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## Model-based approach for assessing value creation to enhance sustainability in manufacturing

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### Abstract

Increasing global competition requires technological innovation with new political, commercial and technical advances empowered by market dynamics. These challenges must be met with appropriate decision-making by manufacturing companies to secure competitive advantage without compromising sustainability. This requires decision-makers to seize opportunities for improving sustainable solutions in strategic and operational activities. Various scientific and case-based methods are applied to measure the performance and sustainability level of manufacturing systems. However, embedding sustainability in decision-making has not been fully realized by academics and practitioners. This paper introduces a model-based approach for assessing value creation to enhance manufacturing sustainability. The major objective of the approach is to evaluate the strategic alignment and sustainability of the solutions to overcome a challenge related with a product, process or equipment in manufacturing. The approach proposes a framework that transforms customer requirements first into descriptive attributes to assign the value for strategic alignment and later into comprehensive metrics to measure the sustainability value. The approach provides decision-makers with a method of comparing sustainable value addition and strategic alignment when evaluating alternatives. In a case-based application, the production equipment of a service provider is evaluated to select the option that adds the most value, both strategically and sustainably, to meet customer requirements.

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### 1. Introduction

Engineers and managers have conducted performance analyses of manufacturing activities for decades. They are responsible for ensuring that technological systems and their elements meet customer requirements. Since the reality of limited resources and continuous growth, and the unequal distribution of wealth cannot be neglected, sustainability has become both a requirement and a challenge in the last decade for mankind’s survival on earth and for future development [1].

While societies have become more economically resilient, there is a need to also become more environmentally sensitive and socially equitable. As promoting sustainability gains importance, the definition of value should be expanded to include environmental and societal in addition to economic benefit.

In manufacturing organizations that are interested in promoting sustainable manufacturing, strategic alignment and sustainability represent two central criteria for assessing options, in addition to other operational criteria. Businesses are uniquely positioned to shape the future of economically beneficial and sustainable manufacturing activities. With the goal of promoting changes in management through sustainability-driven decision-making, this paper introduces a model-based approach for assessing value creation to enhance manufacturing sustainability.

The next section introduces the value creation framework proposed by this approach. A literature review is then conducted in section 3 to offer insights into accomplishments in manufacturing performance and sustainability measurement. A methodology section then follows, in which the model-based approach for assessing value creation is presented. Thereafter,

application of the method to a case study is presented. The conclusions and future work are summarized in the last section.

## 2. Value Creation Framework

In manufacturing, value creation is achieved through changing the ratio between input and output in terms of raw materials and resources for manufacturing activities. Ueda describes value creation transformation at different levels depending on the nature of interactions between different stakeholders and the broader system [2]. Interactions between suppliers, manufacturers, customers and other stakeholders, decentralized decision-making and self-organization shape global value creation.

Companies create value by satisfying customer needs and shareholder requirements to deliver products or services while securing shared benefits for all stakeholders, e.g., suppliers, manufacturers, distributors and customers.

In the horizontal integration of stakeholders, materials flow through a supply chain. Vertically integrated, manufacturing activities transform inputs into outputs along the total life-cycle, including major activities such as raw materials extraction, transportation, processing, assembly, manufacture, use and a range of post-use activities such as disassembly, reuse and remanufacture. **Value creation networks** consist of value creation modules integrated vertically and horizontally, as shown in Fig. 1. It also shows five value creation factors (VCF: product, process, equipment, organization and human) and their interactions for one module in the network [3]. **Value creation modules** are applied to specify a case-based scope representing different stages of a life-cycle.

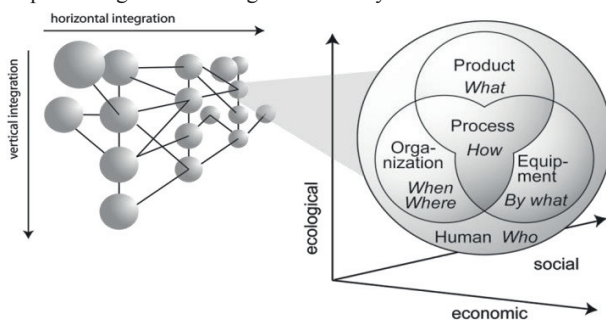


Fig. 1 Value creation framework [3]

## 3. Assessment of Value Creation

Manufacturing requires a complex system that includes the designing, controlling and monitoring the value chain; measuring its performance can support management and improve competitiveness.

Historically, achieving the goals of customer satisfaction, efficiency, quality improvement, and reduction in cost and time have driven the study of manufacturing systems as value creation networks.

Measures, metrics and indicators quantify attributes of an object, product or process and enable comparison and evaluation of goals or benchmarks. They simplify, visualize and communicate complex information [4]. However, a

uniform set of indicators or metrics for measurement does not yet exist. Each case has characteristics that depend on a specific perspective, which determines the types of measures that are relevant for the assessment. To strike a balance between lean, green and sustainable commitments, adequate and representative measures must be selected.

The approach to measure and monitor a company's success and sustainability performance is the fundamental question this paper aims to address.

### 3.1. Performance Measurement

**Performance** investigates effectiveness and efficiency in the achievement of a specified activity [4]. **Efficiency** seeks to increase speed, with less waste and in the most economical way to achieve the best value, expressed as the input-output ratio. It is a fundamental criterion for achieving a competitive advantage in today's market environment. Data envelopment analysis (DEA), e.g., is a method applied to evaluate efficiency within given settings [4]. **Effectiveness** seeks to undertake the best activity at the right time and place, at the right cost to achieve a predetermined desired effect and an overall goal. Quality function deployment (QFD) is one of the quantitative tools of quality management that is used to translate customer requirements and specifications into appropriate technical or service requirement effectively [4].

**Performance measurement** involves using information to evaluate activities as they pertain to meeting strategic objectives and customer expectations. Strategy determines the basic goals and objectives of an enterprise, and influences the allocation of the resources required in the accomplishment of those goals [5]. The main goal is control, communication and improvement of value creation through a set of comparable and measurable indicators.

Both the Total Quality Management (TQM) and Toyota's Lean Production System philosophies assisted in spreading the development and implementation of performance measurement systems in companies. Another acknowledged performance measurement system based on financial and non-financial data is the Balanced Scorecard (BSC) framework [7]. The BSC is used to translate the strategy of organizations into a set of qualitative objectives and quantitative measures that support the future improvement with targets and strategic initiatives. Many strategic measurement models based on BSC have been developed to evaluate some aspects of performance and to offer practical guidelines for companies [6].

To strengthen market positioning at enterprise level, and to solve problems and deliver the same goals at organizational or process level, all objectives need to be aligned, so that they are systematically linked to overall company goals.

Another broadly accepted framework for continuous improvement on VCF level is the Plan-Do-Check-Act (PDCA) cycle [9]. The PDCA cycle describes the iterative application of the planning, controlling and quality management processes to satisfy customer requirements. The process starts with the establishment of a plan (Plan), continues with its execution (Do), monitoring, evaluation and results analysis (Check). Corrective actions (Act) to rectify performance are then implemented. PDCA is considered later to develop Six Sigma

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