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Sustainability in Manufacturing Strategy Deployment

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Abstract

The focus of the paper is the development of a reference model for manufacturing strategy implementation. While many empirical research endeavors report the lack of vigor in implementing sustainability as a manufacturing strategy, also current popular theory-driven approaches are not sufficient to understand the dynamics and organizational barriers in implementing sustainability as a manufacturing strategy. This paper develops a reference model based on systems theory principles and the Viable System Model (VSM). The complexity-based approach helps decision-makers to manage firm-tailored sustainable manufacturing improvement programs.

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Keywords: Manufacturing strategy; Viable System Model; Sustainability

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1. Introduction

Sustainability as a competitive priority has entered the agenda of manufacturing companies with an emphasis on increasing competitiveness by improving economic, environmental and social performance. However, although sustainability has been an important topic for the manufacturing industry, literatures as well as practical endeavors do not provide much guidance on how the pillars of sustainability i.e. economic, environment and society as a business goal can be translated seamless into manufacturing strategy and into measures to improve operational performance along the triple bottom line [1, 2].

Extant research has mainly focused on making unsustainable manufacturing systems and business models less unsustainable. It offers limited insight into how to create an economically viable manufacturing system that at a minimum creates no harm and may even have positive or regenerative impacts on social and environmental systems. Therefore, the major question of how to create truly sustainable manufacturing systems remains unclear [3]. Our aim in this paper is to help move the field from studying how to manage unsustainable manufacturing systems in a more sustainable manner, to managing truly sustainable manufacturing systems [4].

The paper seeks to investigate the manufacturing strategy formation process which is composed of the definition and deployment process. While research on the definition process has been in the focus of previous research endeavors, the deployment process has received far less attention [5]. This explains why theoretical understandings and practical guidance for manufacturing strategy implementation is largely absent. Based on cybernetics principles the paper aims to define management mechanisms that support the implementation of manufacturing improvement programs with the focus on environmental and social betterment.

The basis if the approach is based upon the Viable System Model (VSM). The VSM is a reference model based on cybernetics principles to describe, diagnose and design management of organizations. The VSM is tailored for the purpose of a sustainable manufacturing organization. Here, the manufacturing strategy deployment process has been considered as the core activity to implement sustainability into the manufacturing function. As a major vehicle strategic manufacturing initiative (SMI) or manufacturing improvement programs are considered, since they are considered as vital for implementing manufacturing strategy.

First, the paper describes the design of the different levels of the reference model and the criteria assessed to build them. Second, the paper concentrates one level and on one out of

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five different systems within the reference model. This system is responsible for initiating, managing and changing SMIs and therefore has a crucial relevance in the practical applications. The system functionality is described and is intended to support decision-makers in managing manufacturing improvement programs with environmental and social focus.

2. Background

While several empirical studies report the lack of vigor in implementing sustainability strategies [6], theory-driven approaches like Kim and Arnolds strategy formation framework [7], and the top-down and bottom-up approach by Kim et al. [8] are not sufficient to understand the dynamics and organizational barriers in implementing sustainability as a strategy in new product, process, plant and supply chain development.

Sustainability-oriented strategic manufacturing initiatives, i.e. initiatives with the major intention to decrease environmental impact and increase social responsibility are of major importance for manufacturing firms to improve their operational performance and use their manufacturing competence as a source for competitive advantage [9]. Well-known sustainable strategic manufacturing initiatives (SSMI) like e.g. BMW's Efficient Dynamics, Volkswagen's BlueMotion or Bosch's GoGreen program have been proven to contribute to the firm's success.

However, two major challenges remain: (a) it is unclear how SSMIs besides cost-effectiveness contribute directly and indirectly to enhanced firm's competitiveness, (b) and especially the interrelation with other programs or functional units and their moderating or mediating role remains unclear. Firms competitiveness is a complex construct that has gained utmost attention. Manufacturing is seen as a competitive weapon to be used when seeking world class success. The design of the manufacturer's production system and the design of the technological product portfolio and their interplay are vital to future firm financial outcomes.

Here, the Viable System Model by Stafford Beer may support to understand and investigate the program's impacts on firm's competitiveness and support in shaping firm-tailored efficient SSMIs [10, 11].

