Adaptive Management of Supply Chain Consortia

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ABSTRACT

Purpose of this paper

In this paper, we present the adaptive supply chain consortium as an innovative approach to manage the process of inter-organizational order fulfilment embedded in a volatile environment. We suggest adapting the contribution of each partner to the fulfilment of orders reactively and with respect to the currently observed performance of the order fulfilment processes.

Design/methodology/approach

First, we analyse conceptual weaknesses of existing forms of supply chain consortia. Special attention is paid to the decision process required to allocate the resources of the consortium partners for customer demands. Then, we propose a framework for decision support systems that exploit the innovative idea to adapt the partner's contribution to the current process quality. Simulation experiments are carried out in order to demonstrate the general applicability of the proposed ideas.

Findings

The analysis of the simulation results reveals that the application of the suggested adaptive consortium management concept can be beneficial in volatile environments. It turns out that the application of the proposed management concept causes additional costs but improves the process timeliness and quality significantly.

What is original/value of paper

The major innovation of this paper is the integration of concepts from the organization of supply chain consortia and of concepts from process planning in order to overcome major weaknesses of existing paradigms to manage value creation processes in volatile environments. Furthermore, we are able to proof the applicability of the concept in simulation experiments by evaluating the numerical simulation results.

Keywords: Supply Chain, Consortium, Deployment, Processes, Governance, Adaptive Control

INTRODUCTION

The supply chains of today's flat world (Friedmann, 2005) are the result of an international division of labor where the supply chain members specialize in the provision of particular services and outputs and are able to exploit economies of scale. A drastic reduction of the width of market opportunity windows (Stock *et al.*, 2000) the pressure for continuously re-improving products and services (Ballou and Gilbert, 2000) and all the time more forcing requirement to gain increasing profitability (Lambert and Cooper, 2000) drives the joint-value creation in supply chains. In case that the partnership is only set up to facilitate the realization of such a clearly defined value creation project, the group of independent partners is called consortium (Thommen, 1991). When it comes to the management of such a value creation chain, the organization form consortium becomes a supply chain consortium (Patterson *et al.*, 1999), supply networks or supply chain network (Wathne and Heide, 2004). In the following, we are going to use the term supply consortium as synonym for a formation of partners running a value creation project.

Conventional supply chain literature assumes thereby that the intra- and inter-company integration and management of supply chain processes is a stable process over a long period of time (see e.g. Skjøtt-Larsen et al. 2007). In such settings, where the collaborating partners maintain their legal and economic autonomy, contracts are agreed between the partners. These contracts determine the contribution of the partners to the desired value creation but also fix the decision rights of each partner in the operational process planning. During operations planning unexpected events occur that have not been foreseen at the contract agreement time. Often, unexpected scarceness of resources results from such an event (e.g. load peak, resource unavailability, ...). A certain partner who detects scarceness is alerted because it hinders operations as expected to be generated as well as threatens the own objectives. Consequently, the organization will adjust its behavior in order to protect its own benefit. A consortium member who has the overview of the overall available resources in a consortium (we call such a member the "coordinator of the consortium") would be able to compensate the local scarceness by shifting tasks temporarily from the affected partner to another partner securing the process reliability of the overall consortium. However, it is necessary that the coordinator gets the extraordinary right to intervene, to select, and to shift adequate tasks. It has to be determined in advance (in the consortium contracts) under which circumstances a coordinator intervention is done and how the intervention looks like. Within this article, we analyze the impacts of temporal coordinator interventions. Although coordinator interventions are proposed in the scientific literature (Bitran et al., 2006) there is no work that investigates realizations of the interventions in the operational process planning context. This article aims at contributing to close this research gap.

Adaptivity refers to the ability of a system (e.g. a supply chain consortium) to adjust itself to a varied challenge (after the introduction of a threatening event) by reacting on feedback information. In this article we investigate the adaptivity of a supply chain consortium with respect to the decision competence distribution in a supply chain consortium. The actually observed process quality (e.g. timeliness) is used as feedback information. We assume that during a crisis situation, which threatens the overall consortium, it is useful to shift decision responsibilities towards dedicated partners in a consortium. Thereby, it is intended to consolidate knowledge and coordinate decision making in order to remedy the threatening situation (e.g. to manage workload peaks) as quickly and efficiently as possible.

How does such an adaptation of the decision making process looks in an organizational supply chain arrangement keeping in mind the challenges of hidden intentions and activities of partners? This is the question that we are going to examine in this paper. Furthermore we are interested to find out how a short-term adaptation of the allocation of decision competence can be realized. For this purpose we assume that temporary interventions of a well-informed consortium coordinator into the process planning of another consortium member contribute to the reduction of the severity of impacts caused by spontaneous disturbances of the process environment. In order to prove or disprove our assumption we setup a computational simulation experiment in which we mimic coordinator interventions. We start with a survey and structuring of the decision tasks whose solving is necessary to execute an instance of a process (Section 1). Next, a discussion of the operational decision tasks in a consortium is given (Section 2). Then, we consolidate paradigms found in the scientific literature that determines a static assignment of decision competencies to the consortium partners (Section 3). We demonstrate that the static, unchangeable distribution of decision rights is suboptimal in crisis situations that endanger the consortium's performance and we propose an adaptive re-adjustment of the decision competence distribution (Section 4).

