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1.1 Sustainability incubators: A coordinated collaborative approach towards sustainable manufacturing amongst small and medium-sized enterprises.

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Abstract
Small and medium-sized enterprises constitute a major share of the manufacturing sector in many countries and are known for their dynamic structure and innovative strength. Despite the potential for sustainability performance the economic impact of environmental regulations may impede many business ventures. Business incubators foster entrepreneurship by offering infrastructural facilities and legal support. The central management of environmental impact reduction and cross-application technologies can in some cases be profitable. The entrepreneurial framework may initiate progress towards the application of sustainability principles. Benchmarking as a powerful management tool can induce best practice transfer and the conceivable collaborations may generate eco-innovations, social and creatively beneficial environments as well as economic advantages. The induced performance measurement, comparison and exchange of experiences is directed towards collective sustainability performance.
Keywords:
Business incubators, sustainability, sustainable manufacturing, ecologic innovations, manufacturing networks, Benchmarking

1 INTRODUCTION

The concept of sustainable development has progressed from a political discussion towards a formal commercial performance model and combines the requirements of politics, society and entrepreneurs as well as economic share- and stakeholders. While the ecologic perspective of sustainability is the most formalized research topic within this model, the social and economic determination factors have gained importance and scientific attention. The number of analysis and management tools that attempt to integrate the principles of sustainability into the daily business operations has multiplied accordingly. However, the complexity of the interaction between industrial production and the economic, social and ecologic environment and the necessary manageability of such tools stands in sharp contrast. In some use-cases this may lead to an impaired perception of the necessary sustainability performance of enterprises. The sustainability performance aggregates the result of sustainable management, which is associated with the measurement and evaluation of performance indicators [1]. The exploitation and usage of natural resources, the environmental pollution and social impact of industrial production are very significant determining factors for the necessity of the individual and collective implementation of sustainable manufacturing. The manufacturing sectors of many countries however, are composed of a majority of small and medium-sized enterprises (SME) and smaller numbers of large enterprises. These small and medium-sized enterprises face certain difficulties and restricting factors in regard to the implementation of sustainable manufacturing concepts. This paper designs an application-oriented concept towards sustainable manufacturing amongst small and medium-sized enterprises through a coordinated and collaborative approach.

2 THE CONCEPT OF SUSTAINABLE MANUFACTURING

In order to develop the coordinated collaborative approach towards sustainable manufacturing amongst small and medium-sized enterprises, the following will provide a short overview of the main underlying concepts of sustainable manufacturing. In addition, the determination factors of manufacturing enterprises and the particularities of small and medium-sized enterprises are outlined to denote the application-oriented theme of the concept.

2.1 Sustainability of manufacturing activities

The determination and progression of sustainability performance in manufacturing enterprises has been the focal point of many recent publications and scientific events. The fundamental idea of the substantial potential contribution to sustainable development by the manufacturing sectors [2] is adapted as the basis of the further elaboration. The main understanding of sustainable manufacturing is based on the transmission of the triangle of tension of sustainability to manufacturing activities, wherein the three perspectives (economic, ecologic and social sustainability) are expanded by five basic strategies [3]. These strategies simultaneously complement the model of sustainability and elaborate on the interdependencies between the perspectives. Figure 1 shows the triangle of tension with the three perspectives supplemented by the socio-effectiveness, socio-efficiency, eco-efficiency, eco-effectiveness, sufficiency and ecologic justice strategy.