3. Methodology and Viable System Model

The work follows a prescriptive research approach embedded in complexity theory. While empirical quantitative as well as qualitative methods like survey or case study are well established nowadays in the field of operations and manufacturing management, complexity theory has been named by several scholars as a vital approach to minimize the science-practice gap, contribute to novel insights in the field and enhance understanding of currently rival theories e.g. the trade-off and cumulative manufacturing capability approaches [12]. The theoretical basis is built upon complexity and systems theory, especially the Viable System Model.

Complexity is the major construct in complexity theory, cybernetics and the Viable System Model. Complexity is described as an indicator of the perceived effort necessary to cope with the system from an observer's point of view [13]. Variety is the operationalization of the construct of complexity and provides a measurement system being capable to quantify and benchmark different systems. Variety is closely related to the state of a system. Each state of the system adds one more progress to the variety and therefore to the entire complexity of the system.

In cybernetics the firm as an organization is seen as a management and operations entity embedded in the environment. The operations unit generally consists of the major tasks that constitute the organization's existence, i.e production, purchase and development and distribution of products, services and technologies. The management unit encompasses all managerial activities that are required to maintain the system condition. It is responsible to create policies and strategies on how the operations units are designed and which purpose in which way they have to serve. The third unit environment contains all elements that are not by definition within the system boundaries. This can include suppliers, competitors, political and legislative bodies, associations, countries, regions, technologies etc. The diversity of the unit environment is manifold.

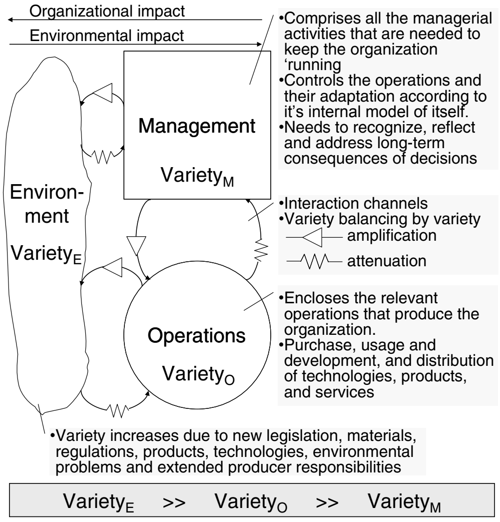


Figure 1: Variety of environment, operations and management

This diversity causes the variety of the unit environment to be extremely high in comparison with the operations and management. The variety increases due to new legislation, materials, regulations, products, technologies, environmental problems and extended producer responsibilities. The operations and management unit have to cope adequately with the massive increase of the variety in the environment unit in order to maintain the existence of the system. The management unit is responsible to adapt the firm's policy in a way that the organization's stability is assured. The management unit has to deal with variety induced by the environment and to align the normative, strategic, tactical and operational plans of the organization and besides to maintain the functioning of the operations units. Here, it responsible to shape the operations unit so that they efficiently and effectively contribute to the organization's target system autonomously. Being supplied with a framework of behavioral policies the operational units have to function and detail their performance autonomously (Figure 1).

The interrelationship of the complexities of this construct was formulated in Ashby's Law of Requisite Variety that says "only variety can destroy variety" [14]. Ashby points out the mechanism how to deal with complexity in organizations. It is only possible to cope complexity with other complexity. Hence, in fact variety is the tool to be used to deal with amounts of complexity. A system has two basic opportunities to deal with complexity, i.e. bringing its variety balance to a higher level, or decreasing the incoming variety of other systems it is connected to. In the special case of organizations as shown above the challenge exists that the variety of the environment is tremendously higher than the variety of the operations unit. Furthermore, the variety of the operations is much higher than the variety of the management unit. The management main responsibility is by applying appropriate tools, methodologies and policies to absorb the environment and operations variety or to increase its own variety to effectively manage the operations.

The balancing act of increasing a unit's own variety or decreasing other unit's variety is referred to as variety engineering. Variety engineering seeks to provide instruments that are proven to be capable in dealing with the variety balancing problem. Variety engineering distinguishes between six different patterns of variety increase and decrease [10]. The attenuation of variety is performed by means of three different patterns:

- Structural attenuation; e.g. by minimization and filtering of input information or delegation of responsibilities.
- Planning and prioritization; e.g. future planning with adequate time horizon and adequate detail level.
- Operational attenuation; e.g. by usage of highly aggregated figures or strict administration with minimal individual decision scope.

