High Resolution Supply Chain Management – Resolution of the polylemma of production by information transparency and organizational integration

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Abstract. High Resolution Supply Chain Management (HRSCM) aims to stop the trend of continuously increasing planning complexity. Today, companies in high-wage countries mostly strive for further optimization of their processes with sophisticated, capital-intensive planning approaches [3]. The capability to adapt flexibly to dynamically changing conditions is limited by the inflexible and centralized planning logic. Thus, flexibility is reached currently by expensive inventory stocks and overcapacities in order to cope with rescheduling of supply or delivery. HRSCM describes the establishment of a complete information transparency in supply chains with the goal of assuring the availability of goods through decentralized, self-optimizing control loops for Production Planning and Control (PPC). By this HRSCM pursues the idea of enabling organizational structures and processes to adapt to dynamic conditions. The basis for this new PPC Model are stable processes, consistent customer orientation, increased capacity flexibility and the understanding of production systems as viable, socio-technical systems [1, 2].

1 Introduction

Within today's manufacturing business the ability to produce individualized goods for a price close to a mass product is one of the key challenges to keep production in high-wage countries. Additionally companies have to be able to adapt themselves and their processes to dynamic environment conditions like shifts in customer's demand, reschedules in supply as well as turbulences in networks without loosing the high objective synchronization enabled by today's planning approaches. These two challenges constitute the polylemma of production, which's resolution is the goal of the German Cluster of Excellence on "Integrative Production Technology for High-Wage Countries" at Aachen University (RWTH) (www.production-research.de). "High Resolution Supply Chain Management" is part of this national initiative funded by the German Research Foundation (DFG).

"High Resolution Supply Chain Management" focuses to solve the dilemma between a high grade of adaptivity (value orientation) and a high objective synchronization (planning orientation). The final aim is to enable manufacturing companies to produce efficiently and be able to react to order-variations at any time, requiring process structures to be most flexible.

2 Methodological Approach

To achieve a higher flexibility and a better value-orientation of inter- and in-company PPC processes, it is necessary to replace the present static arrangement of the central-controlled processes [1, 2]. In consequence, self-controlled and self-optimizing supply chains based on decentralized production control mechanisms must replace the classic approach of PPC. Goal of the decentralized PPC is a higher robustness of the system by distributed handling of complexity and dynamics [6].

Technological Preconditions: The higher the knowledge about the facts, the more sophisticated decisions can be made. Thus, a higher information transparency on all levels of the PPC is a precondition for the implementation of a decentralized planning system. The information transparency enables decision makers or intelligent objects to act adequately. Advantages in miniaturization, sensor systems and communication technology enable the paradigm shift of centralized information handling to intelligent objects with mobile capabilities (cp. Fig. 1) [5].

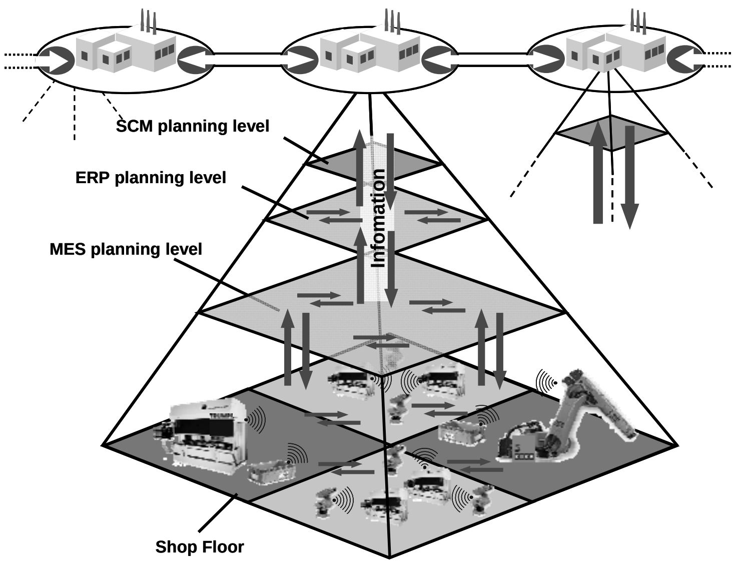

Fig. 1. HRSCM – Vertical and horizontal information transparency in production networks

Organisational Preconditions: Producing companies are complex organizational systems. They consist of sophisticated, technological subsystems, constitute a social structure with individuals having own values and goals, interact with a dynamic environment, and last but not least are adapting or are adapted.