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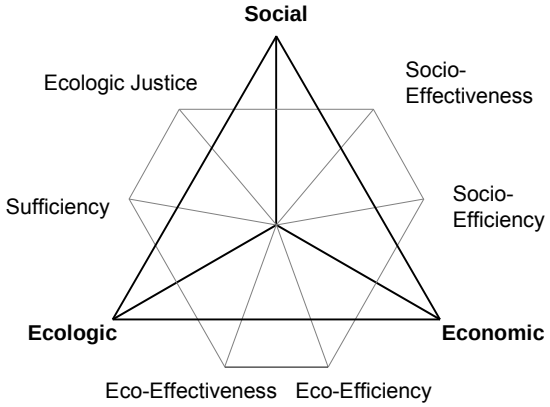

Figure 1 : Tension triangle of sustainability, modeled after [3]

The expansion of this concept across the borders of the individual production systems is on the one hand an imperative, as the sustainability performance of any enterprise is rendered mute if the subcontractors counteract the sustainability of the corresponding product. On the other hand it is seems rather complicated to control the conduct of other enterprises even if they are part of the immediate value chain.

Based on the described tension triangle of sustainability, the determination factors of manufacturing enterprises can be summarized to a standardized set of cause-effect relationships. From these, the principles and strategies can be transformed into directives for sustainable manufacturing, when taking into account the internal and external stakeholders. The directives aim at enabling the implementation of systems and processes that are “non-polluting, conserving of energy and natural resources, economically viable, safe and healthful for workers, communities, and consumers, and socially and creatively rewarding” [4]. From a systems-theory perspective, cause-effect relationships are possible within and between the three perspectives of sustainability. These dependencies and interactions can have either a positive, negative or neutral impact on the underlying objective of preserving the ecological, economic and social environment. Furthermore, these can be categorized by location, time and reflexivity [5]. Thus, interactions may occur within the considered systems or across the system boundaries to influence other systems. Simultaneous or delayed interactions are often difficult to identify because the simultaneous influence may be misinterpreted as independent or latent interactions are not detected. Such interactions may have the characteristic of being reinforcing, respectively debilitating mechanisms or actions. The measurement, evaluation of cause-effect relationships and determination factors and the definition of activities or actions that specifically deal with these are the challenge of the operative management of sustainability performance.

2.2 Particularities of manufacturing SME

Small and medium-sized enterprises evidence certain particularities in terms of the implementation capabilities of actions that increase the sustainability performance. As the competitive situation on the globalized market has tightened, the financial scope for action has notably decreased for most enterprises. As activities that actively deal with determination factors of manufacturing enterprises are associated with additional costs for the enterprises, the demonstration of the direct benefit of these activities is of high significance in this context. While economic impact is the most direct to be measured, it is the performance of enterprises directed towards the improvement of the environmental and social impact that is of interest to the public and regulating authorities. The aforementioned problematic cross-enterprise responsibility is underlined when considering the economic influence of a single small or medium sized enterprise. The supplier-consumer relationship in this case does not necessarily allow an extensive requirements profile, as the quantities of economic transaction of individual SME fall into insignificance to some suppliers.

2.3 Concernment of enterprises

It has been argued, that the concernment of small and medium-sized enterprises in regard to legal requirements is likely to be much lower than that of large enterprises [6]. This argument is based on the limited capacity of regulation authorities, which prevents the thorough enforcement of regulations in all enterprises of the corresponding domain. Meanwhile, the imposed regulations are mostly concerned with or complied with downstream or additive technologies that reduce environmental or social impact. Therefore, the influence of regulations and legal requirements is not likely a driver for a holistic progression of sustainable manufacturing.

While large enterprises are in fact faced with an arguably higher concernment in terms of environmental, social or economic requirements and regulations, they are additionally exposed to the public on a much larger scale. This implicates further requirements by stakeholders and the public as sustainability has also transformed to a rather publicity effective topic in the positive but also negative sense.

2.4 Towards sustainable manufacturing

The limited concernment of small and medium-sized enterprises and the restricted exposure to the public are factors that may hinder the active increase of the individual sustainability performance. Furthermore, the limited scope for actions of SME may be misinterpreted as an inability to act, which would neglect the principle concept of sustainability to preserve the operability of the own enterprise as part of the intra- and inter-generational responsibility and fairness.

It is the private organizations’ responsibility to shape the future actively and incorporate sustainability not only as a concept but as an imperative policy to their operation. This directly induces the disentanglement from sustainable development barriers as for example the concernment of enterprises in terms of regulations and the exposure to the public. The progression of this development needs to be actively driven by the private sector enterprises as potential and resources to foster sustainable development are anchored within these structures.

