, see Table 1. Empirical data was collected in a larger context to investigate PMS. Based on an earlier study presented in [3], a methodology for PMS present state analysis in large companies was introduced. These results are briefly described in section 4. This paper however focuses on the sustainability aspect of the PMS. The data collection approach consists of a top-down interview and bottom-up observation and investigation of PIs in the meeting areas and production control measures on shop floor. The selection of companies was on basis of companies' involvement in a Swedish research project called "Sustainable and resource efficient business performance management systems (SuRe-BPMS).

Table 1 Information about the sites

Site	No. of employees	Product	Manufacturing process
A	1000	Machines and Tools	Machining, assembly
B	1200	Aero space components	Machining, welding, surface treatment, testing
C	270	Vehicle components	Machining, surface treatment, assembly
D	380	Machines and tools	Machining, heat treatment, assembly, surface treatment
E	1800	Machines	Machining, assembly
F	1000	Heavy vehicle	Machining, welding, painting, assembly
G	800	Heavy vehicle	Machining, welding, painting, assembly

The empirical data analysis consists of data reduction, data displays, and conclusion drawing and verification [13]. Afterwards, empirical results were analyzed in an iterative process in several meetings and workshops together with companies' representatives and academic researchers to validate the empirical findings.

3. Method

3.1. Sustainability frameworks

To answer the research questions, an understanding and definition of sustainability is needed that goes further than the original one of "*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" [14].

The three dimensions of sustainability: environment, economic and social can be dependant and interrelate in different ways as shown in the figures below.

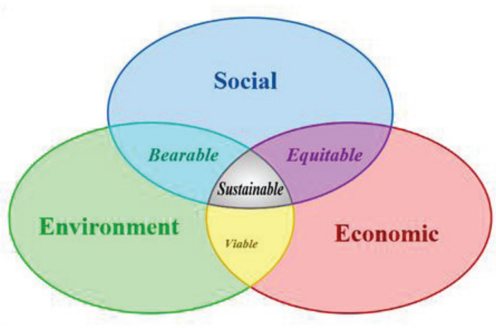

Fig. 2. Three dimensions of sustainability according to Cato [15]

Fig. 3. Three dimensions of sustainability according to Adams [16]

To achieve better understanding of sustainability, four internationally renowned frameworks for sustainability were considered:

- UN Sustainable Development Goals
- ISO 26000 Guidance on Social Responsibility
- Global Compact
- Global Reporting Initiative, GRI

UN´s goal for sustainable development is the latest addition to the sustainability framework family. The 17 goals were formulated at a UN meeting in New York in September 2015 [17].

ISO 26000:2010 [18] is a guidance standard, which means that it is not possible to certify an organization with this standard. The standard provides guidance to organizations on, among other: concepts, terms, definitions, background, trends, characteristics, principles, practices and the core subjects and issues of social responsibility.

Global Compact [19], the oldest of the sustainability frameworks, is formulated as ten actions or attitudes for companies in the areas of human rights, labour, environment and anti-corruption.

GRI [20] is a comprehensive system which includes 91 well defined indicators (specific standard disclosures) organized in three main categories (corresponding with the three dimensions of sustainability described above) and four social subcategories:

- Economic aspects
- Environmental aspects
- Social aspects
  - Labor Practices and Decent Work
  - Human Rights
  - Society
  - Product Responsibility

In addition to the sustainability indicators examples, GRI provides a helpful definition or description of economic aspects as: “The economic dimension of sustainability concerns the organization’s impacts on the economic conditions of its stakeholders and on economic systems at local, national, and global levels. It does not focus on the financial condition of the organization” [20]. The strength of GRI, the multitude of well defined indicators, is also its weakness as many regard it as too time consuming for operations to use in practice [21].

In addition to the frameworks described above, Sweden's national environmental quality objectives [22] were considered to ensure that no aspect that is of environmental concern in Sweden was excluded. It recommends 16 environmental quality goals and 110 indicators to be achieved by 2020. The Swedish framework cannot be regarded as a complete sustainability framework as it lacks both social and economic goals.

In conclusion, all the above frameworks were explored and compared to each other and found to be largely overlapping. Due to its practical level, GRI was mostly consulted in the categorization of indicators needed to answer the research question whether indicators at lower levels have indirect connections to sustainability and what they look like.