1 PROCESSES IN A SUPPLY CHAIN

We start our research report with a summary about the organization and derivation of supply chain processes (Subsection 1.1). Then, we work out the elementary decision tasks whose solving is necessary in order to run value creating processes. Some specific challenges that have to be overcome in the supply chain process planning are discussed (Subsection 1.2).

1.1 Planning the Execution of Process Instances

In a typical supply chain consortium setting, plants, warehouses, transshipment or selling facilities of different partners are involved in the physical flow of a specific product through several value creation stages. In order to bridge the spatial distances between subsequent locations in the process of guiding products physically through the supply chain stages, extensive transportation of raw-materials, semi-finished and finished goods is performed. Furthermore, storage activities are carried out in order to ensure a permanent covering of demand at intermediate value creation stages.

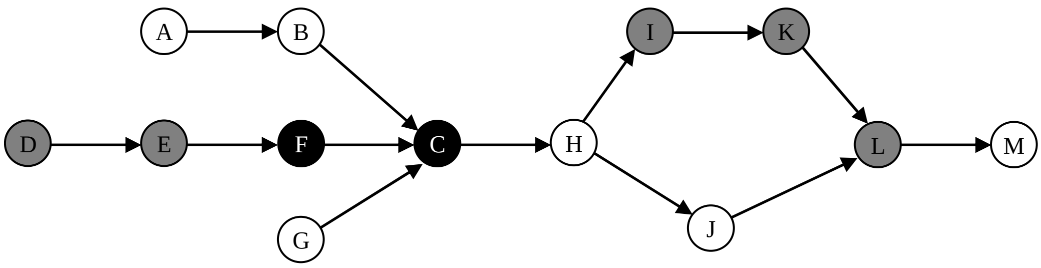

Fig. 1.1: Supply process (the activity color indicates the responsible consortium member)

A process is a well-specified sequence of concatenated and interdependent activities that must be fulfilled in a given logical succession in order to achieve a certain value creation output.

Fig. 1.1 exhibits an example process including 13 activities A, B, ..., M. The arcs in the network structure represent logical precedence constraints. An activity can only be started if its predecessor(s) is (are) finished. Some activities (represented by the nodes in the network structure) can be started simultaneously (A, D and G) while others require the completion of several upstream activities (C) or triggers more than one downstream activities (H).

As mentioned before a supply chain consortium is understood as a group of independent partners who set up a partnership for managing a specific collaborative value creation system by executing instances of a value creation process. The arrival of specific customer demand triggers a supply chain consortium to start a new process instance. A process instance can be understood as a copy of the process that is adjusted to the requirements and needs originating from a specific customer demand. A similar demand specified by different customers or the same customer at a different time point might lead to different environmental states in which an instance of the same process is faced with quite different challenges and requisites. Thus, a process is a rough description of the general value creation steps to be taken for realizing a required output. For each instance of a process, a context-sensitive process calibration must be carried out in order to prepare the successful execution of the customer-demand-specific process instance. Each consortium partner is thereby contributing with its knowledge and experience and also provides capacities of its resources to ensure the physical flow of material through the value creation stages.

The necessary decisions which need to be taken in order to prepare and start a process instance by the supply consortium can be classified according to the following three classes of (decision) tasks:

- **Network Capacity Disposition.** The customer demand is split into several supply consortium orders. Such an order comprises the execution of one or more activities in the selected process. The supply consortium orders are afterwards distributed among the consortium partners and each partner overtakes the responsibility for the correct and well-timed fulfillment of the received orders (Fu-Ren and Shaw, 1998). In the example process shown in Fig. 1.1 the activities (represented by the labeled nodes) are distributed to supply consortium partners according to the color of the activities. It is agreed that the white consortium member overtakes the responsibility for the execution of all white-colored activities, all gray activities have to be fulfilled by the gray partner and all black activities are taken over by a third partner (the black one).
- **Resource Dispatching.** Each supply chain consortium partner acts as a service providing agent which receives supply consortium orders for fulfillment. In the example introduced in Fig. 1.1, the ‘black’ agent is responsible for the fulfillment of the supply consortium orders C and F. Each order comprises several indivisible tasks to be fulfilled in order to contribute to the total fulfillment of the corresponding supply consortium order. We assume that order C comprises the three tasks $T_{C,1}$, $T_{C,2}$ as well as $T_{C,3}$ and we assume that order F consists of the three tasks $T_{F,1}$, $T_{F,2}$ and $T_{F,3}$. Tasks from different orders are re-grouped and compiled in requests that can be fulfilled by a certain resource belonging to the service agent (Schotzko and Hinson, 2000). For example, the requests $r_1:=\{T_{C,1}\}$, $r_2:=\{T_{C,2}, T_{F,1}\}$, $r_3:=\{T_{C,3},T_{F,2}\}$ and $r_4:=\{T_{F,3}\}$ are derived from the supply consortium orders C and F. Each request is assigned to an appropriate resource for fulfillment. This resource is used to fulfill the forwarded request(s). If the two requests r_1 and r_2 are transportation requests then they are assigned to an appropriate truck. In case that the remaining requests contain production tasks they are assigned to machines. The provision of resource capacity by the consortium member in response to a coordinator's call for resources is regulated in the contracts agreed for a fixed period between the partners of the consortium. Incentives to

be given to the service agencies for covering the service agencies expenditures are also fixed in these contracts.

