

Measures and a Concept for Realizing Sustainability in the Manufacturing Industry

Mikko Koho¹, Mikko Tapaninaho², Juhani Heilala¹, Seppo Torvinen²

¹ VTT Technical Research Centre of Finland, P.O. Box 1000, FI-02044 VTT, Finland

mikko.koho@vtt.fi, juhani.heilala@vtt.fi

² Tampere University of Technology, PO Box 527, FI-33101 Tampere, Finland
mikko.tapaninaho@tut.fi, Seppo.torvinen@tut.fi

Abstract This paper proposes and outlines a concept for manufacturing companies to improve their sustainability performance and manage sustainable production. Reviews of the current state of sustainable development at global and company level show that manufacturing companies need support and guidance to realize the objectives of sustainable development. Related to this, the challenges and barriers to realizing sustainable development faced by the manufacturing companies identified in the authors' recent research projects are also summarized in this paper. The proposed concept aims to overcome the challenges and shortcomings related to measuring, reporting, controlling and improving sustainability performance. The structure, content and development process of the concept are discussed and outlined in the paper.

1. Introduction

The objective of sustainable development, according to the definition presented in the Bruntland Report [1], is to “meet the needs of present without compromising the ability of future generations to meet their own needs”. This objective requires humanity's demand for natural resources and planet Earth's supply of such resources to be balanced, which has proven to be very challenging. In 2013, the Earth Overshoot Day, i.e. the day when the Earth's resource budget had been exhausted by humanity, was the 20th of October. Thus, we currently have a demand for resources of more than 1.5 planets, and the “business as usual” projection indicates that resources of more than two planets will be needed by 2030 [2, 3]. Hence, on a global level, a radical change is needed in order to realize sustainable development. The results of the recent research projects presented in this paper indicate that a similar challenge is faced by the manufacturing industry, and radical change is needed for it to realize sustainable development and sustainable production.

This paper aims to promote and support the realization of sustainability in the manufacturing industry by reviewing both the current state of manufacturing companies and the state of the art, and by proposing and outlining a concept for

improving and managing sustainability performance in manufacturing companies. The concept aims to overcome the challenges and shortcomings identified in the reviews and covers measuring, reporting, control and improvement of the sustainability performance of manufacturing companies.

The paper is structured as follows. Section 2 provides the background to sustainable development, sustainable production and sustainable consumption based on a literature review and the results of recent research projects by the authors and their organizations. The section presents a definition and decision areas of sustainable development in more detail and discusses the current state and challenges of sustainable development in the manufacturing industry. It also reviews the current measuring and reporting practices. Section 3 outlines the proposed concept for improving sustainability performance and managing sustainable production as well as the research and development work needed to develop the concept. Finally, the conclusions and summary are presented in Section 4.

2. Background

This section provides the background to the need for and development of a concept for improving sustainability performance and managing sustainable production. This section is based on literature reviews, two research projects carried out by the authors and one research project by colleagues of the authors. The three research projects, 'Visualization of Sustainability Key Performance Indicators' (VS-KPI), 'Competitive and sustainable production systems and networks' and 'SustainValue', reviewed the current state of sustainability in industry and development needs based on surveys, interviews and expert workshops. More detailed descriptions of the research projects and methods used can be found in [4-6].

2.1. Sustainable Development, Sustainable Production and Sustainable Consumption

At a general level, sustainable development can be defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [1]. Sustainable development is typically further divided into three pillars: environmental, social and economic sustainability, which are also referred to as "the triple bottom line" or "the 3 P's": planet, people and profit (Figure 1) (e.g. [7, 8]).

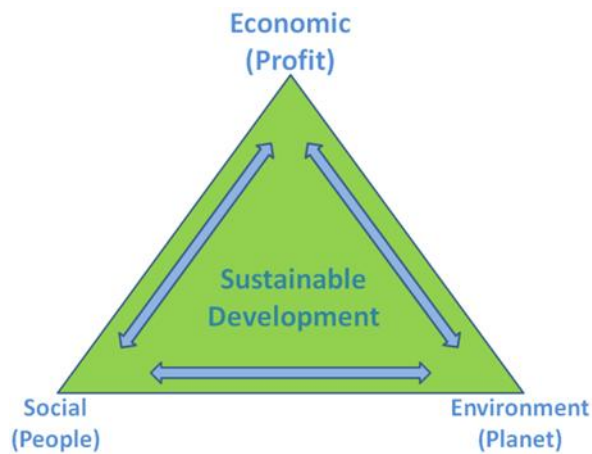


Figure 1. The three pillars of sustainable development

Sustainability can also be considered from the perspectives of production and consumption. The Lowell Centre for Sustainable Production [9] has defined sustainable production as “the creation of goods and services using processes and systems which are non-polluting, conserving of energy and natural resources, economically viable, safe and healthful for employees, communities, consumers and socially and creatively rewarding for all working people.” Sustainable consumption, on the other hand, is “the use of goods and services that respond to basic needs and bring a better quality of life, while minimising the use of natural resources, toxic materials and emissions of waste and pollutants over the life cycle, so as not jeopardise the needs of future generations.” [10]

