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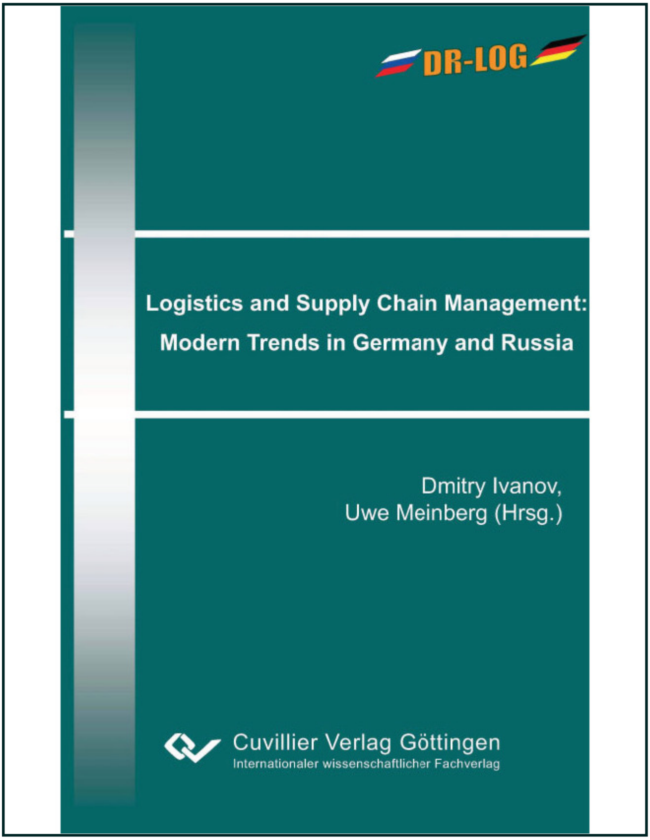
Logistics and Supply Chain Management: Modern Trends in Germany and Russia



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UP-TO-DATE CHALLENGES IN SUPPLY CHAIN (RE)-PLANNING AND POSSIBLE APPROACHES

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Abstract. Responsiveness, agility, and flexibility shape enterprise competitiveness and demand a comprehensive value chain management. The recent crashes in financial markets, disruptions in global supply chains like gas supply, terrorist attacks, piracy, and numerous natural disasters as well as considerable misbalancing demand and supply in value adding chains through increased complexity and uncertainty in supply chains themselves provide evidence that the efficiency of supply chains depends not (only) on ideal optimal processes with maximal profitability but adaptable, stable, and crisis-resistant processes to compete in real perturbed execution environment. In this paper, the most important challenges in supply chain (re)planning are highlighted and possible methods to approach practice-relevant solutions are proposed.

1. INTRODUCTION

Planning, in the broad sense, is a purposeful, organized, and continuous process including synthesis of SCs structures and elements, analysis of their current state and interaction, forecasting of their development for some period, forming of mission-oriented programs and schedules, and development of SC structure-dynamics control programs for SC (SC) transition to a required (optimal) structural macro-state. The main requirements to a plan are as follows:

- Goal-approachability (the plan should ensure the fulfilment of set goals),
- Analysability (the plan execution should be subject to comprehensive analysis),
- Controllability (the plan execution should be subject to control),
- Adaptability (the plan should be able to be adapted in the planned and unplanned modes),
- Synchronisability (the plan should be coordinated in the horizontal mode under the SC partners and in the hierarchical mode with the plans of superordinated and underordinated levels).

SC planning is composed of setting management goals and defining measures to their achievement (Kreipl and Pinedo 2004). On the basis of the goals of the superordinated level of a SC, plans of a current level are formed. E.g., strategic goals can be referred to service level and costs. The measures are in this case plans of customers' orders

realization that in turn are realized on the basis of scheduled operations. Planning approaches can be distinguished into incremental planning that concentrates on situation predictions in terms of mathematical models, satisfactory (formal) planning that considers SC reaction to external impacts, and adaptive planning that supports SC interaction with the environment. Planning decisions in SCM can be divided into strategic (SC design), tactics (planning), and operations.
In this paper, the most important challenges in SC (re)planning are highlighted and possible methods to approach practice-relevant solutions to these challenges are proposed.