- **Resource Deployment.** Availability information about the resources of the supply chain consortium members is needed to decide on how the available resources are deployed in order to fulfill the received requests (Fleischmann et al., 2008). In transportation logistics, routes have to be compiled for the trucks and vehicles but in production logistics, machine schedules are compiled that determine the sequence and duration of jobs on a particular machine or in a shop floor.

1.2 Challenges of Process Planning in Supply Chain Consortia

As opposed to value creation in a single enterprise, the coordination and planning of value creation activities in supply consortia come along with several additional challenges. The members of the consortium want to autonomously make decisions about the activities that form their contribution to the coalition (Villa, 2002). Conflicts and mistrust between the consortium partners occur from information asymmetry (Ballou and Gilbert, 2000) and endanger the efficiency of the supply networks' business operations. The impacts of these disturbances in the interaction between superior consortium partners (the principals) and subordinate partners (the agents) are tried to be explained in the principal-agent-theory (Elschen, 1991). (Kaluza et al., 2003) apply the principal-agent-theory to coordination and adjustment problems in supply consortium scenarios. They point out two major sources of information asymmetry. At first, a principal does not know how the agents will react after they have been instructed to fulfill a certain order (hidden action). Secondly, a principal is not informed about all (actual) objectives of the agents (hidden intention).

Another challenge is the management of dynamicity. While important design and configuration decisions are made in the strategic and tactical context, it is necessary to react continuously to appearing of unexpected events in the short-term context in order to ensure a continuous process execution. Thus, the customer demand-oriented process determination turns out to be a dynamic decision situation. Most efforts to cope with dynamicity originate from supply chain design and configuration and these approaches aim at providing physical buffers to compensate exogenous shocks. However, it is also necessary to equip the actors in the consortium with tools to cope efficiently with the impacts of uncertain events in the short-term (operational) context.

After we have identified the decision tasks for preparing the execution of a process instance and the corresponding specific challenges, we are prepared to analyze the responsibilities for making the corresponding decisions in the next section.

2 DECISION COMPETENCE IN A SUPPLY CHAIN CONSORTIUM

We have found out in the previous section that a variety of decisions has to be made in order to enable a successful execution of a process instance. Firms have established coalitions with trusted partners in order to maintain and even increase their competitiveness with the aim of coping with the market-related challenges initially mentioned in section 1.

For reaching this state it is necessary to achieve a successful integration of the partners as well as to continuously coordinate the acting of the partners. A clear distribution of responsibilities among the coalition partners is required in order to make clear process decisions in all three areas (network capacity disposition, service agency resource dispatching and resource deployment).

A governance policy of a supply chain determines which partners are responsible for which decisions. To prepare the discussion of different paradigms and ideas of governing a supply chain consortium, we first review the responsibilities that have to be distributed among the partners in a consortium (Subsection 2.1). Next, we propose the semi-formal method of autonomy profiles to quantify the extent to which partners in a supply chain consortium are integrated in the sense that a common process-related decision making is performed (Subsection 2.2).

2.1 Responsibilities in the Supply Chain Consortium

A consortium member is called a coordinator of the consortium if he is responsible to receive customer demand and convert it into consortium orders (network capacity disposition). Such a coordinator works as the interface between the consortium and the customers. A member in the role of a service providing agent splits a received order into resource requests and instructs resource controlling agents to fulfill requests (resource dispatching), which leads in turn to the fulfillment of orders and the fulfillment of all orders finally completes the fulfillment of the customer demand. Finally, a member, who is in the role of a resource agent receives requests and is allowed to decide how to use the represented resource to fulfill the request (resource deployment).

Resulting from the definition of possible partner roles we can make out two principal-agent interfaces in a supply consortium. At first, a coordinator acts as a principal towards the service providing agents who act as subordinate agents ensuring the fulfillment of the supply consortium orders. Here, the information asymmetry is caused by incomplete knowledge about the customer demand. Secondly, a service agency plays the role of the principal towards the agents representing its resources. In both principal-agent relations, mistrust and conflicts prevent the identification and realization of common decisions that lead to so-called Pareto-optima representing those disposition or dispatching decisions that provide non-dominated solutions to the benefit of both, the principal and the agents and hence of the overall supply consortium. Thus, conflicts caused by hidden action and hidden intention must be recognized and even accomplished in order to preserve a well-organized and efficiently acting supply consortium.