The amplification of variety is also traced back to three different patterns:

- Structural increase; e.g. by enabling teamwork or job rotation to share knowledge and experiences.
- Capacitive increase; e.g. by employing more managers; employing managers with new qualitative skills or engaging external consultants.
- Informational increase; e.g. by improving the level of information of managers by comprehensive information systems.

Using the concept of variety engineering and the Law of Requisite Variety to allocate and define management resources for an organization's viability, Beer has defined a reference model for an autonomous system that is designed to survive in complex environments. The Viable System Model is recursive, i.e. one viable system contains another viable system and is cybernetic isomorph.

The VSM consists of 5 systems and connections between them. While the beforehand described operation unit is labelled as system 1 in the VSM, and the environment unit stays as it is, the management unit is expanded to 4 different systems, i.e. systems 2 to 5, within the VSM. Therefore, the model emphasizes its orientation on management cybernetics and the structuring of the management system.

System 1 as the operations unit shows the primary activities where the system's purpose is fulfilled. The entire operation unit must contain at least one system 1, but it can be compromised of an indefinite amount of system 1 units which are interconnected with each other. The example in figure 2 consists of two system 1. Due to the cybernetic isomorphism, every system 1 consists again of an operations and a management unit. Here, the recursion of the VSM takes place.

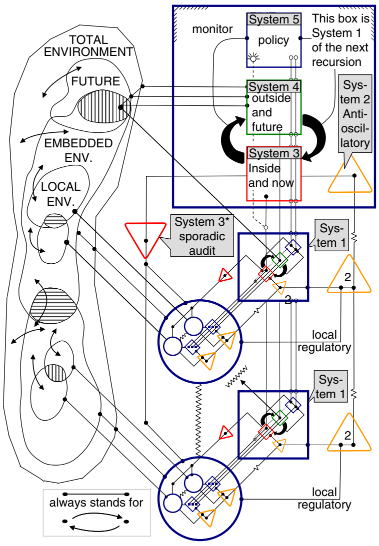


Figure 2: Viable System Model

Systems 2 to system 5 are metasystems which are over and above a system of lower logical order. In cybernetics metasystems are equal to management and in turn to the control system. The systems 2 to system 5 have only indirect connection with the execution of the system's purpose. The execution is performed in System 1 and the metasystem's responsibility is to ensure and support the performance of the operation units. System 2 and system 3 have an operational accountability and system 4 and system 5 form the long-term responsibility. The task of system 2 is the coordination of the operation units. It uses diverse information and communication channels to balance the autonomous behaviour of system 1. Systems 1 are in principle autonomously behaving but they have to be harmonised and adjusted according to the entire system's purpose. System 3 is the operative management. Its task is to assure an optimal process in and between the operational units.

Table 1: Task assignment in Viable System Model

System	Main responsibility and tasks
System 1	Primary activities; performing system's core work
System 2	Coordination of system 1; conflict resolution
System 3	Internal regulation, optimization, and synergy creation
System 4	Corporate strategic planning; matching environmental needs and normative internal planning
System 5	Corporate policy and identity

System 2 is coordinating the system 1 activities indeed, but it is not guaranteed that system 1 activities are efficient and their co-operation leads to better effect than the sum of their single activities. System 4 deals with corporate development and strategic management. It has a connection to the environment and its main task is future planning. System 4 generates possible future models of the environment and the organisation. Its main purpose is to gather information from the environment, to separate them, and to provide them to other systems. System 5 is the normative management. On the one hand it is responsible for the interaction of system 3 and system 4, on the other hand system 5 represents the organizational values, norms and rules. System 5 builds the ethic and culture of an organization. Furthermore, each system is described by detailed information and communication channels which are not reported in this paper.

The Viable System Model is especially appropriate to be used when designing and assessing managerial systems due to the model characteristics described above. With very detailed descriptions of the managerial unit, any management system independent from the firm characteristics or technologies in place can be designed and optimized based on the principles and references of the VSM. Hence, the VSM is a powerful tool to address the problem of sustainable strategy deployment in this research approach.

4. A reference model for strategy formation

In this section a reference model for sustainable manufacturing strategy formation based on Beer's VSM and cybernetics principles is developed. First, the embodiment of system 1 and the recursive levels are discussed. Afterwards, the entire structure of the reference model is described.