2. CHALLENGES IN SC (RE)-PLANNING

2.1. Potential SC efficiency is realized through SC stability

During the last years, research into global production and logistics system have been concentrated on the creation of executable predictive baseline (optimal) plans, however not assuming that during execution, a plan may be subject to numerous unplanned disruptions. After a long-lasting research into optimal SCM, the research community begins to shift to a paradigm, that the efficiency of SCs is to consider with regard to adaptable, stable, and crisis-resistant processes to compete in real perturbed execution environment (Sheffy 2005; Kleindorfer and Saad 2005; Van de Vonder et al. 2007).
Achievement of planned (potential) SC goals can be inhabited by perturbation impacts and crises in a real execution environment. The real SC efficiency is based on a maintaining planed execution and a quick cost-efficient recovering once being disturbed. The profit losses through non-purposeful (e.g., demand fluctuations) and purposeful (e.g., terrorism or thefts) perturbation impacts can amount up to 30% of the annual turnover. For example, in 2000 the material damage to the European retail trade amounted to 13,4 billion euro, and the material damage to the European manufacturers reached 4,6 billion euro. With regard to empirical data of international insurance, companies loose up to 15% of the turnover only by threats. The discrepancies between demand and supply caused by coordination failures or demand fluctuations can influence up to 30% of added value. That is why the issue of composite objective of *maximizing both the SC stability and the SC efficiency can be considered as a timely and crucial topic in modern SC management*

2.2. Dynamics and uncertainty

Traditionally, improvements for SC planning and scheduling have been algorithmic (Kreipl and Pinedo 2004). However, in recent years, the works on SC management have been broadened to cover the whole SC dynamics. Actually, the most important shortcoming of the conventional modelling techniques for the SC practice is that the planning is mostly concentrated on the creation of executable predictive baseline (optimal) plans, however not assuming that during execution, a plan may be subject to numerous schedule disruptions.
The wide-broaden techniques mostly support the incremental planning that does not include dynamic feedbacks. Such an approach can be justified for such problems to those a single plan computation should be fulfilled. These problems may be either of a

very strategic nature or very operative nature. In the most tactical-operational problems that refer to SCs dynamics to be under control, the gathering current information about the SC execution and adapting SC operations, plans, and configurations as well as the updating related models is mandatory. Planning in SC environment should be considered not a static jobs appointment to machines but as dynamic planning in accordance with current demand fluctuations and resource availability (Proth, 2006).

In the most tactical-operational problems that refer to SCs dynamic to be under control, the negative feedback is mandatory. Although the feedbacks have been also extensively investigated in the systems dynamics, these models have been successfully applied only for strategic issues of network configuration and showed many limitations with regard to the tactical and operation control levels.

With regard to these two levels, the recent literature indicates an increasing renewed interest to theoretical background of control theory (Disney *et al.,* 2006; Ivanov *et al.,* 2007; Ivanov *et al.,* 2009; van Houtum *et al.,* 2008, Wang et al., 2008). The control theory is multi-disciplinary scientific discipline that contains powerful conceptual and constructive tools to conduct research into dynamic problems of flexible (re)distribution of a variable set of jobs to a variable set of resources. The closed-loop control systems are of a particular interest in these settings.

2.3. Interrelations and optimality of decisions at different management levels

Conventionally the planning decisions at different management levels have been considered as to be isolated from the other levels. In practice, the interrelation of these three management levels is very important. Not only a problem solution in a fixed environment (system under control) but also a simultaneous consideration of system formation and management problems solution in this system should be in focus of investigations. This aspect is of a significant practical importance.

This is the problem of compatibility of decision theory and managerial tendencies as highlighted by Peck (2007) and more recently by (Riddel and Webber 1973) in the "Dilemmas in a General Theory of Planning". Scientists and engineers commonly deal with clear identifiable problems with a known desirable outcome. Such problem localizations lead to unrealistic simplifications and the connection of the model to reality fails. Real problem are different and involve multiple decision makers, different interests and value-sets (e.g. individual risk perception). Hence, a danger that an optimal solution may negative influence the processes of another management level or structure is evident. This evidence challenge the supply chain models to provide not (only) an output value but a number of alternative solutions with respect to diverse management styles. The other challenge is to conduct research not only in artificial localized problems (actually, this is an engineering task), but to consider the modelling level with a higher degree of abstraction and to develop generic methodical constructs, that can be localized in concrete environments with the help of methodical guidelines.