2.2 Evaluating the Integration of Partners in the Consortium

The organization of a supply consortium plays an important role in the dynamic control of the process instances. (Stock *et al.*, 2000) list three generic concepts for the definition of a governance policy of a supply consortium. These three approaches are distinguished by the instantiation of the two parameters **degree of vertical integration** and **degree of linkage**. The degree of vertical integration is defined as the percentage to which decisions of two or more coalition partners are exclusively made centrally. If this degree is zero then all partners are allowed to made decision about the deployment of their resources independently. In case that the degree approximates 1 no partner has to right to decide about the deployment of its own resources. The degree of linkage expresses to availability of inter-organizational information systems among supply consortium partners. If the degree of linkage is close to zero then nearly no common information infrastructure is available, which is often evidence for a fragile and non-resilient partnership. If the degree of links is quite high then all partners share the same data basis and inform themselves about process related events and data modifications. This is interpreted as the existence of trust among the consortium members who wants to act together to reach common goals. The three aforementioned government configurations can now be defined using the extent of vertical integration and linkage degree.

Hierarchical governance exhibits a high degree of vertical integration and a high degree of linkage. In contrast, **market governance** comes along with low degrees of linkage and vertical integration. As a compromise between hierarchy and market governance, **network governance** is proposed. Here, a strong degree of linkage is preserved but the vertical integration is low, e.g., independent partners are intensively linked by an embracing information system.

The governance type definitions by (Stock *et al.*, 2000) are misleading because the cluster-oriented categorization of the three governance types suggests that the membership is based on explicit values of linkage and vertical integration degrees. Actually, the transformation from one type of governance to another is smooth and continuous. To remedy the inaccuracy of the previously proposed definitions, we present a revised categorization. At first we propose to consolidate the two linkage degrees by defining the i-th partner's autonomy degree p_i as the quotient between the number of decisions to be made by the i-th partner and the number of decisions the i-th partner would be able to make. According to the current value of p_i, we can now classify the state of partner i in the consortium. If p_i is close to 0 then the i-th partner is granted almost no decision rights, thus he is a dominated consortium member. In case that p_i is close to 1, the i-th partner is nearly autonomous because he can decide almost alone.

The autonomy degrees of the partners in a consortium can now be compiled to an autonomy profile of a supply chain consortium (Fig. 2.1). Market-type governance exhibits a very high degree of autonomy (close to 100 %) of each partner (middle picture in Fig. 2.1). In a hierarchy-type governed consortium at least one partner comes along with a low autonomy degree close to 0% and the autonomy degree of at least one partner is quite high (right picture in Fig. 2.1). We call all other governance types simply a “consortium" (e.g. left picture in Fig. 2.1).

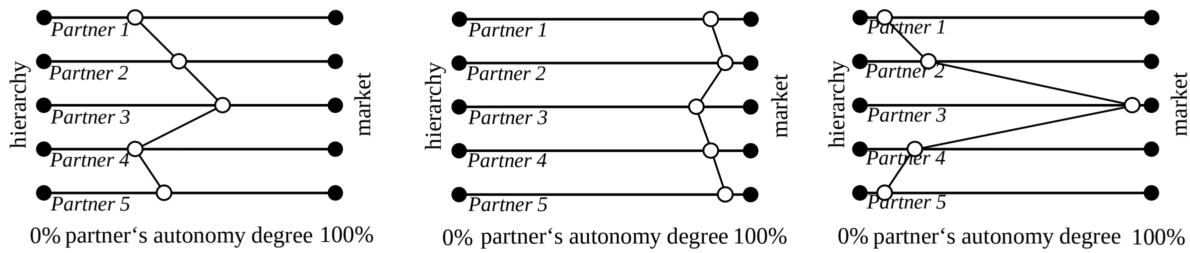

Fig. 2.1: Autonomy profiles of a supply chain consortium: network structure (left), market structure (middle) and hierarchical structure (right)

The specific autonomy profile of a consortium results from the determination of the decision competence distribution that remains unchanged as long as the agreement among the partners remains valid. It is therefore a static configuration. In the next Section, we analyze the relationships between specific characteristics of an autonomy profile of a consortium and process control paradigms.

3 PROCESS CONTROL AND STATIC AUTONOMY PROFILES

A process control system coordinates the decision tasks (capacity disposition, resource dispatching and resource deployment) required for the preparation of the execution of a process instance (cf. Section 1.1). The autonomy profile (which is equivalent to the selection of a governance type for the consortium) determines the structure of the used process control system. Fig. 3.1 shows the three basic structures of a consortium consisting of three partners, which are the white one, the gray one and the black one. In this section, we uncover relationships between autonomy profile layouts and process control paradigms.