HRSCM aims not only for the technological advantages in production systems, but chiefly for the efficient organization of production systems. In order to understand production systems as socio-technical systems methods of management cybernetic are used to establish a new model of the PPC widening the current perspective and leaving beaten tracks [7,10]. One of the most proven corporate-cybernetic approaches which orientates itself explicitly towards the living organism is the „Viable Systems Model" by Stafford Beer [2] (cp. Fig. 2).

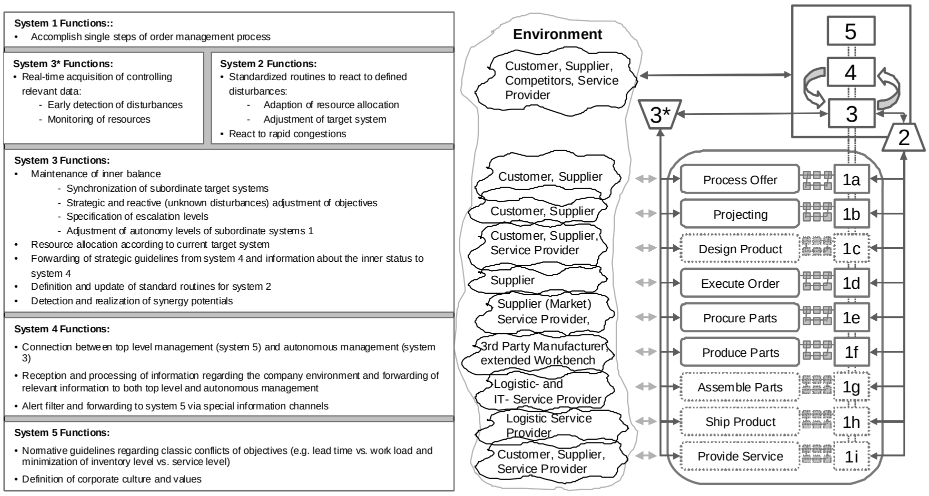

Fig. 2. The order management process as a socio-technological, viable production system

3 Findings

The Viable System Model (VSM) is conceived in analogy to the human nervous system which has proven its reliability due to the evolutionary process of billions of years to be the most reliably organized and most adaptable system. The VSM specifies the necessary and sufficient constraints for the viability of complex organizations. These constraints can be subsumed as completeness and recursivity of the system structure. This leads to the requirements of the basic model:

First, all specified managerial and operative functions must be present and networked in a way that every function has access to the necessary information. Second, every viable system has to be subsystem of a superior viable system and has subordinate viable subsystems itself. Preconditions for this recursive structure are integrated, synchronized target systems, which can be concretized top-down consistently.

The application of the VSM to the order process in manufacturing companies constitutes the structure of the reference model for a Viable Production System (VPS). The reference model is characterized by an explicit process orientation and comprises the whole order processing from the processing of an offer, over the PPC- control loop to the production and delivery of the final product [9]. Within this scope the model incorporates the organizational view and the process view in one holistic enterprise modeling method.

Figure 2 shows the top level of the reference model applied to the case of a project producer including exemplary tasks of the different systems. Together with the following explanations it outlines the general structure of the model:

Semi-autonomous operative units (systems 1) are embedded in a superordinate multi-level managerial structure. The operative units plan, carry out and control the assigned tasks based on a given target system and act autonomously within defined boundaries. In cases exceeding the usual grade of dynamics the coordinating system (system 2) is taking action. The central control system of the operative units (system 3) defines the objectives and boundaries of autonomy to obtain the maximal synergy between the assigned units. It is triggered by the coordinating system as well as the monitoring system (system 3*) and hierarchically superior systems. The duties of these superior systems deal with more strategic issues like the consideration of relevant future developments (system 4) and the definition of the general orientation of the overall target system. Systems 4 and 5 therefore determine requirements and target values for the operative management (systems 3, 3* and 2) as well as for the operative units (systems 1).