3.2. Categorization

The categorizations of indicators were done in three steps:

A. The companies´ own categorizations were documented during the present state analysis.
B. Categorization based on Galbraith [23] and Salloum [24] adopted by Landström et al [3] in:
   1. Financial indicators – Indicators measuring cost and other financial aspects of production.
   2. Human resource indicators – Indicators related to employees and staffing.
   3. Research and development indicators – Indicators measuring both larger development projects and continuous improvement work.
   4. Productivity indicators – Indicators measuring the productivity and efficiency of the production processes.
   5. Quality indicators – Indicators measuring the quality of the products and quality activities.
   6. Flexibility indicators – Indicators measuring the flexibility in production processes.
   7. Delivery reliability indicators – Indicators measuring the delivery quantity as well as the ability to deliver on time.
   8. Speed indicators – Indicators measuring the lead time aspects of production processes.
   9. Equipment indicators – Indicators measuring the availability of the equipment and maintenance issues.
   10. Supply chain indicators – Indicators connected to suppliers and customers.
   11. Safety indicators – Indicators measuring safety and safety improvement work.
   12. Environmental indicators – Indicators measuring the environmental impact of production.

   The result of categorization B is shown in Figure 6 below.
C. The sustainability categorization was done based on answering the question: Has the indicator any bearing on or relation to sustainability? The following alternative answers were feasible: Yes definitely, Possibly, No chance, or question mark for poorly understood indicators. As a description and justification, each indicator was also placed into one or more of the three sustainability dimensions: environment, economic or social. While doing the sustainability categorization the following information was consulted for each indicator: Categorizations according to A and B above, title, whether absolute or

relative, and the mathematical formula. Whenever unsure about whether an indicator was related to sustainability or not, GRI was consulted.

The categorization methodology was applied on collected empirical data from seven different sites of six large multinational companies located in Sweden. In section 4, the results of categorization A and B are presented as input data. In section 5 the results from categorization C, the sustainability categorization, are presented. The sustainability categorization was done on the bottom-up collected data, i.e. on the data containing indicators used in the production and production support at shop floor level.

Finally, to evaluate what sustainability areas that were not present in the studied operational PMSs, GRI was used to identify which types of key performance indicators (KPIs) were present and which were not in the operational PMS for three of the companies. In addition, the annual sustainability reports were checked.

4. Input data from the present state analysis

The empirical results presented here were extracted from a previous study presented by Landström et al [3].

The amount of performance indicators per site is presented in figure 4. The amount of unique measures is less, since many measures were used at more than one organizational unit. The total amount of indicators collected and systematically categorized in the bottom up study and in the following sustainability categorization was 3100.

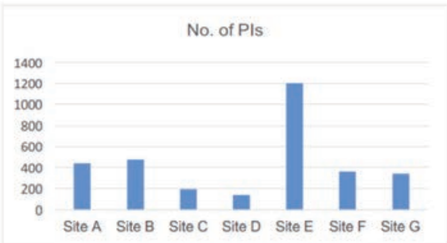

Fig. 4. Number of performance indicators at the studied sites [3]

Figure 5 shows that the average number of indicators per organizational unit varies between 13 and 27.

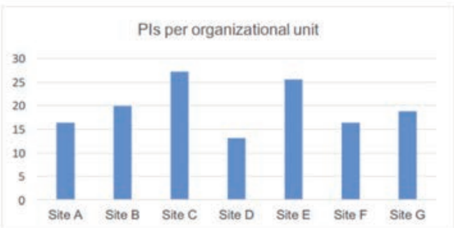

Fig. 5. Number of performance indicators per organizational unit [3]

Figure 6 shows the distribution of indicators after the categorization B performed by Landström et al [3]. The categories with most indicators were: quality, delivery, safety, and human resources. These are common on every level at all sites. Very few indicators (<0.1%) measuring flexibility were identified during the study. Another interesting result is the quite low amount of environmental indicators. The lack of environmental indicators is further explored in section 5 below. An observation is that environmental indicators are mostly found in environmental reports and not displayed in the operation [3].