Let us provide a short example. In practice, the challenge is not to calculate optimal schedules to optimize local order fulfilment parameters but to schedule SCs subject to achievement of SC goals with regard to efficiency, service level and stability. That is why the efforts should not (only) be directed to improve algorithms for a benchmarling problem (e.g., 5x5) with regard to their speed, but to schedule SCs in dynamics with regard to the goals of a superordinated planning level (e.g., service level). To achieve this, this can be necessary to employ more resources or to plan less customers' orders, so the problem may i.e. look like 4x7.

2.4. Supply chains as multi-structural systems

Decisions on SC strategy, design, planning, and operations are interlinked and dispersed over different SC structures (functional, organizational, informational, technological, and financial). The efficiency and applicability of the decisions decrease if decision-supporting models are considered in isolation for different SC managerial levels and structures (Ivanov et al., 2009a).

Furthermore, the SC execution is accomplished by permanent changes of internal network properties and external environment. In practice, structure dynamics is frequently en-countered. Decisions in all the structures are interrelated. Changes in one structure affect the other structures. Furthermore, the structures and decisions on different stages of SC execution change in dynamics. Output results of one operation are interlinked with other operations (the output of one model is at the same time the input of another model). This necessitates structure dynamics considerations. In the case of disruptions, changes in one structure will cause changes in other relevant structures. Structure dynamics considerations may allow establishing feedback between SC design and operations.

2.5. Supply chain complexity

The *first group* of complexity factors is related to structural complexity. This consists of a number of elements in a system and a number of interrelations between these elements. Moreover, the variety of the elements and the interrelations is under consideration. The *second group* of complexity factors is related to functional complexity. This includes dynamics of the change of the elements, their variety, and interrelations between the elements. Another aspect is the consideration of system complexity at certain instants of time. A system can be composed of a great number and variety of the elements and interrelations, but in a snap-shot at an instant of time, the system may appear as very simple. Last but not least point in the functional complexity is the uncertainty of the change of the elements, their variety, and interrelations between the elements. This point is one of the most critical while considering system complexity.

The *third group* of complexity factors is related to modelling complexity. The problems in systems are tightly interrelated. Different methods and data are needed for solving different tasks. Let us consider an example. In SCs, the concurrent open shop problems are encountered the most frequently. It is well-known that the most scheduling problems of this class are NP-hard due to high dimensionality. That is why heuristics (e.g., genetic algorithms) are usually applied instead of optimization. They don not guarantee the optimal solution but allow finding a permissible result within an acceptable period of time. The quality of this solution with regard to the potential optimum, however, remains unknown. Secondly, the multiple criteria problems are still a "bottleneck" of the heuristics. The problem dimensionality remains to be a great inhibition in application operations research techniques for real-world problems. Hence, other techniques like dynamic systems should be frequently applied.

Complexity management can be considered as a theoretical basis for handling uncertainty in SCs. From the perspective of the complexity management the problem of a system under control and uncertainty is related to an area under control and an area under uncertainty. By broadening the control area and narrowing the uncertainty area, the system control can be adapted. This idea is based on the Achby's principle of requisite variety.

2.6. Multi-disciplinary research into SC management

Supply chains are characterized by a great number and variety of elements and interrelations between them. Moreover, decisions in SCs are dispersed over different structures and management levels. The SC structures change in dynamics, so the structure dynamics is frequently encountered.

The SC dynamics is characterized by a high uncertainty due to numerous subjective and objective, internal and external factors. Moreover, elements in supply chain are active. This means, they act self-goal-oriented, autonomous but collaborative, and may join or exit the SC on their own free-will. Hence, SCs may be justifiably named as *complex dynamic multi-structural systems with active elements of free-will behaviour.* Research into such systems requires application of different methods and disciplines.

The necessity of the SC multi-disciplinary treatment is caused by a complex composition and tight interlinking of different SC problems, which exist in different structures and change in their dynamics. (Beamon, 1998) emphasized that value chain systems are inherently complex. Thus, the models and methods used to study these systems accurately are, expectedly, also complex.

Cross-linked SC planning and operations control problems require combined application of various modeling techniques (optimization, statistics, heuristics, and simulation). At different stages of the SC life cycle, a particular problem can be solved by means of different modelling techniques due to changeability of data nature, structure, and values, as well as requirements for output representation. Selection of a solution method depends on data full-ness, problem scale, one or multiple criteria, requirements on output representation, and inter-connection of a problem with other problems.