To concretize the concept of sustainable development and better link it to manufacturing companies and their operations and products, key areas that have an effect on sustainable development and the sustainability of production and consumption have been outlined and presented in the following figure (Figure 2).

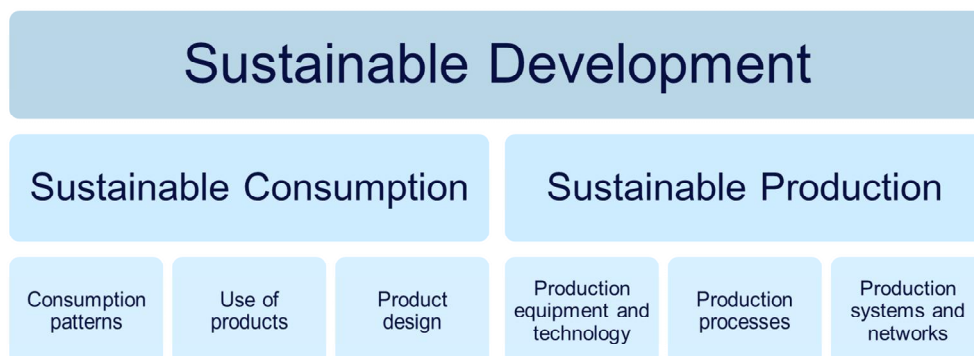


Figure 2. Sustainable development, production and consumption and related decision areas

An important area related to sustainable consumption is the customers' consumption patterns, e.g. the volume and variety of products and services bought and consumed and the frequency of replacing products. Furthermore, the actual use of products, e.g. how products are operated and maintained, has an important effect on environmental, social and economic aspects such as energy consumption, safety and productivity. However, manufacturing companies have limited influence on their customers' consumption patterns and how they use the products. Hence, for manufacturing companies, product design is probably the most important aspect of sustainable consumption. The decisions made in product design have significant effects on the sustainability performance of a product, e.g. energy consumption and waste and emission creation, during its use. Product design also connects the consumption and production aspects of sustainability, i.e. the use and production phases of a product, which further increases the importance of product design in realizing sustainability in the manufacturing industry.

From the sustainable production perspective, product design decisions have an effect on the manufacturability and assemblability of the product, i.e. the ease and efficiency of the production processes. These decisions as well as the material choices made in product design are clearly linked to the environmental and economic aspects of sustainability. Of the three areas directly linked to production, decisions related to production equipment and technology affect the efficiency, environmental performance and safety of the production operations. Similarly, the design and operation of production processes are linked to the three aspects of sustainable development via, for example, the efficiency of processes, the amount of waste generated and the safety and well-being of employees. Finally, decisions related to the organization and layout of the production system or network, transportation and logistics affect the sustainability performance of production.

With regard to the proposed concept, the definitions and discussion presented above mainly assist in defining the focus and scope of the concept. For manufacturing companies, the main focus in realizing sustainable development is on sustainability of production, i.e. decisions related to product design, production equipment and technology, production processes, and production systems and networks.

2.2. Current State and Development Needs in Industry

Several surveys and research projects show that sustainable development and sustainable production have yet to be realized in and pose significant challenges to the manufacturing industry. In 2007, the Human Resource Institute conducted a large global survey with almost 1400 respondents that focused on the current state

and future outlook of sustainability and sustainability-related practices in organizations. As part of the key conclusions, HRI reported that sustainability-related initiatives were not yet deeply ingrained in most organizations, that companies had made only moderate progress toward sustainability and that there was definite room for improvement [11]. More recently, the authors conducted a research project that included a survey of Finnish manufacturing companies, and industrial interviews and workshops focusing on the current state and future expectations of sustainability. In the survey, a similar questionnaire to the HRI report was used and 70 responses from over 50 companies were received, while the interviews and workshops involved 23 persons from 21 companies (see [4, 5]). Table 1 provides an insight into the state of sustainability and sustainability-related practices in the Finnish manufacturing industry based on the survey.