Sustainable manufacturing can also be interpreted as an opportunity rather than a challenge. The integration of one’s own enterprise to the a new market that demands sustainable products and codes of conduct may be a potential source of new or increased sources of revenue adding to the possible savings of increased efficiency [7]. Further opportunities of sustainable manufacturing can be categorized by the involved stakeholders and the three perspectives of sustainability [1].

This brings the responsibility of the individual enterprise to the focus of attention, as a possible misconduct is assumed.

3 COLLABORATIVE SUSTAINABILITY

The collaboration of small and medium-sized enterprises can be considered separately with regard to the collaboration within networks and along value chains. The collaboration of SME in networks, as those being discussed within this concept, is likely to develop if the participating enterprises benefit from such activities. The collaboration along value chains in terms of sustainable manufacturing may be requirement-driven, as the responsibility of enterprises is not limited to the individual organizational unit but extends across the downstream value-chain.

3.1 Sustainable manufacturing in SME networks

The collaboration of enterprises in networks that are not necessarily bound in the compound structure of a purchaser-supplier relationship (see 3.2) is increasingly becoming the basis for innovation and lasting business success. The management of sustainability performance is herein a substantial part of the cross-company cooperation strategies that tend to form due to the increasing competitive challenges [8]. Enterprises are moreover faced with challenges induced by changing framework conditions and structures of the markets. In retrospect the increasing economic pressure due to increasing competition and product variants, parallel to decreasing liquidity of enterprises as well as the scarcity of resources [9] of the past decade has escalated this situation.

Many of the existing management approaches to sustainable development or specifically sustainable manufacturing revolve around the ecologic perspective, as the determination factors are sufficiently described through the technological processes. The efficiency of these processes and the reduction of environmental impact are emphasized. However, these approaches only focus on the individual enterprise, while the true strength of such activities that increase efficiency and reduce environmental impact has to be attributed to the collaboration in networks. Sharing tangible resources within networks organizations may increase efficiency and business opportunities for all participants, since the optimal use of capacities and technological capabilities is enabled. The collaboration in terms of the reduction of environmental impact as well as the increase of technological capabilities is driven by the sharing of tangible resources. To some extent the collaboration may in fact have positive effects on more than one perspective of sustainability. The identification and avoidance of environmental impact of cross-application technologies has a significant economic impact to the operation of individual enterprises. This effect may be exploited on a larger scale in networks of enterprises relying on the same or similar technologies.

Intangible assets however, are essential success factors for enterprises and to some extent determine the effectiveness of the previously discussed collaboration potential. The intellectual capital of an organization – categorized into the human capital, structural capital and relation capital [10], [11] – in an inter-organizational exchange can be assessed as an alternative reason for the formation of enterprise networks [12]. While the concept of inter-organizational collaboration regarding intellectual capital is relatively new [13], some efforts have been taken to incorporate sustainability into knowledge management systems [14]. The entire organizational structure requires sustainability knowledge in regard to the corresponding processes in order to implement the sustainability strategies [15].

Based on the model of cooperation (Figure 2) the interfaces of collaboration could be assessed in regard to the assessment of social, environmental and economic impact along with the integration of knowledge management systems in network organisations.

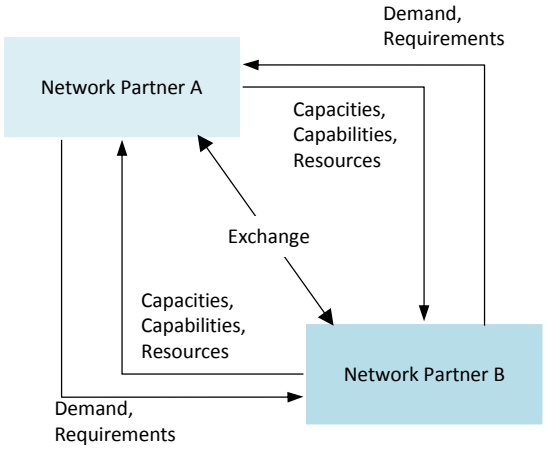

Figure 2: Basic Model of Cooperation, modeled after [16]