Different approaches from the operations research, control theory, and agent-based modelling have a certain application area and a certain solution procedure. Isolated application of only one solution method leads to a narrowing in problem formulation, overdue constraints and sometimes unrealistic or impracticable goals. Actually, the research into SC as complex systems should impart much more universality than is really considered in today's social and business systems. Usually, investigations in complex system are performed by means of combined application of different methods and involve specialists in economy, mathematics, and computer technologies.

3. ELABORATED APPROACHES

3.1. STREAM – Stability-based Realisation of Efficiency and Management

The concept STREAM, as the name implies, is based on the idea that SC potential efficiency will be realized trough the SC stability. The basic idea of the developed framework is to reveal the fundamental properties of SCs concerning the mutual influence of perturbation and control (adjustment) impacts, interrelations between these properties and various kinds of positive and negative influences, and also working out on the basis of these interrelations a comprehensive concept to support decision making under uncertainty in SCM domain. We conceptualized the subject domain of SCM under uncertainty from uniform system-cybernetic and SC management points of view. The business and formal SC properties of SC reliability, flexibility, security, vulnerability, BIBO-stability, resilience, robustness, and adaptability have been brought in correspondence with each other to cover the domain of SC planning and control under uncertainty and dynamics. The findings suggest that stability can be seen as fundamental system property as balancing perturbation and control actions in SCs to maintain SC economical efficiency.

3.2. Generic framework for SC adaptive planning and control

The elaborated adaptive planning and control approach is based on combination of the model predictive control and adaptive control frameworks as well as of control theory and operations research.

The main purpose of the adaptation framework is to ensure a dynamic planning model parameters tuning with regard to changes in the execution environment. In the proposed framework, plan adaptation is connected to the model adaptation. The parametric adaptation is enhanced by a structural adaptation.

We took as a basis the adaptive planning in which the SC plan is modified periodically by a change of SC parameters or characteristics of control influences on the basis of information feedback about a current SC state, the past and the updated forecasts of the future (Skurihin et al., 1989). For the forecasts updating the model predictive control techniques has been used; the adaptive control application has been extended from the signal identification to the whole complex systems dynamics with the help of structure dynamics control theory.

In Figure 1, the general conceptual framework of the adaptive planning and scheduling is presented. By designing the controller, the delays between the deviations identification and adjustment decision making are handled within the structure dynamics control approach and a combined people-machine adjustment system for the SC adaptation in case of different disruptions is used. To different deviations in sup-ply chain execution, a hierarchy of adjustment actions is brought in correspondence. As such, the controller serves both for the deviations identification and the adjustment measures generation taking into account the distributed system nature and managerial decisions delays. Besides, this allows to transit from continuous control models that are characterized for the process industry and to apply the adaptive planning and control to many other branches with discrete operations.