Table 1. Current state and role of sustainability in Finnish manufacturing companies

On a scale from 1 to 5, rate your company on the following questions		n=70
Issues		Mean
Sustainability is a key factor in our production		3.31
Sustainability is a major part of our product design		3.27
Do you believe that your organization is implementing a sustainable strategy?		3.07
Is your organization seeing measurable results from sustainability initiatives?		2.72

The above table shows that, in general, the level of implementation and the realization of sustainability in companies and their operations is relatively low. Linking back to the key decision areas of sustainable production and consumption (Section 2.1.), the current role of sustainability is not significant in production or product design, as the average scores are just above the neutral grade of 3. This observation was supported by the interviews and workshops from which one of the conclusions was that costs play a much greater role in decision-making than sustainability, both in production and product design [5]. Furthermore, the table shows that the respondents did not believe that their companies implemented a sustainable strategy, and they reported that sustainability initiatives had not provided measurable results for their companies. Thus, further work and development are needed to implement sustainability-related practices and to realize sustainable development and production in the Finnish manufacturing industry.

In addition to the current state, the surveys and interviews covered challenges and barriers to realizing sustainability in industry and organizations. The HRI report mentioned a lack of demand from consumers and customers and from managers and employees, a lack of awareness and understanding, and a lack of standardized metrics or performance benchmarks as the highest rating, although

not particularly strong, as barriers to making organizations more sustainable [11]. Table 2 shows that the results of the survey carried out by the authors were quite similar, highlighting the lack of standardized metrics or performance benchmarks as the biggest challenge.

Table 2. Challenges and barriers to realizing sustainability in manufacturing

On a scale from 1 to 5, to what degree does each of the following issues hinder your company from moving toward sustainability? (n=70)

Barriers	Mean
Lack of standardized metrics or performance benchmarks	3.56
Lack of specific ideas on what to do and when to do it	3.49
Lack of demand from shareholders and investors	3.46
Lack of awareness and understanding	3.41
Lack of demand from consumers and customers	3.38

The experts' opinions also point out similar challenges and needs to those expressed by the companies. For example, in the SustainValue project, which is aimed at developing a roadmap towards more sustainable and better-performing production and service networks, the results of expert workshops were grouped into three sub-roadmaps: 1) empowering stakeholders, 2) increasing efficiency, and 3) creating new performance criteria, models and means of measuring success. Of these, empowering stakeholders called for greater awareness and changed behaviour regarding sustainability issues, better ways to demonstrate the benefits of sustainability actions and improvements, and standardization and legislation that support sustainable production. Efficiency improvements were seen as needed in production and manufacturing as well as in the operation of products, while the third sub-roadmap focused on making sustainability measurable [6].

The presented review assists in defining the focus and objectives of the proposed concept. The most important challenges for realizing sustainable development and sustainable production are seen as measurement and indicators of sustainability. These were highlighted in all the reviewed results, and their importance is also supported by a survey recently conducted in the VS-KPI project in which all the respondent companies indicated their interest and need to measure the sustainability performance and effects of their operations. However, measurement and reporting alone are not sufficient, and improvement ideas and means, i.e. the specific ideas on what to do and when in Table 2, need to be identified based on the measurement results. Thus, the proposed concept should assist in sustainability performance measurement, reporting and improvement.

2.3. Sustainability Performance Measurement and Reporting

Several sustainability performance indicators as well as guidelines for measuring and reporting sustainability are already available. For example, the Global Reporting Initiative (GRI) provides guidelines for sustainability measurement and reporting, and it presents 80 sustainability indicators [12]. Furthermore, OECD presents 18 Sustainable Manufacturing Indicators, while EUROSTAT has identified and proposed 15 Sustainable Consumption and Production Indicators [13, 14].

Sustainability indicators can be categorized in various ways, e.g. based on temporal focus, level of detail or object of measurement and reporting [e.g. 15]. With temporal focus, the indicators can be categorized as past, present or future oriented. In the production context, typical objects and levels of measurement and reporting are

- Machine, e.g. energy consumption of a machine during a certain period
- Factory, e.g. energy consumption of a factory and all its operations during a certain period
- Company or network, e.g. energy consumption of all the company's or production network's factories during a certain period

Based on a review of available indicators, measurement and reporting guidelines, and companies' practices, the authors' conclusion is that sustainability performance measurement and reporting are currently mainly carried out at company level and that they focus on past performance. A typical example is annual sustainability or corporate social responsibility (CSR) reporting at company level. Such reports provide high-level, aggregated data, but the authors argue that the reports do not provide sufficient assistance for decision-making aimed at sustainability performance improvement in production and product design. Hence, performance indicators as well as measurement and reporting systems and practices are needed that better support sustainability-related decision-making and improvement.