3.2 Sustainable manufacturing along value-chains

The labor division among SME along value-chains, which may be induced by the specialization on core competencies and therefore the decrease of depth of the value added of the individual enterprise, presents a special form of network collaboration. The basic collaboration is manifested in the transmission of requirements in terms of technical specifications within the manufacturing process (Figure 3).

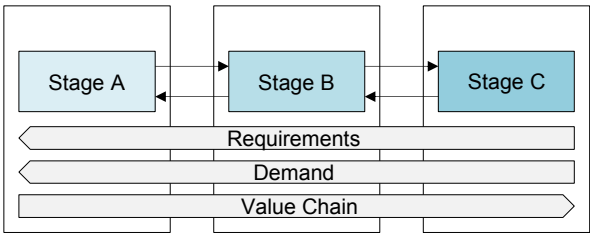

Figure 3: Collaboration along value-chains.

The technical requirements and production quantities are specified in the respective subsequent stage of production – in a single stage model of value-chains this is represented by the industrial consumer. If the principle of responsibility beyond the individual enterprise boundaries is adopted, these requirements can also include parts of the sustainability objectives of the subsequent enterprises. However, an insignificant economic influence may limit this influence if not considered on a broader scale. If a critical mass of enterprises adopts the requirements that go beyond technical specifications and integrate sustainability principles to the selection of suppliers, the demand-driven sustainability performance of suppliers may increase.

4 COORDINATING SUSTAINABLE MANUFACTURING

Business incubators and technology or innovation parks have proven to be a nurturing environment for enterprises of similar industry affiliations and especially equal or similar value-chains. Specifically small and medium-sized enterprises may benefit from the infrastructure and organizational services offered by such entities. One particular concept of a business incubator is to support the affiliated enterprises by offering adapted and favorable framework conditions. The following chapters will incorporate the sustainability perspectives and strategies into the coordination of enterprises within an assumed network independently of the cause of its development.

4.1 Business incubators as the coordinating pioneer

The coordinating functions of the business incubators are herein focused on enabling the discussed collaborative sustainability as well as individual sustainability performance of the affiliated enterprises. Therefore, the business incubators may act as a coordinating pioneer, as the enterprises are supported in adapting sustainable manufacturing and are encouraged through possible good practices by other enterprises in this environment. Provided that the sustainability performance is measurable and existent in the individual enterprises, the business incubator may in fact impose own regulations and specifications that specify requirements for the performance of the enterprises. Thereby, the business incubator further enhances the sustainability performance of the enterprises, which may in turn lead to a certain added value for the enterprises through reputation.

4.2 Central management for sustainability performance

The operational objective of a sustainability incubator is to provide the enterprises with the framework that enables the increase of sustainability performance. The organizational structure of business incubators allows the central management of determination factors, which can improve the efficiency of the processes involved by utilizing scale effects. These management support services need to be regarded as optional as the provision is associated with costs that have to be re-distributed to the enterprises. However, the framework of such a business incubator and the enterprises within are construed on the assumption that the centralized support will be accepted.

The framework that is to be provided applies to the entire production system (Figure 4). The provision of factory and office space at favorable conditions is the initial service provided in this regard, as the ramp-up phase of manufacturing SME relies on the operability of the production system. On the input side of this system the enterprises may benefit of a centralized purchasing unit. Thus, parts of the relational capital of the enterprises are combined to a network resource. Further beneficial framework conditions may be provided through a sustainability intelligence system that serves as an adapted knowledge management system.