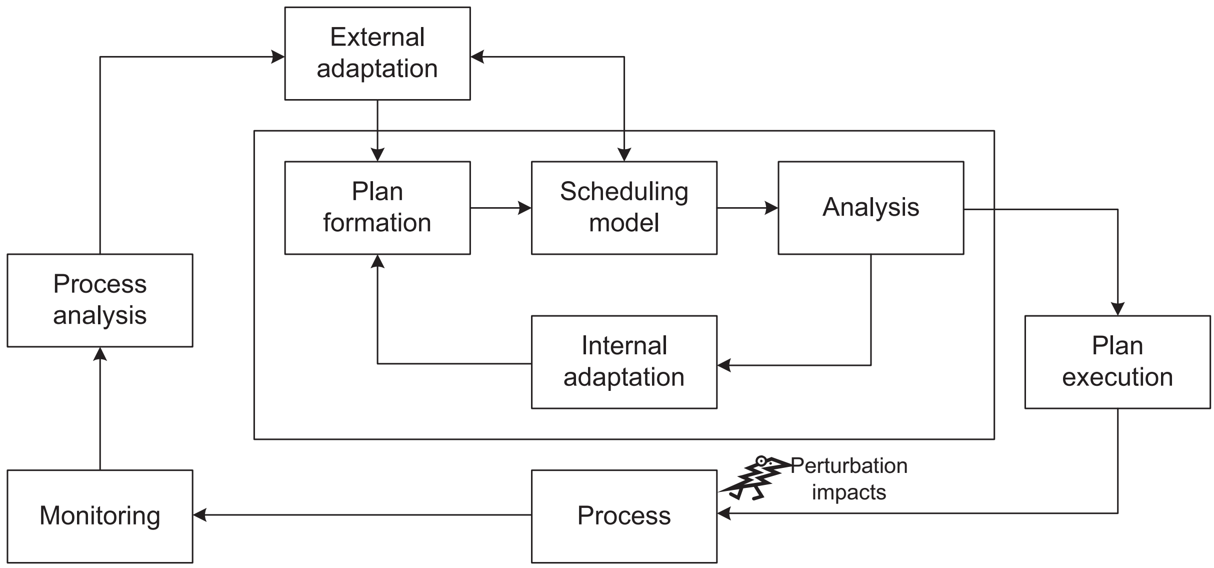

Figure 1. General conceptual framework of the SC adaptive planning and control

We interpreted planning and scheduling not as discrete operations, but as continuous adaptive process. In the adaptation framework, we interpreted SC functioning as a SC operations dynamics. Plan adaptation is connected to the model adaptation. A particular feature of the model is that not only control u but also a number of conjunctive variables can be adapted to a current execution environment.

The explicit integration of the external and internal adaptation control loops and the operations dynamics model makes it possible to integrate the monitoring and control models and to connect the measured and controlled parameters explicitly. In integrating monitoring and control models, the rational extraction of only current necessary execution parameters for monitoring and control from the whole high-dimensional parameters' vector becomes possible.

Another result of the integration of the adaptation control loops and the operations dynamics model is that the parameters of the SC execution and operations dynamics model can be tuned simultaneously. This so called dual control makes it possible both to fulfil SC mission (goals set by management) and to construct an adequate model of SC dynamics control.

The proposed approach provides the possibility to cover the whole SC dynamics and the permanent changes in SC processes and environment without the strong necessity to accomplish the total "re-modelling". In these settings, the integration of planning and scheduling stages is possible. This means that not only a problem solution in a fixed environment (system under control) but also a simultaneous consideration of system formation and management problems solution in this system is possible. Hence, the goal-oriented formation of SC structures and solution of problems in this system are considered as a whole.

The process control model is presented as a dynamic linear system while the non-linearity and non-stationary is transferred to the model constraints. This allows to ensure convexity and to use the interval constraints. As such, the constructive possibility of discrete problem solving in a continuous manner occurs. The modeling procedure is based on an essential reduction of a problem dimensionality that under solution at each

instant of time due to connectivity decreases. The problem under solution can be presented with a polynomial complexity rather then with the exponential one. This results in the possibility of solving high-dimensional NP-problems in a dynamic manner.
The Pareto-optimality based multiple criteria problem formulation allows taking into account individual managers' preferences, SC strategies, etc. The model is scaleable to other management levels of SCs. I.e., orders and operations can be presented as SC configuration elements and orders correspondingly. The transformation of parameters and goal criteria is also possible. I.e., the lead-time can be considered as the SC cycle time. Hence the SC strategic configuration and tactical planning can be optimized.

3.3. Multi-structural framework of SC management

In SCs, different structures (functional, organizational, informational, financial etc.) are (re)formed. These structures interrelate with each other and change in dynamics. Some examples of the structural interrelations follow. Business processes are designed in accordance with SC goals and are executed by organizational units. These units fulfil management operations and use certain technical facilities and information systems for planning and coordination. Business processes are supported by information systems. Organizational units have a geographical (topological) distribution that also may affect the planning decisions. Collaboration and trust (the so-called "soft facts") in the organizational structure do affect other structures, especially the functional and informational structures. Managerial, business processes (distribution, production, replenishment etc.), technical and technological activities incur SC costs, which also correspond to different SC structures. So the SC can be interpreted as a complex multi-structural system. The paper (Ivanov et al. 2009) introduced a new conceptual framework for multi-structural planning and operations of adaptive SCs with structure dynamics considerations. SCM is addressed from perspectives of execution dynamics under uncertainty. Supply chains are modelled in terms of dynamic multi-structural macro-states, based on simultaneous consideration of the management as a function of both states and structures. The research approach is theoretically based on the combined application of control theory, operations research, and agent-based modelling.