3. Concept for Improving Sustainability Performance and Managing Sustainable Production

The discussion and reviews above show that sustainable development has not yet been realized at global or company level, and it highlights challenges and barriers related to realizing sustainable development and production in manufacturing industry and points out shortcomings of currently available sustainability performance measurement and reporting practices and guidelines. To overcome these challenges and support the manufacturing companies in realizing sustainable production, the authors aim to develop a concept for improving

sustainability performance and managing sustainable production. This section presents the objectives and requirements of the concept and outlines the concept and the required research and development work.

3.1. Objectives and Requirements

The main objective of the proposed concept is to assist companies to improve the sustainability performance of their production and guide them in developing a system for managing sustainable production. To meet the identified needs of manufacturing companies, the concept is required to cover performance measurement, analysis and reporting and to support decision-making and performance improvement. Based on the discussion and conclusions in Section 2, more detailed objectives and requirements for the concept and the system can be defined as:

- Measurement and reporting should be done at machine or factory level
- Measurement and reporting should focus on present and future rather than past performance
- Measurement and reporting should be linked to production and decisions related to product design
- The concept is expected to increase sustainability-related awareness and understanding and assist in demonstrating the effects and benefits of sustainability actions and improvements to stakeholders

If these objectives are met, the proposed concept will greatly contribute to fulfilling the needs presented by manufacturing companies and overcoming the identified shortages of current measurement and reporting guidelines and practices.

3.2. Outline of the Concept and Research and Development Work

The proposed concept covers both improvement and management of sustainability performance of production. The well-known DMAIC (Define, Measure, Analyse, Improve, Control) approach (e.g. [16]) is seen as well suited to performance improvement and to defining a management system, as it includes the key elements of an improvement project as well as important aspects of management. The planned content of the concept and its five parts as well as the required research and development work are briefly outlined below.

The define phase focuses on defining and identifying appropriate and useful sustainability performance indicators for a company. This requires clarification of the measurement needs within the company and from the stakeholders, e.g. customers, investors and legislators. Sustainability performance indicators relevant

to the identified needs are subsequently selected and defined. Hence, this phase focuses on “What should be measured?” and “How should it be measured?”. With regard to research and development work, an approach and tools for identifying the measurement needs and selecting and defining appropriate performance indicators must be developed. As the currently available indicators mainly measure past performance at company or corporation level, indicators that provide more real-time and future-oriented data at factory and machine level need to be developed.

In the measure phase, the defined sustainability performance indicators are implemented in practice. The research and development work focuses on defining an approach to efficiently and effectively implement the sustainability performance measurement system in a company. In addition, methods for collecting the required data at factory or machine level in real time need to be developed.

The analyse phase paves the way for performance improvement and enables reporting of relevant and useful information both within the company and to external stakeholders. With regard to reporting, the measurement data must be analysed and summarized to provide useful information to stakeholders. Then, to enable performance improvement, the cause-effect relationships between measurement results and decisions related to production and product development must be identified and described. This should enable practical performance improvement actions and projects based on the measurement results and current sustainability performance to be determined, i.e. answering the question “How can sustainability performance be improved?”. The research and development work related to reporting includes defining practices for identifying the information needs and analysing, summarizing and providing the required information to the stakeholders. With regard to performance improvement, the required research and development work focuses on better understanding and describing the cause-effect relationships to define effective improvement actions.

In the improve phase, the planned improvement actions and projects are executed, and changes and improvements are made to products, production systems and production processes in order to achieve higher levels of sustainability performance. For this, approaches and methods for efficient and effective improvement project management and execution need to be identified or developed.

Finally, in the control phase, the new processes and improved sustainability performance are stabilized, standardized and controlled. The control phase also involves monitoring processes and sustainability performance using the performance indicators and analysis and reporting systems developed in the define and analyse phases. Such monitoring aims to identify any deviations from the

standardized processes and performance, and opportunities and needs for new performance improvement actions and projects. Hence, the control phase contributes to a sustainable production management system that aims to standardize the processes and sustainability performance, and enable continuous improvement. The research and development work focuses on defining and describing the processes for managing and controlling sustainability performance and sustainable production, e.g. how often and by whom current performance is monitored and how improvement actions are initiated and carried out.

The development of the proposed concept and the research and development outlined above are planned to be carried out in on-going and future research projects. The work has been started in the VS-KPI project, which is part of the FIMECC's (Finnish Metals and Engineering Competence Cluster) MANU programme. The project focuses on sustainability performance measurement practices and needs of Finnish manufacturing companies and is hence linked to the defining part of the proposed concept. The next logical step is to move to the measure phase, which, depending on the size and budget of the project, can be carried out either on its own or combined with the analyse phase. The improve and control phases covering practices for improving products, processes and performance and controlling the new, improved situation could then be combined into one research project or carried out as separate projects.