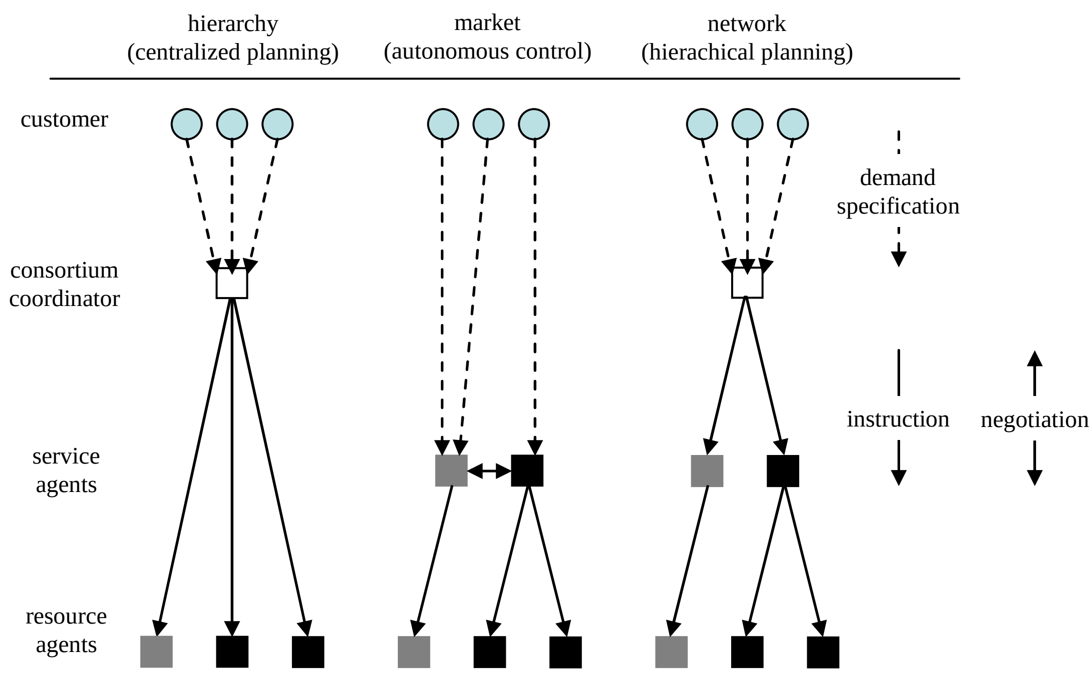

Fig. 3.1: Process control structures for different governance types

3.1 Centralized Planning

A hierarchically governed supply consortium (focal supply consortium) is typically characterized by the presence of one single leading partner (focal partner, which is the coordinator), who is elected as the leader due to its financial power or exceptional knowledge of products and processes (Stadtler, 2005) or because it provides a well-known brand. In a hierarchically organized supply consortium, the leader is responsible for all three planning steps network capacity disposition, service agency resource dispatching and resource deployment. The coordinator directly instructs and deploys the resource agents. In the example shown in Fig. 3.1, the white partner has direct access to the resources provided by the gray and by the black partner.

This kind of process configuration is referred to as centralized planning (Pibernik and Sucky, 2006) and (Lin and Shaw, 1998). The application of centralized planning requires the willingness and acceptance of all supply consortium partners to subordinate themselves and to transfer all decision privilege to the coordinator (white partner), who acts as a focal partner. Furthermore, it is necessary that the supply consortium is transparent, so that all information and data relevant for the process configuration are available to the leading entity. This is the reason why the degree of linkage is quite high in hierarchically governed supply consortiums. However, the degree of autonomy is close to 0%.

3.2 Autonomous Cooperation and Control

In a supply consortium that is organized as a market there is no distinguished leading entity. Therefore, each consortium partner itself performs as a coalition representative and collects demand from customers (cf. the dashed arc in Fig. 3.1). Consequently, each member becomes responsible for fulfilling a specific customer demand. It derives supply consortium orders. In order to determine the necessary process instance(s) for fulfilling the demand of the customers, each partner tries to hire other consortium members that are willing to execute one or several orders. Payments are transferred for the execution of orders and/or orders are interchanged among consortium partners (cf. the double arcs in the middle picture within Fig. 3.1). In addition, a similar negotiation is performed among the resources in the assignment of requests. Similar to a traditional market trading, the responsibilities for the fulfillment of orders and requests are traded on a virtual market where the reward is fixed pair wise between coalition partners or even between resource representatives.

This paradigm for process-related decision making is referred to as autonomous cooperation and control (Hülsmann and Windt, 2007). A necessary prerequisite for the forming of an autonomous cooperating and controlled supply consortium is the willingness of all members to interact with each other member of the consortium. In the example in Fig. 3.1, the capacity disposition is carried out collaboratively by the three partners but the resource dispatching (as well as the resource deployment) is made by each partner only for its own resources.

Furthermore, a common communication platform is required to which a partner can connect for exchanging messages with other consortium members. However, this platform is used only for exchanging information. An integration of data sources is not intended. For this reason, the degree of linkage is low. In addition, the vertical integration of the coalition members is also quite low due to the autonomy of the coalition partners. As a result, the degree of autonomy is close to 100%.