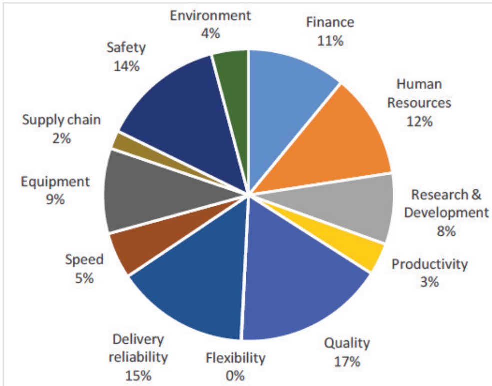

Fig. 6. Distribution of performance indicators after primary categorization B [3]

5. Results

5.1. Results of the sustainability categorization

Figure 7 shows the main result of the "sustainability" categorization. Very few indicators without any possible connection to sustainability were found. As much as 85-95% (average 90%) of the indicators were categorized as having some relation to one or more of the sustainability dimensions: economy, environment and social. This can be compared to the, 41% of indicators categorized as Safety, Environment, Finance or Human resources in the previous study.

Furthermore, figure 7 below indicates that 18-39% of indicators (average 26%) are related to the environment. This can be compared to the 4% average found in the B categorization. In figure 7 the average standard deviation between the two experts performing the categorization is shown as error bars in each column.

The sustainability categorization method was applied to the seven data sets (containing 3100 data points) by two independent experts. Figure 8 shows the variation in their respective categorizations. A1 is the categorizations done to site A by expert 1 so it should be compared to A2, and so on, in the context of evaluating the method. It can be concluded by visual inspection that the variation between the experts is so large that the method is not functional at that level of accuracy. However, the variations, especially regarding environmental relations, show some systematic consistency: expert 1 has always more *Yes environmental*, while expert 2 has always more *Possibly environmental*, thus the sum of indicators related to the environment have much less variance. The average standard deviation for the environmental dimension is still fairly large, but not larger than to lend some credibility to the method at the level of accuracy depicted in figure 7.

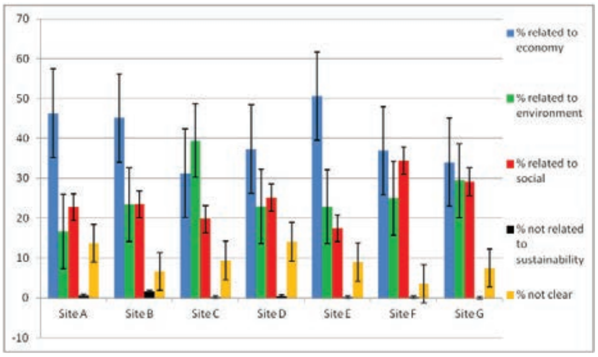

Fig. 7. Percentage of indicators directly or indirectly related to the three sustainability dimensions

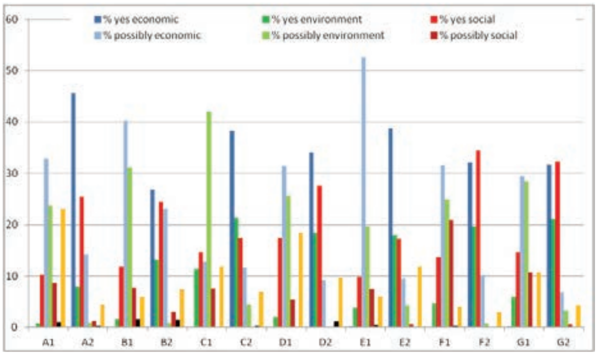

Fig. 8. Sustainability categorization results non-aggregated

5.2. Results from GRI mapping

In order to explore whether and which additional indicators could be used at shop floor level, a mapping versus GRI was done for the three companies with the most environmental indicators. It was found that GRI-indicators relating to Market presence, Human rights, Society, Biodiversity, Compliance and Environmental grievance were largely missing, while GRI-indicators concerning: Economic performance, Indirect economic impact, Labor practice and Decent work, Product responsibility, Material, Emissions, Product and services, and Transports were reported directly in accordance with or in related form to GRI KPIs. In a focus group discussion, the missing GRI KPIs were discussed and it was concluded that many of the missing KPIs are controlled in assessments or measured at company level rather than on shop floor level. For example, one of the three companies reports most of GRI suggested KPIs for social sustainability although the operational KPIs on shop floor only cover a few of the GRI KPIs (from Labor practice and decent work and some from Product responsibility). In the focus group discussion, it was also stated that several of the GRI KPIs were not suitable at shop floor level. The conclusion was that several parameters were indeed part of the companies´ PMS but a number of the KPIs suggested were not applicable as operational KPIs on the shop floor.