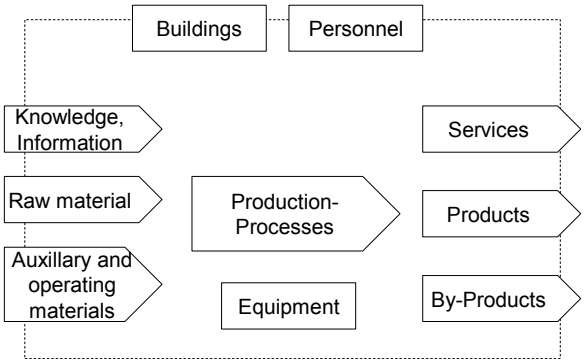

Figure 4 : Production-System modeled after [17]

Information on codes of conduct and regulations regarding the ecological and social environment can be gathered and provided, whereas the insights to technological design options of manufacturing processes can only be provided if the participating enterprises share this knowledge with their peers. Assuming that the willingness to share information is provided, the enterprises may form innovative networks, where the provided information is utilized to generate new solutions for the avoidance or reduction of environmental or social impact. The dissemination of the generated knowledge within the network is provided through the knowledge management system and may be further spread beyond the boundaries of this system, provided that it is not an essential competitive advantage.

The coordination of the cross-enterprise utilization of infrastructure and equipment may on the one hand enable enterprises to expand their production and create further added value. On the other hand, the enterprise that is allowing the utilization of its own equipment can benefit from an increased load factor. The network as a whole is thereby increasing its efficiency, simply by sharing and utilizing un-used equipment-time. Thus, the single production systems' boundaries are partly dissolved and a network production system is formed, which utilizes network resources in terms of technological equipment as well as sharable resources in terms of the intellectual capital (Figure 5).

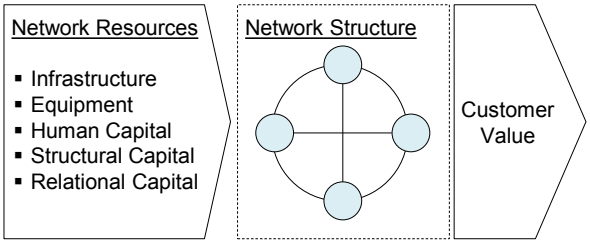

Figure 5 : Network production system.

Downstream and additive technologies to reduce environmental impact can be shared in order to increase the effectiveness and efficiency of these systems. For instance the centralized waste heat utilization, waste water and exhaust treatment may induce monetary savings through scale effects and increase the effectiveness of these technologies.

4.3 Monitoring and management of sustainability performance

The following gives an evaluation of approaches to the monitoring and subsequent management of the sustainability performance of the sustainability incubator with regard to the structure and peculiarities of the enclosed enterprises.

The monitoring – and reporting – of the sustainability performance could follow established systematic approaches such as the reporting guidelines of the *Global Reporting Initiative (GRI)*. However the incremental reporting in accordance with the GRI framework, as a baseline approach for reporting enterprises [18] may account for an inhomogeneous reporting of the incubator – due to the particularities and differences in maturity of the enterprises. Thus, the centralized management of the sustainability performance would only create a distorted snapshot of individual Key Performance indicators.

Considering the intended purpose of an incubator it is herein proposed to develop a predefined set of target domains in which the enterprises define individual qualitative targets and measure qualitative achievement values. In accordance to the tension triangle of sustainability (Figure 1) the following systematic describes an approach to the definition of individual strategic targets within a common structure. The overall performance of the sustainability incubator, as the sum of individual performances is apriori limited by the data collection of the individual enterprises. However, the coordinated definition of targets within the predefined domains may on the one hand create a common reporting framework within the hemisphere of the sustainability incubator. On the other hand it may well be beneficial to the individual enterprise as it induces the process of defining targets that have beneficial effects in all perspectives.

If the sustainability performance monitoring is construed in a consistent, uni-directoinal manner – either burden-oriented or reduction-oriented – and consist of homogeneous target dimensions then the comparison of the individual sustainability performance against that of the business incubator as a virtual organization allows the identification of performance gaps.

Figure 6 shows a generic model of an intra-network comparison of sustainability performance in accordance with the tension triangle of sustainability.