3.3 Hierarchical Planning

If a market-type decision framework is not realizable and if a strict centralized decision making in a hierarchy layout is also not desired then a compromise between the pure central control and the completely distributed decision making is required. The consortium members agree that there are (is) some (or actually one) leading unit(s) in the consortium that are (is) elected to supervise and instruct other coalition members as well as to establish connections to and keep in contact with the customers. In addition, a hierarchy among the leaders is setup. A higher ranked leader specifies instructions towards lower ranked leaders, which are free to decide how to fulfill the instructions (orders). The previously described hierarchy in the supply consortium induces a step-wise decision sequence for the deployment of the consortium resources. (right picture within Fig. 3.1). There is again one consortium coordinator (the “white” global coordinator in the aforementioned picture) for the complete supply consortium. This leader receives the customer demand, specifies the supply consortium orders and assigns these orders to the service agents. Here, the global coordinator represents a principal compared to the other coalition members. However, in contrast to the strict centralized planning paradigm, the global coordinator does not decide how the resources of the coalition partners are used to fulfil the supply consortium orders. Figuratively spoken, the global coordinator selects only the colours of the activities in the selected process instance

(Fig. 1.1). The derivation of requests from the tasks of an order assigned to a certain partner is made by a dispatcher belonging to a service agent. This so-called service-agency dispatcher compiles the requests from the received orders and assigns these requests to the resources (represented by the resource agents) controlled by the considered coalition partner. This stepwise decision making is referred to as hierarchical planning (Hax and Meal, 1975). The degree of autonomy is now somewhere between 0% and 100% for each partner.

After having compared the three paradigms, we conclude that the selection of a governance policy paradigm determines a) who is responsible for the resource dispatching and b) who is responsible for the generation of the requests. Independently from the selected type of supply consortium governance, the determined decision distribution remains stable for a longer time. For this reason, we refer to such a consortium as a *statically-controlled* one. In the following section, we demonstrate that external impacts can easily lead to a collapse of a statically-controlled consortium. We therefore, propose to adjust the process control system over time, so that a temporary shift of the responsibility of dispatching and request generation is made leading to so-called *dynamically-controlled* consortia.

4 DYNAMIC GOVERNANCE OF A SUPPLY CHAIN CONSORTIUM

This section is dedicated to an empirical study in which we demonstrate the theoretically discussed shortcomings of static governance approaches for the process management in a supply consortium. Furthermore, we propose dynamic governance approaches consisting of coordinator intervention strategies for biasing the decision making of consortium partners. We start our empirical study with the description of a simulation environment in which a small consortium that is regularly feed with additional customer demand is cloned (Subsection 4.1). The process performance of the consortium can easily be outperformed by an unexpected workload peak (Subsection 4.2). As general idea to remedy this shortcoming, we propose to adjust the autonomy profile of the consortium (Subsection 4.3). Three approaches to adjust the autonomy profile to the currently observed process timeliness are proposed (Subsection 4.4). We repeat the initially mentioned experiments but incorporate the proposed dynamic governance policy. Simulation results are presented and discussed (Subsection 4.5).

4.1 Outline of the Simulation Experiment

We simulate a supply consortium formed by two partners. A coordinator regularly receives demand from customers. In order to fulfill the customer demand the coordinator forms transportation orders that are given to the transport service agent (TSA) who is the second actor in the simulated consortium. The TSA splits the orders into requests and deploys its own fleet (self-fulfillment) and/or incorporate external service providers (subcontraction). The coordinator and the TSA are organized in a hierarchical fashion, and the coordinator has no possibility to intervene into the deployment decision making of the TSA. The TSA executes a rolling horizon planning of the transport processes: whenever additional orders are specified by the coordinator the TSA splits the order into executable transportation requests and decides how the requests are fulfilled by solving a vehicle routing problem with soft time windows and subcontraction opportunities using a genetic algorithm. The technical details of the simulation environment, the decision models and the incorporated optimization algorithms can be found in (Schönberger and Kopfer, 2009).

The coordinator submits regularly every 100 time units up to 50 additional orders and the TSA gets a regular budget to cover its order fulfillment expenses. After having paid all costs the TSA gets the remaining amount as its profit. In order to maximize its own benefit, the TSA aims at minimizing its over expenses. Since the subcontracting rate for a requests is three times higher than the accountable costs for using TSA-owned trucks the TSA preferentially selects the self-fulfillment mode to fulfill the transportation requests. Using its own 25 trucks and the opportunity to hire external service partners (subcontracting) the TSA determines transport processes that run at a timeliness of around 80%.

4.2 Simulation of a static governance

We simulate the following crisis situation. During the period from time 1500 to 1700 the relatively balanced volume of incoming customer demand explodes (e.g. due to some marketing activities of the customers) up to 150 additional requests specified at time 1500, 1600 and 1700. After the acute crisis is over, the timeliness of the transport processes falls below 50% and it takes around 2000 time units (ten times the duration of the crisis) until the pre-crisis punctuality is re-achieved again (Schönberger and Kopfer, 2009).

An ex-post analysis of this unexpected situation reveals that the transport service partner refrains from hiring external forwarding companies because the costs for the hiring where larger than the costs for the delayed arrivals. By refraining from hiring external freight forwarders the TSA maximizes its private profit. The coordinator of the consortium has recognized the demand increase quite early but was not able to intervene, because the choice of the request fulfillment mode was with the transport offering partner and this consortium partner does not decide in the sense of the overall consortium in the described crisis situation.