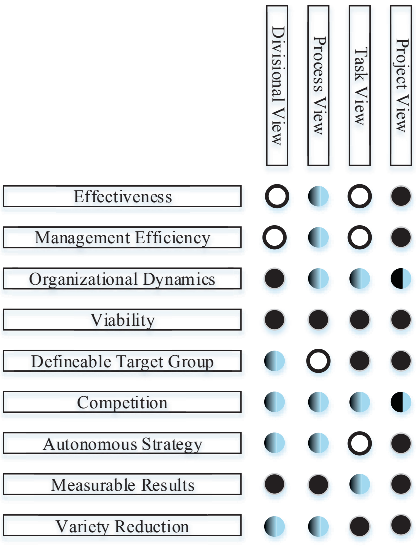
4.1. Transformation of strategy deployment process into VSM

The modelling of the viable system fluctuates with the system 1 declaration. The system 1 is the central unit inside the VSM whose activities are regulated, monitored and coordinated by the supra-systems and whose definition determines the recursion of the VSM. Hence, to ensure a rigid and rigorous modelling of the real system, the system 1 needs to be chosen according to the object of investigation in focus. In this research, the object of investigation is the manufacturing strategy deployment process which can be formulated as a manufacturing capability building, maintaining and extending task. As shown in the previous section, manufacturing improvements programs are seen as vehicles to transform strategic choices and competitive priorities into manufacturing capability in order to serve the manufacturing as well as business strategy and lead to competitive advantage. The starting point for the investigation is to perceive the strategy deployment and with it the SMIs as a viable system. Without them the company would not be able to act and react upon internal and external disturbances, and based on the theory of production frontiers the company would miss betterment and improvement activities which lead to a decrease in competitive strength and therefore a worse operating performance up to the downfall of the firm, i.e. in cybernetics terms the incapability to maintain a homeostasis.

As scholars have done successfully previously, the VSM was traditionally modelled with the system 1 as the division of the corporation. Further approaches for modelling are based on process views and tasks. According to Miltenburg, SMIs have frequently the characteristics of projects, i.e. clear objective and (sub-) tasks with dedicated time and resource constraints and benchmarking mechanisms [15]. These four potential perspectives are assessed according to criteria formulated by Beer, Bachmann and Michel, and Herold [10, 16, 17].

The divisional, process and task view are impractical to catch the necessary interrelationships for the modelling purposes. The divisional perspective is improper mainly due to three reasons. First, the exclusive system purpose is not only capability building. Second, due to the linkage of the divisions the principle of autonomy is neglected. And third, a highly complex planning effort for system 3 and 2 would be existent. These criteria apply as well to the process and task perspective. Furthermore, the capability building process itself would be manifested among other processes in the systems 2 to 5, so as that a dedicated investigation without separation of other inherent processes is difficult.

These considerations lead to finding that a project view may support the system purpose in the best way among all assessment criteria and should be used for modelling. Hence, in the first recursion the elementary units are based upon SMIs. This modelling approach serves the required level of autonomy of the units and allows in addition a detailed view on the SMIs in the second recursion as well their relationships and their impact to the system purpose in the first recursion.



	Divisional View	Process View	Task View	Project View
Effectiveness	○	◍	○	●
Management Efficiency	○	◍	○	●
Organizational Dynamics	●	◍	◍	◐
Viability	●	●	●	●
Defineable Target Group	◍	○	●	●
Competition	◍	◍	◍	◐
Autonomous Strategy	◍	◍	○	●
Measurable Results	●	●	◍	●
Variety Reduction	◍	◍	●	●

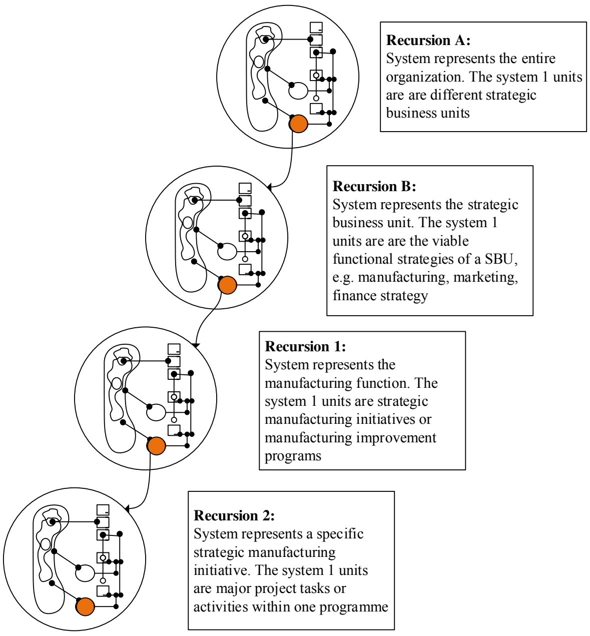
Figure 3: Assessment of system 1 structuring alternatives