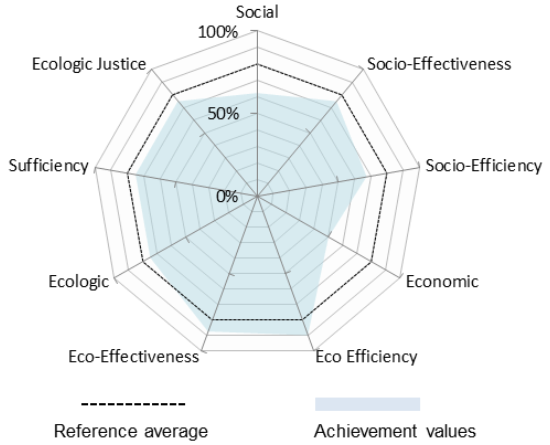

Figure 6 : Target Dimensions and Values of an Individual enterprise within the Incubator Framework

The thereby created monitoring of qualitative target achievement in combination with the coordinating function creates the possibility of intervention or control of improvement and incorporates a network or Incubator governance, with self-imposed targets.

4.4 Benchmarking sustainability performance

As discussed the systematic management of sustainability performance is an essential aspect of the operability and implementation of sustainability strategies within manufacturing enterprises. A significant problematic aspect of sustainability performance of manufacturing enterprises - if considered detached from legal regulations or requirements - is the definition of the necessary level of sustainability performance. If a development process is assumed that will shape the informal requirements of the concept of sustainable manufacturing, a basis for the improvement of sustainability performance needs to be defined. Differentiated Benchmarking-applications for the activities of the individual organizational structure levels provide management tools to integrate the directives and strategies to the different management levels of the enterprises [19]. Yet the operation of the individual enterprise is significantly responsible for the level of sustainability performance. The classical approach of identifying potentials for improvement across the enterprises structure [20] may be transformed into a continuous process to increase sustainability performance.

A fundamental yet challenging approach to define a basis for the measurement and comparison on the operational level is to develop reference values of certain key performance indicators. The comparison of the individual enterprises in regard to these reference values immediately gives an estimate of the potential surplus or deficit of sustainability performance. The BenchmarkIndex™ as described in its sustainable procedure may enable manufacturing SME to improve their economic performance and simultaneously measure and compare innovative key performance indicators that allow statements on the ecologic and social performance [21]. At the same time the described discrepancy between the actual and aspired level of sustainability performance may be solved.

5 CONCLUSION AND OUTLOOK

Combining the strength of small and medium-sized enterprises to operate and innovate in networks and the guidance of a sustainability incubator is an application-oriented solution to the described mission to progress the sustainable development from the private sector. The beneficial framework conditions for the enterprise network and the direction predetermined by the objective of the sustainability incubator are an initial step towards this imperative. Supporting the small and medium-sized enterprises of the manufacturing sector is an essential economic policy to underline the sustainable development of almost any economy. The provision of education, employment and economic added value are substantial contributions of these enterprises.

The knowledge of the enterprises and thereby the capabilities of the personnel within the network are utilized to create services and products in an effective and efficient way enabling the increase of sustainability performance of the individual enterprises. The strong and innovative network that is coordinated by the sustainability incubator benefits of the

systematic management of the success factors and their utilization and gains potential to increase its innovation activities in regard to environmental and social determination factors.

The division corporate management of the Fraunhofer Institute for Production Systems and Design Technology (IPK) has gathered experience in both the provision of knowledge management solutions as well as the research regarding knowledge management in networks to increase sustainability. Furthermore the development of new methodologies for the measurement and evaluation of the sustainability performance of SME is an essential aspect of its research and development activities [22]. As part of the future research, a case study with a network of collaborating SMEs is intended that utilizes the learning about small scale enterprises and incubators, the strategic and implementation planning of science and technology parks as well as the comprehensive understanding of national innovation systems [23].

6 ACKNOWLEDGEMENT

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