From these observations we conclude that it is not appropriate to define a static distribution of decision competence (static autonomy profile) for supply chain consortium governance if the governed process instances run in a volatile environment. Often, a consortium coordinator has a better overview about the needs and challenges the consortium is currently faced with. Therefore, is seems to be reasonable to grant the coordinator of a consortium additional decision competence during crisis situations. The benefit of this idea is that the consortium is better capable to survive threatening situations. A temporary concentration of decision competence is well-known and has been approved for emergency response and disaster relief situations.

4.3 Adaptation of the Autonomy Profile

From a theoretical perspective, the conceptual weakness of a statically-controlled consortium is obvious: A significantly changing decision situation concerning the process instance management can drive a process control system is a deadlock or low-performing state because significant changes in the decision tasks associated with the process instance management are not foreseen in the profile. These unforeseen developments might push stable and intact principal-agent relationships into situations where hidden intention and/or hidden action apply. The reason is that the planning objectives of consortium partners often do not fit anymore or are even contradicting if assumptions made during the agreement of the consortium partners become hurt. If the consortium members agree that the coordinator of a consortium is granted temporarily additional rights to navigate the consortium through a threatening situation then the consortium has to adapt its autonomy profile (Fig. 4.1) to the new requirements and challenges coming along with the detected crisis situation. The gray profile represents the configuration of the consortium before the demand peak had occurred (default configuration). In order to cope with the crisis challenges it is necessary to increase the autonomy degree of the coordinator by Δ_{CC} and, simultaneously, decrease the TSA's autonomy degree by Δ_{TSA} for a certain period.

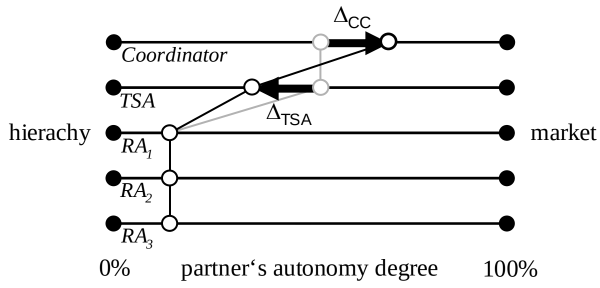

Fig. 4.1: Variation of the autonomy profile of a supply chain consortium

In order to achieve the shifts in the autonomy profile of the consortium it is necessary to apply some special actions. These actions must have been coded before into the agreements between the consortium partners. In general, three concepts are available. At first, additional (monetary) incentives can be used to induce desired activities of some members. Secondly, options can be defined in the agreements between the consortium partners. Such an option preserves a consortium coordinator the right but not the obligation to intervene into the decision making of another member. The simultaneous application of incentives as well as options represents the third approach to initiate shifts in the autonomy profile of a supply chain consortium.

Although incentives and options are in use in a variety of applications there is no experience about their appropriateness for their exploitation in order to adapt the decision competence distribution within a supply chain consortium although the technical basis for such a process control system is available (Schönberger and Kopfer, 2009). Furthermore, neither long-term nor short-term spillover effects of the autonomy profile adaptation are known.

4.4 Simulated Governance Policies

We repeat the simulation of the scenario reported in 4.1. Four governance policies are setup. One policy represents the static governance approach (STATIC) introduced in 4.1. The three remaining configurations exploit the capabilities of dynamic supply chain governance and adapt the decision competence distribution to the current timeliness of the processes (INCENTIVES, OPTIONS, and HYBRID INTERVENTIONS).

INCENTIVES: The coordinator promises additional payments to the transport service agent if the agent decides about the request fulfillment mode in accordance with the coordinator's desires. In the crisis situation after the occurrence of the load peak (where the frequency of on-time delivery decreases) the coordinator offers the transport service agent additional transfer payments if the reliable (but more expensive) subcontracting mode is selected as request fulfillment mode. The intention of the coordinator is to give an incentive to the subordinate transport service agent to make process decisions that comply with the needs of the consortium (SC-mode selection) and not only with the TSA's private goal of maximizing its private profit (which means to select the self execution mode). The TSA will accept the incentives if these extra payments compensate at least the additional expenses of the TSA resulting from the TSA's deviation from its optimal decision.

OPTIONS: In order to provide the consortium coordinator an intervention opportunity if the incentives cannot convince the TSA to decide in accordance with the coordinator's requirements, a direct intervention opportunity for the coordinator is required. We propose that the coordinator and the transport service agent agree fulfillment mode selection options. Such an option preserves the coordinator the right but not the obligation the select the fulfillment mode for specific requests. Thus, in a crisis situation, the coordinator is able to select the reliable SC-mode for some requests and, if necessary, overrules the decisions of the subordinate service agent.

HYBRID INTERVENTIONS: Here, the consortium coordinator is equipped with incentives as well as options in order to enforce its process decisions during the crisis situation.