To be able to cover all different perspectives on the order processing the structural model is concretized in 4 separate views: The task view, the process view, the information view and the objective and control view. The task view describes the specific tasks of the different systems. In the process view the sequence of the single process steps to perform both operative and control tasks are defined. Within the information view the flow of information between the systems is characterized. The establishment and sustainment of the synchronized target system is outlined in the objective and control view. Thereby the first and fourth view define the information items and the control logic to be supported by a production management system, while the second and third view support management activities.

To get a more precise impression of the design of such a cybernetic based enterprise model, exemplarily the process and information view are concretized within a use case. Object of the described case is the process “Inventory Management” as a representative process to be performed and controlled within a semi-autonomous operative unit (system 1).

Ensuring the self-optimizing character of the operative units they are designed consisting of two elements: A process designed according to the logic of a control loop (cp. Fig. 3) is embedded in an organization for process control (cp. Fig. 4). The control loop character enables the process to cope with a certain level of dynamics by adapting the respective process parameters. In the case of consumption-driven inventory management the whole control loop consists of the three sub-loops forecasting, inventory control and procurement. The first control loop forecasting minimizes the forecasting error by an appropriate parameterization of the applied forecasting method. The highly accurate forecast enables the inventory control loop to determine a dynamic reorder level taking the replenishment time and the required internal service level into account. Initiated by an inventory level lower than the reorder level the optimal order quantity is calculated and compared to the economic order quantity. Based on this calculation the order is placed.

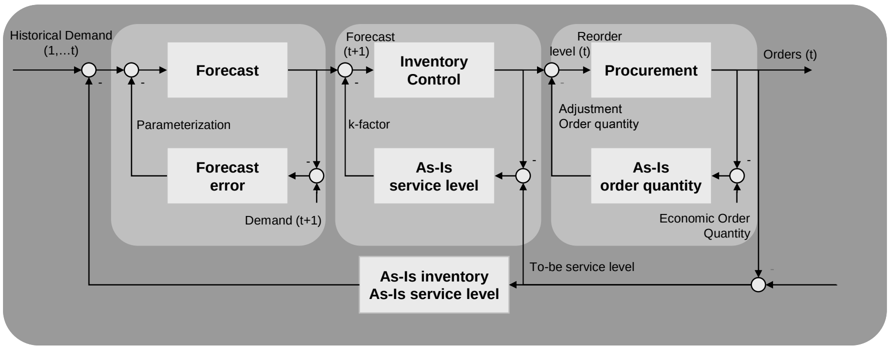

Fig. 3. Control loop for dynamic, consumption-driven inventory management

The process internal absorption of dynamics (e.g. variations of replenishment time or shifts in customers demand) avoids an overload within the organization of process control. In times of normal dynamics the organization of process control's activities can be limited to the calculation and monitoring of performance indicators, the supply of the process with the relevant information as well as forwarding of performance information to other processes (cp. Fig. 5). Thus a cross-process transparency is assured and the process owner (e.g. material planner) is able to focus on critical products which are for example subject to a high level of dynamics.