6. Discussion and conclusions

6.1. Categorization method and indirect relations to sustainability

It is clear from the large variations between the two experts doing the sustainability categorization that the method as such cannot well explore indicators´ relations to sustainability at the accuracy aimed for. One explanation is the differing interpretations of the sustainability concept [25]. Furthermore, it was perceived as difficult by both experts to be consistent in the categorizations, possibly because “related to” can be stretched into infinity since sustainability is such a holistic concept. So the variation between the two individuals can be expected given that background knowledge and imagination differed. However, when aggregated to the level “related to sustainability”, the average standard deviation is less than 5% of the average 90%. The conclusion that on average 90% of the indicators have some relation to one or more of the sustainability dimensions: economy, environment, social, is therefore considered robust. This is more than twice as many categorized as sustainability indicators in the B categorization, i.e, on average 41% of shop floor KPIs are directly related to sustainability and 49% are indirectly related in the investigated companies.

As pointed out above, when aggregated to the level of “related to sustainability dimension x” the variation between the two individuals is consistent enough concerning the environmental dimension that it strongly suggests that on average 26% of indicators are related to the environment. This should then be compared to the 4% environment related according to the B categorization, see figure 6. Thus, it can be concluded that there are many indirect relations to the environmental dimension of sustainability among existing indicators. This will be further explored below.

6.2. The need for more, alternative, sustainability indicators

A company´s need for additional sustainability indicators stems from a need to track and improve the company´s sustainability goals. This paper suggests that 90% of existing indicators are related to sustainability. Combining existing indicators with new or other existing indicators related to sustainability, is probably easier and more cost-efficient than to invent new ones. Furthermore sustainability should consider all three dimensions, as shown in figure 2.

Indicators should match the sustainability ambitions of respective company. This issue was explored in a workshop with four of the participating companies and it was concluded that there is room for improvement. Many of the areas in GRI with no measurement found in the operative KPIs were deemed not suitable for operational sustainability KPIs. Such areas or indicators could instead be explored for use at other levels in assessments as suggested by Chen et al [21]. The discussion also brought some suggestions for operative measurements not suggested by GRI. The Overall Equipment Effectiveness indicator, OEE, and in particular its constituent parts was brought forward as useful at shop floor level. OEE consists of the product of Availability (percentage of scheduled time that the work unit is available to operate), Performance (the speed at which the work unit runs as a percentage of its designed speed) and the Quality (good units produced as a percentage of the total units started (e.g. first time through rate)). OEE and its constituent parts are typical and frequent examples of indicators categorized as indirectly related to sustainability in the sustainability categorization carried out.

Furthermore, it was suggested that the concept of Green Performance Map [26] at shop floor level could be a way to engage work units in sustainability work by allowing them to develop environmental indicators relevant for each work unit. For example, one of the participating sites aims for carbon neutral production and has in this endeavor tried Green Performance Mapping at work unit level as a means to engage the whole workforce in pursuit of avoiding carbon emissions.

6.3. Conclusions

The results presented suggest that at shop floor level in the Swedish industrial sites contributing in the study:

- 90% of the indicators have a relation to one or more of the sustainability dimensions economy, environment and social; 41% are directly related while 49% have an indirect relation.
- 26% of the indicators have a relation to the environment; 4% are directly related while 22% have an indirect relation.

This knowledge could be used by managers to create new improved sustainability KPIs based on existing indicators. Furthermore using Green Performance Map [26] or similar tools could be a way to engage work units in sustainability work by allowing them to develop environmental indicators relevant for them. The Overall Equipment Effectiveness indicator, OEE, and in particular its constituent parts, are examples of indicators related to sustainability that could be useful at shop floor level.

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