We have set up a specific rolling horizon process planning system that incorporates autonomy degree adaptation in order to improve the management of request peak situations for transport request in a supply consortium. In order to decide if a crisis situation has occurred both the coordinator and the transport service agent agrees a least punctuality rate of the transport processes. Here, this threshold rate is set to 80%. The current process punctuality is used as process feedback that is evaluated in order to decide about the necessary adjustments of the recent autonomy profile in the consortium (Fig. 4.1). As long as the transport processes run with the sufficiently high punctuality above the threshold there is no crisis situation. Consequently, no right shift of the autonomy degree of the coordinator is made and the autonomy profile remains unchanged. In case that the process quality begins to decrease or even falls slightly below the agreed threshold a small incentive amount is offered by the coordinator to the transport service agent for each request that is externalized by the service agent (INCENTIVES) or a subcontracting option is drawn for few requests (OPTIONS) or both (HYBRID INTERVENTION). This leads to a de facto small right shift of the degree of autonomy of the coordinator and a small left shift of the autonomy degree of the service agent. If these countermeasures do not convince the subordinate service agent to select the SC-mode for a sufficient large number of requests and/or if the punctuality decreases further then the incentives are increased and/or more options are drawn by the coordinator until the punctuality of the process climbs up again. This results in an additional right shifting of the coordinator's autonomy degree and in an additional left shifting of the subordinate service agents' autonomy degree. The coordinator gets more and more influence in the resource dispatching. As soon as the process punctuality re-increases the degree of autonomy is shifted back until, finally, it re-achieves the default degree that has been fixed in the long term contract between the consortium members.

4.5 Presentation and Discussion of the Simulation Results

We have extended the simulation environment outlined in 4.3 so that we are able to simulate coordinator interventions, in which the three aforementioned intervention techniques are evaluated and compared. In the following, we present an extract of the observed simulation results in order to examine our initially presented assumption. During the experiments, we have fetched the maximal punctuality decrease. Furthermore, we have recorded the cumulated request fulfillment costs (travel costs, penalty payments and subcontraction costs). Finally, we measured the duration of the recovery period until the pre-peak timeliness is finally re-achieved after the peak's introduction at time 1500. In order to compare the results from all four simulation experiments we have compiled them in Table 4.1. We find out that the adaptation of the autonomy degree leads to a significant reduction of the maximal punctuality decrease after the introduction of a demand peak (2nd column). A reduction of the decrease from 38.8% down to 5.6% validates the assumption that an autonomy degree adjustment supports protecting the process punctuality even in severe workload situations.

Table 4.1 Simulation Results

	on-time delivery decrease after peak	cumulated request fulfillment costs	recovery duration
STATIC	-38,8%	55748,3	2000
INCENTIVES	-5,6%	64225,6 (+15,2%)	1700 (-15,0%)
OPTIONS	-9,5%	82696,6 (+48,4%)	1000 (-50,0%)
HYBRID	-5,8%	78350,8 (+40,5%)	1000 (-50,0%)

Next, we direct our attention to the additional costs (compared to the results in the STATIC-experiments) caused by the interventions (e.g. resulting from the autonomy degree adaptation). The application of the incentive-control results in additional costs of around 15% compared to the situation without any autonomy degree adaptation (3rd column). If options are used to intervene into the resource dispatching the increase is even worse and an increase of more than 48% of process costs is observed. However, the application of hybrid interventions (incentives as well as options) leads to only 40% increase of process costs. Finally, we compare the recovery durations (4th column in Table 4.1). The application of STATIC results in the longest recovery period. A switch to the INCENTIVES policy leads to a reduction of the recovery period by 15% but if OPTIONS or HYBRID are applied then the duration of the recovery period is halved. In conclusion, the analysis of the simulation experiments results reveals that our initially stated assumption is true for the investigated scenario. Coordinator interventions into the subordinate service agent's dispatching and disposition decisions significantly lifts up the quality of the process-related decisions with respect to the process reliability. The timeliness decrease after the acute workload peak can be reduced as well as the recovery duration. The processes-related expenses increase significantly if the coordinator intervenes. The HYBRID policy is outperformed by the OPTION policy. Here, the mix of different intervention approaches cannot convince.

5 CONCLUSIONS

In this article we have proposed the concept of adaptive autonomy profiles for determining the competence distribution among partners in a supply chain consortium. This concept is based on the idea to temporarily shift and consolidate decision competences among consortium partners in order to manage crisis situations that threaten the overall consortium by exploiting well-coordinated and concentrated process-related decision making. Within simulation experiments, we succeeded to verify our initially stated research hypothesis and demonstrated that an adaptive governance concept is able to outperform the commonly found static approaches based on central planning, hierarchical planning or autonomous control. However, we also found out that the price for enabling a consortium coordinator to intervene into the deployment and dispatching decisions is quite high because additional process costs occur. In summary, we have proposed an additional tool for managing cooperative value creation systems in dynamic and volatile environments especially for the management of ad-hoc crisis situations. The autonomy profile adaptation seems to be a reasonable tool to support the accomplishment of extraordinary and critical situations. The additional expenses for the process instances can be understand as the “price for the higher process reliability”. The potential users of the concept have to decide if it is worth to spent additional expenditures for achieving a higher process stability and reliability. Future research efforts will be dedicated to transfer this concept into other application contexts and to evaluate adaptive governance strategies there. Future research efforts should be dedicated to reduce to find intervention techniques with a “lower price”. Furthermore, it is necessary to analyze more sophisticated metrics to evaluate the process feedback especially to enable a consortium coordinator to detect upcoming crisis earlier.

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