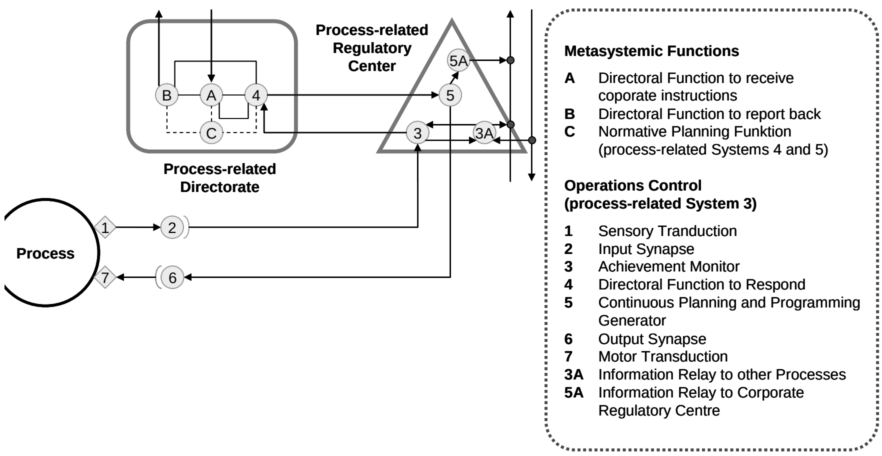

Fig. 4. Organization of process control

In those cases when the level of dynamics is exceeding the absorption capability of the process, the organizational process control detects deviations between the performance indicators and the target values. As a consequence countermeasures like an external adjustment of the process are necessary. This could mean the adjustment of one or more process parameters or even the necessity to reconfigure the whole process. Concerning the case of inventory management this dynamics could be caused for example by a planned marketing action.

Figure 5 subsumes on a general and exemplarily concretized level the flow of information which is necessary to assure the required transparency and enable the self-optimization within the target system.