3.4. Multi-disciplinary framework of SC modeling

The basics of the SC multi-disciplinary treatment were developed in the DIMA (Decentralized Integrated Modeling Approach) methodology (Ivanov, 2009; Ivanov, 2006) to contribute to comprehensive SC modelling and to establish foundations for SCM theory as called for by an increasing number of researchers. The main principles of the DIMA are as follows. These principles take into account the sup-ply chain elements' activity, multiple modelling, integration, and decentralization. We are the first to consider agents as part of the generic model constructions (Ivanov et al. 2007). The agents are expressed as conceptual modelling entities or active modelling objects. They belong to multidisciplinary complex of models used not only at the simulation stage, but also at the levels of conceptual modelling, formalization, and mathematical modelling.
Integration is considered from four perspectives: the integration of various modelling approaches and frameworks, the integration of planning and execution models, the

integration of decision-making levels, and the implementation of integration throughout: “conceptual model - mathematical model – computation algorithm”.
Decentralization in the DIMA methodology considers the main principle of management and decision making in SC. This means that all the models contain elements of decentralized decision making and SC elements’ activity. Decisions about SC management are not established and optimized “from above” but are a product of iterative coordinating activities of the enterprises (agents) in a SC and a SC coordinator.
In the DIMA methodology, it is understood under multiple modelling that various modelling approaches like control theory, operations research, agent-based modelling, fuzzy logic, and the psychology of decision making are not isolated, but are considered as a united modelling framework. Integration and combined application of various models is implemented by means of multiple-model complexes (Ivanov et al., 2007; Ivanov, 2009), which are based on the application of functors (Okhtilev e tal. 2006; Sokolov and Yusupov, 2004).

4. TOOLS

4.1. Vision of an integrated experimental environment

For experiments, we elaborated a software environment that is composed of two main software prototypes: SNDC – Supply Network Dynamics Control and SCPSA – Supply Chain Planning and Stability Analysis. Besides, simulation tool AnyLogic and tool Extended Value Chain Management (EVCM) have been used for experiments. Based on these partial components, a vision a special software environment, which contains a simulation and optimization “engine” of ASC planning, a Web platform, an ERP system, and a SC monitor can be presented (s. Figure 2).

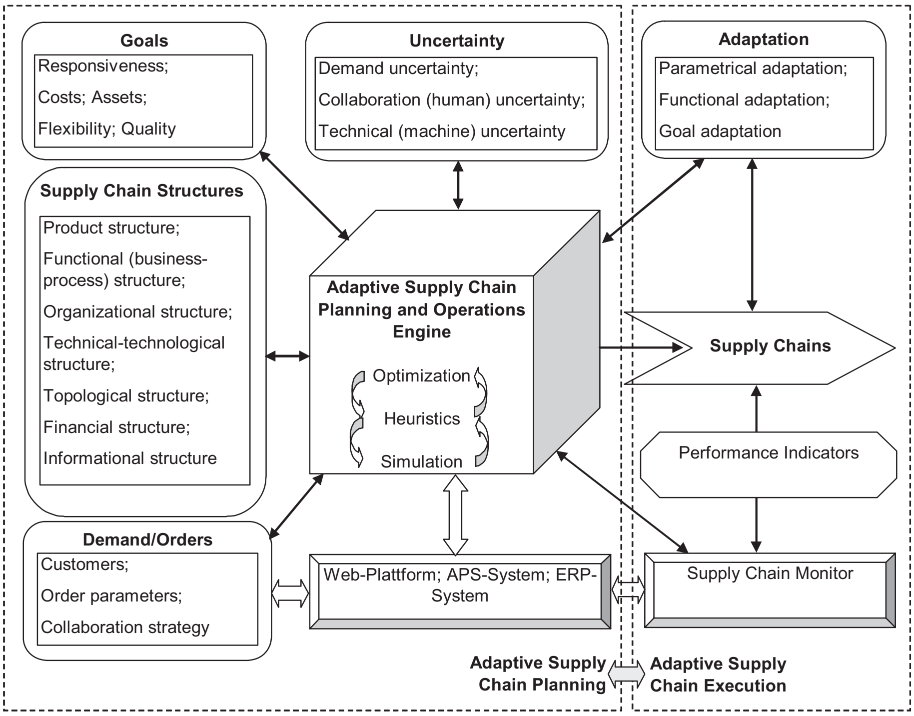

Fig. 2. The vision of software environment for adaptive SC planning and control (Ivanov et al. 2009a)