Moreover, from a cybernetics perspective the regulatory units account for process control and supervision to alleviate disturbances on one side and to shape the system 1 progress according to the systems purposes. This means that this perspective fulfills the need to understand and model the strategy deployment process, the co-existence of the SMIs and their mitigating or mediating behavior to other SMIs and the ultimate manufacturing strategy. Due to this view, all monitoring, controlling, and disturbance functions can be depicted. Hence, the application of the VSM extends the traditional views on the corporation and puts emphasis on the strategy process.

4.2. Reference recursions

Based upon the section above, the meta-system is modelled through four recursive layers which are marked as recursion A, B, 1, and 2 in figure 4. Recursion shows the recursive level of a manufacturing function within a firm, whereas the elementary system units are enabled as SMIs. This recursion of the reference framework can be tailored in an application case according to the case characteristics. E.g. the recursion can be applied to a factory-within-a-factory, a single factory, or a manufacturing network. Hence, it is the basis for in-depth investigation of manufacturing strategy deployment independently from the production system characteristics. Based on the first recursion and its elementary units, the recursion 2 shows each single SMI with its detailed information and coordination mechanisms. The system 1 units are the (sub-) project tasks that have to be performed in order to enhance the manufacturing system. Besides, recursion A and B are higher level reference perspectives. Recursion A and B can be merged to one recursive level, if the company does not possess different business units, but is organized according to its functional characteristics. While recursion A and B are mostly applicable to multi-national companies, a combined recursion A and B is favored for small and medium sized enterprises.

Recursions 1 and 2 are the elementary levels for the purpose of this research, while recursions A and B are useful to investigate strategic fit questions regarding the relation between manufacturing strategy and corporate or other functional strategies. Hence, investigations on recursion level A and B foster the external consistency of the manufacturing strategy. Recursions 1 and 2 on the other side emphasize on the contribution of improvement programs to the strategic directions of the manufacturing function and therefore foster the internal consistency if manufacturing strategy.



Recursion A:
System represents the entire organization. The system 1 units are are different strategic business units

Recursion B:
System represents the strategic business unit. The system 1 units are are the viable functional strategies of a SBU, e.g. manufacturing, marketing, finance strategy

Recursion 1:
System represents the manufacturing function. The system 1 units are strategic manufacturing initiatives or manufacturing improvement programs

Recursion 2:
System represents a specific strategic manufacturing initiative. The system 1 units are major project tasks or activities within one programme

Figure 4: Recursions of reference model

These recursions allow four different types of investigations. First, it is possible to focus the investigation onto the internal stability of the system by monitoring, control, and coordination mechanisms of the systems 1, 2, and 3 in the here and now. Second, it allows the investigation of the external conformation, i.e. additionally to the efficiency aspect of the systems 1, 2, and 3, the systems 4 and 5 control the effectiveness of the SMIs concerning changes in the environment and the normative plans of the functional unit. Here, the contribution of the SMIs to the manufacturing capability building and their relation to the competitive priorities of the firms is investigated. Third, it enables the view on the system homeostasis and therewith holistic investigations to the state of the system. Fourth, based on the internal stability, external conformation and system homeostasis different strategies and SMIs can be evaluated in this reference model. In the following, the paper describes the internal stability mechanism with focus only on system 3.

5. Formation mechanism

5.1. Target system for internal stability

Although all recursions and systems play a central role in the strategy deployment process, system 3 of recursion 1 has the main task to use synergies among the systems 1 and to contribute to the adhesiveness of the autonomous systems 1 under consideration of success potentials. System 3 is responsible to assess and (re-)configure the elementary units due to the normative and strategic plans of the entire system. Hence, system 3 is the regulatory mechanism to successfully deploy the manufacturing strategy. Its functionality and stability mechanism for manufacturing improvement programs is described below.