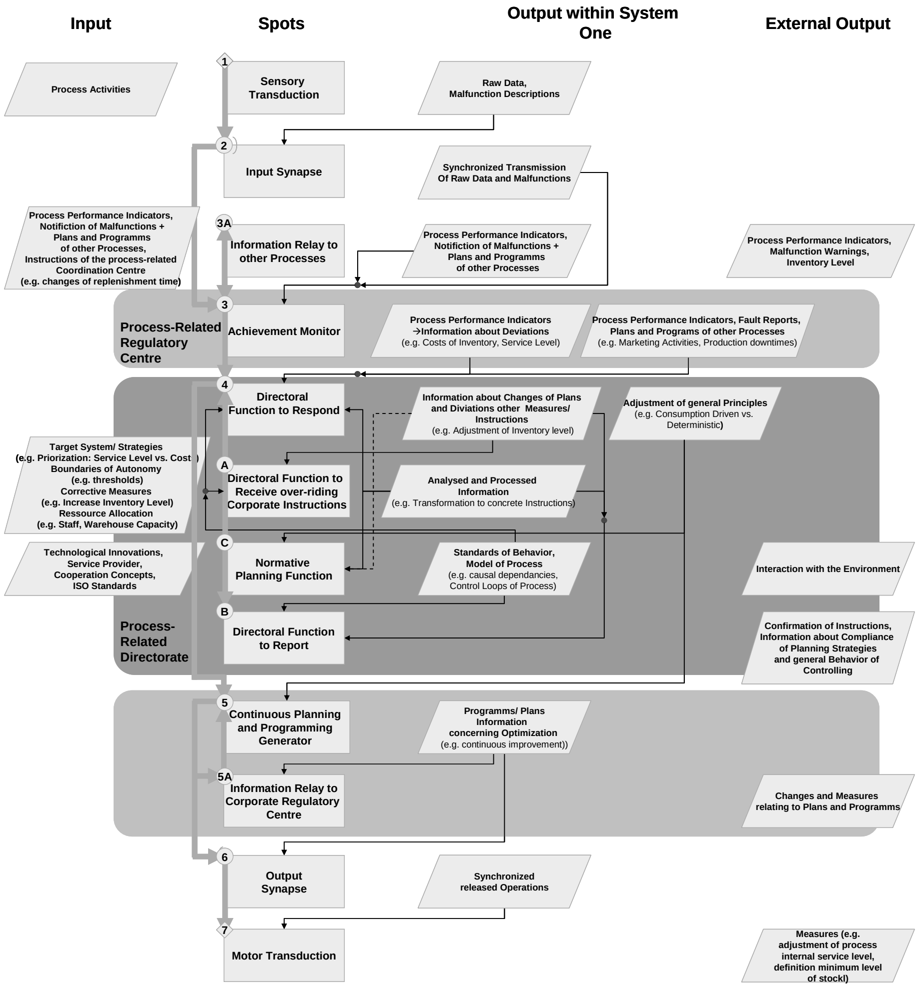

Fig. 5. Information flow within the organization of process control

4 Findings and Practical Implications

In order to assure the practical relevance of HRSCM several industry workshops have been accomplished. Within these workshops branch-specific problems have been derived and are further analyzed within use cases. These use cases as well as best practices of the participating companies are incorporated in the HRSCM approach [8]. As one example implications for the process and process control of inventory management have been derived by applying the reference model for a Viable Production System. Configuring the process and its control according to the principles of the reference model leads to a better handling of dynamics and thereby higher process stability and efficiency. Furthermore the definition of escalation levels stops the continuous firefighting of the organization of process control. In practice the process owner e.g. material planner is enabled to use the saved time to deal with critical issues and the continuous improvement of the operative unit. The establishment of the flow of relevant information between the processes improves the planning quality and enables process control to take anticipatory measures.

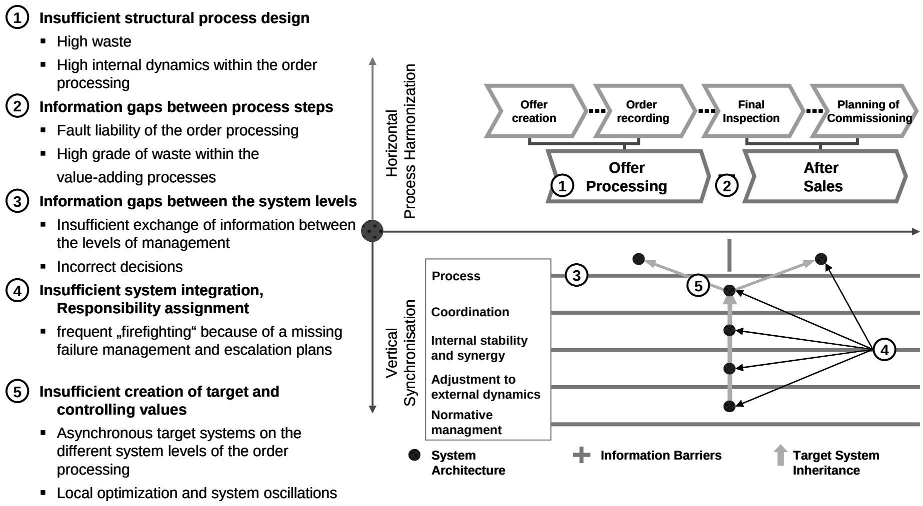

Fig. 6. Solution competences of the reference model for a Viable Production System

Figure 6 systematizes the solution competences of the reference model for a Viable Production System to horizontal process harmonization and vertical synchronization. Widely spread practical problems are related to these two dimensions and thus can be solved by benchmarking with the proposed reference model. While the horizontal process harmonization is mainly enabled by adaptive processes and cross-process information transparency, the key factors to improve the vertical synchronization are synchronized target systems. A methodology to synchronise target systems in decentralised organizations is currently being developed as the next steps towards the viable production system.

5 Conclusion

In this paper the application of Stafford Beer's Viable System Model (VSM) on the order process has been discussed as a holistic regulation framework for production systems. The technological and organizational preconditions as well as the general structure of such a cybernetic based production management model have been described. Within a practical use case a self-optimizing control unit based on information transparency, escalation levels and adaptive processes has been implemented. The resulting benefits are an increased level of adaptability and stability leading to a higher efficiency of the process. The establishment of a synchronized target system over the whole order processing avoids the nullification of these effects on both horizontal and vertical level. Thus it can be stated that the application of HRSCM will contribute to the resolution of the polylemma of production by reducing the dilemma between planning and value orientation. Thereby high-wage countries will be supported in keeping a competitive edge.

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