4. Conclusion and Summary

This paper proposed and outlined a concept for improving sustainability performance and managing sustainable production. Relevant literature and recent research projects were reviewed and, based on the reviews, the need for and the objectives of the concept were identified. The reviews provide an overview of the current state and practices of manufacturing companies related to sustainability and sustainable production and are hence an important part of the paper's contribution.

The proposed concept is intended to assist companies to improve their sustainability performance production and to guide them in developing a system for managing sustainable production. It needs to cover performance measurement, analysis and reporting and support decision-making. As the objectives and requirements of the concept are defined based on industrial surveys and interviews, the proposed concept is expected to contribute greatly towards fulfilling the needs of manufacturing companies. The concept will be developed using the DMAIC approach and structure, and the outlined research and development work is planned to be carried out in on-going and future research projects.

Acknowledgements

Support from the Finnish Metals and Engineering Competence Cluster (FIMECC) MANU (Future digital manufacturing technologies and systems) -research program, Tekes – the Finnish Funding Agency for Technology and Innovation, VTT Technical Research Centre of Finland and Tampere University of Technology is gratefully acknowledged.

References

- [1] WCED: Report of the World Commission on Environment and Development: Our Common Future, Oxford University Press, Oxford. (1987)
- [2] Global Footprint Network: Earth Overshoot Day. www.footprintnetwork.org/en/index.php/GFN/page/earth_overshoot_day/
- [3] WWF: Living Planet Report 2012. WWF International, Gland, Switzerland. (2012)
- [4] Koho, M., Tapaninaho, M., Torvinen, S.: Towards sustainable development and sustainable production in Finnish manufacturing industry In: ElMaraghy, H. (ed.) Enabling Manufacturing Competitiveness and Economic Sustainability, Proceedings of the 4th International Conference on Changeable, Agile, Reconfigurable and Virtual production CARV2011, pp. 422-427. Springer, Berlin (2011)
- [5] Tapaninaho, M., Koho, M., Torvinen, S.: Current state and future expectations of sustainable development and sustainable production in the Finnish manufacturing industry. In: Seliger, G. (ed.) Proceedings of the 9th Global Conference on Sustainable Manufacturing, pp. 302-307. Technische Universität Berlin, Berlin (2011)
- [6] Palomäki, K., Reunanen, M., Valkokari, K., Valkokari, P.: Sustainability gaps and stakeholder requirements. SustainValue Deliverable D 1.1. VTT, Espoo (2011). http://www.sustainvalue.eu/publications/D1_1_final_Rev1_0_web.pdf
- [7] Martins, A.A., Mata, T.M., Costa, C. A. V., Sikdar, S.K.: Framework for Sustainability Metrics. Ind. Eng. Chem. Res., Vol. 46, pp. 2962-2973. (2007)
- [8] Elkington, J.: Cannibals with Forks: The Triple Bottom Line of 21st Century Business, In: American Management Association, Creating a Sustainable Future: A Global Study of Current Trends and Possibilities 2007- 2017. American Management Association, New York (2007)
- [9] Veleva V., Ellenbecker M.: Indicators of sustainable production: Framework and methodology. J. Cleaner Prod., Vol.9, No.6, pp.519-549. (2001)
- [10] IISD Reporting Services. Oslo Roundtable on Sustainable Production and Consumption. <http://www.iisd.ca/consume/oslo00.html>

- [11] American Management Association: *Creating a Sustainable Future: A Global Study of Current Trends and Possibilities 2007-2017*. American Management Association, New York (2007)
- [12] Global Reporting Initiative: *Sustainability Reporting Guidelines version 3.1*. <http://www.globalreporting.org/ReportingFramework/G31Guidelines/>
- [13] Organisation for Economic Co-operation and Development: *Environmental Indicators Towards Sustainable Development*. (2001)
<http://www.oecd.org/dataoecd/37/1/33703867.pdf>
- [14] Eurostat *Sustainable Production and Consumption*
<http://epp.eurostat.ec.europa.eu/portal/page/portal/sdi/indicators/theme2>
- [15] Ness, B., Urbel-Piirsalu, E., Anderberg, S., Olsson, L.: *Categorising tools for sustainability assessment*. *Ecological Economics* vol. 60, no. 3, pp. 498-508. (2007)
- [16] Stamatis, D.H. *Six Sigma Fundamentals: A Complete Guide to the System, Methods and Tools*. Productivity Press, New York. (2004)