Maintaining the internal stability is done by system 3 by interfering with the autonomy of system 1. System 3 can access system 1 either directly via the central control channel or indirectly through system 2 or system 3*. Thus, system 3 is responsible to gather appropriate information and assess the performance of the firm concerning the major goal that is the development of sustainable manufacturing capabilities. System 3 creates the internal stability by balancing manufacturing targets concerning the competitive priorities cost, quality, delivery, flexibility and/or additional priorities like innovation, environmental soundness and social solidarity according to the firm’s objective function. The manufacturing targets are passed through each system and recursion so as to alleviate oscillation during SMI conduction which can be seen as a failed manufacturing improvement program. The management of the manufacturing strategy as a function of system 3 decides upon the specification of the target system and passes them to the single SMIs. Each management of the SMI is then capable to adjust their operations in a manner that they define targets according to the entire spectrum of ongoing initiatives.

5.2. Design of operational strategic management

The four nodes P, Q, R and S of system 3 comprise the mechanism to operationally plan, manage and coordinate the diverse strategic actions initiated by the firm (Figure 5). The node complex Q-S receives information on the variations according to the planning of SMIs. Variations mean that not the project status or actual results are reported but deviations from the expected end status. Hence the complex Q-S can use this information to include it in the system 3 I/O-matrix and derive further actions. The complex Q-S checks whether the initiated projects deliver expected results. Based on pre-defined KPIs e.g. for energy efficiency improvement, the value and contribution of each initiative and improvement program is measured. Based on these measurements, actions can be threefold. SMIs can be abandoned, new SMIs can be initiated or the current SMIs can be changed in a way to fulfill the expected targets.

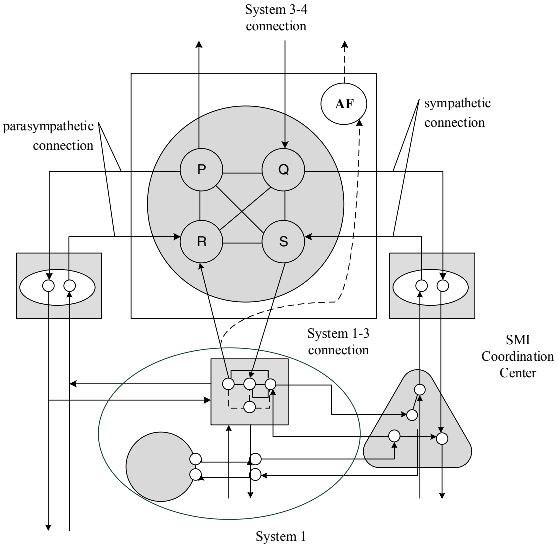


Figure 5: Organizational Management of Strategic Manufacturing Initiatives

While the complex Q-S handles more standard situation with little deviations, the parasympathetic connection is responsible for the highly volatile manufacturing improvement programs. The P-R complex and its associated regulators will directly interfere with the SMI management. E.g. the implementation of a SMI concerning energy-efficient production scheduling is performing in such a robust manner that gains are directly and fast achieved, thanks to the P-R complex the improvement program may be rolled out faster in other factories or production units. While these two mechanisms manage more the ongoing process and try to optimize it, the remaining to complexes R-S and P-Q have more tactical view on these issues. Complex P-Q integrates the information it has gained from the corporate strategy, other functional strategies and environment to contribute to the definition of the manufacturing strategy. The input here is the corporate social responsibility strategy, new legislations, environmental standards, technological advancements etc. The complex R-S on the other hand has the crucial task to define, implement and change all system 1 according to the designed manufacturing strategy. Here, the question which improvement programs should be tackled and how are they designed is answered. Complex R-S is capable of not only delegating the existing plan, but to capture ideas directly from the shop-floor and transmit them into the manufacturing strategy definition process if they seem appropriate.

6. Conclusion

The approach offers a valuable tool for decision-makers in defining and implementing their appropriate manufacturing strategy. It supports the analysis of spread production networks with different plant roles, and triggers a better understanding of how each plant role supports the strategy implementation. It is especially suited for internationally operating firms with more than one production center. A limitation of the approach is its complexity itself and the external validity. The Viable System Model is a quite complex tool which requires in-depth understanding to be used especially in time-constrained industrial environments. However, the application of the VSM to design world corporations like Henkel is a profound direction to improve manufacturing strategy implementation. Future research will focus on empirical efforts that are required to test and adapt the developed reference model.

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