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Decision support systems and the coordination of supply consortium partners☆

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Abstract: We propose to enhance decision support systems (DSS) by coordination capabilities to align the decision making of consortium partners for improving the process quality in volatile process environments. In computer simulation experiments, we reveal conceptional shortcomings of traditional DSS if unforeseen process-threatening events like unexpected workloads have to be handled by a consortium. It is demonstrated for a transportation process planning scenario that a process quality increase is achieved if a DSS is extended by components that align the process-related decision making of legally independent supply consortium partners. The central idea proposed to add coordination capabilities to DSS is to temporarily adjust decision models of subordinate consortium partners to the fulfillment degree of consortium objectives in order to establish a coordinated decision making.

1. Introduction

A decision support system (DSS) is an information processing system especially dedicated to derive or support the derivation of goal-oriented decisions in complex decision situations. Such a system combines process-related data with analytical decision models in order to enable a computer-based control of value creation processes [1]. DSS are set up according to some commonly agreed design paradigms.

Within this contribution we report a research about the evaluation of existing DSS-concepts for the management of transport processes in a volatile process environment. In such an environment, the planning conditions and requirements vary significantly within a small time span. Processes running in a volatile environment need a frequent update in order to maintain their efficiency.

The management of processes in a volatile surrounding becomes even more challenging if two or more decision makers are involved (often on different decision levels). Here, the needs and objectives of all participating acteurs have to be considered simultaneously during the process planning. A supply chain consortium is an often found example for such a complicated decision making scenario. The superior coordinator instructs a subordinate service partner to fulfill certain orders. In reaction to this call, the service partner deploys its resources to fulfill the orders by executing processes. In this report, we deal with such a two-decision-maker-situation arising from a supply chain scenario, in which the subordinate service partner offers transportation.

By means of the two-decision-maker situation from supply chain planning, we reveal shortcomings of DSS design paradigms caused by extraordinary events whose processing is not defined in advance. Although previous research [2,3] has addressed new ideas for handling those events DSS architectures are unable to handle these events efficiently. The main contribution of this article is the proposal of an extension of the three-layer event-handling-concept [4] by a fourth layer that controls even the handling of extraordinary events. We define and evaluate a four layer event handling system for the management of extraordinary situations in the above-mentioned two-decision-maker-situation.

We state the following research hypotheses guiding the research reported here: (i) two (or more) concurrent process decisions makers cannot be sufficiently supported by a DSS set up according to existing design paradigms. (ii) A consideration of several decision makers in the layout of a DSS contributes to overcome some deficiencies arising from conflicting or even contradicting planning goals of interacting process decision makers.

The organization of this paper is as follows. We start with the description of the investigated process decision situation (Section 2). Then, we compile DSS-design principles (Section 3), propose a multi-agent-system-based DSS for the aforementioned decision situation (Section 4), and demonstrate its shortcomings. A conceptual extension of design guidelines for DSS is proposed in Section 5 and applied to extend the DSS from Section 4. Performing computational simulation experiments, we evaluate the extended system (Section 6).

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2. A dynamic transport process planning problem

We start with the description of the derivation of transport processes from customer demand in a supply consortium (Subsection 2.1). Then we introduce a specific transport process challenge (Subsection 2.2) and discuss the need for a coordinated decision making in a supply consortium (Subsection 2.3). An online optimization model for the investigated scenario is proposed (Subsection 2.4).

2.1. Transport process planning in a supply chain scenario

A supply chain consortium is a collaboration of independent companies that set up, maintain and operate a value creation chain contributing their specific knowledge and resources to the value creation processes. Due to the spatial scatter of the value creating locations (plants, storages, and customers) excessive transport of raw materials, semi-finished or finished goods has to be carried out. A freight forwarding company is the partner within the consortium that is responsible for configuring the necessary transport processes and deploying the accessible transport resources (trucks or external and booked capacities).

The derivation of profitable and reliable transport processes from customer demand is figuratively presented in Fig. 1. It is a realization of the hierarchical planning idea [5,6]. Initially, customers of the consortium specify their supply demand towards the coordinator. The coordinator derives internal orders and reserves capacities at the consortium partners. Especially, the fleet manager receives transportation orders. This order specification implies a decision problem because the fleet manager has to derive transportation requests and to decide about the setup (or update) of transportation processes for fulfilling the requests. A fleet manager decides about the deployment of own trucks or external resources provided by logistic service providers (LSPs). The execution of the transportation processes leads to the fulfillment of the orders given to the fleet manager so that the necessary flow of goods between the value creation locations is executed. This finally contributes to the customer demand fulfillment.

2.2. A transport process planning challenge in a supply chain

We assume that the supply consortium coordinator has agreed a contract with a customer. This customer specifies demand and submits this demand un-regularly and at unpredictable times to the coordinator. Immediately after the reception of the demand, the coordinator specifies the consortium orders and injects the generated orders into the order pools of the involved service agents.

The coordinator receives customer demands continuously over time. He generates orders from the customer demands and the resulting requests are to be executed by the transport providing partner. A reception of additional requests triggers a process revision to incorporate the additional requests into the so far followed transport processes. The process-planning problem of the fleet managing agent is therefore a dynamic decision problem [7], which is solved in online fashion, e.g. a process revision is carried out in an event-driven fashion in response to the additionally submitted requests. Consequently, a sequence of concatenated decision problem instances P_i is stated. Each instance is formulated as a static and deterministic mathematical optimization model (all relevant data at the re-planning time t_i are assumed to be known). Solving such a model means to find the most profitable process decisions for the transport operations considering the so far actually known planning data.

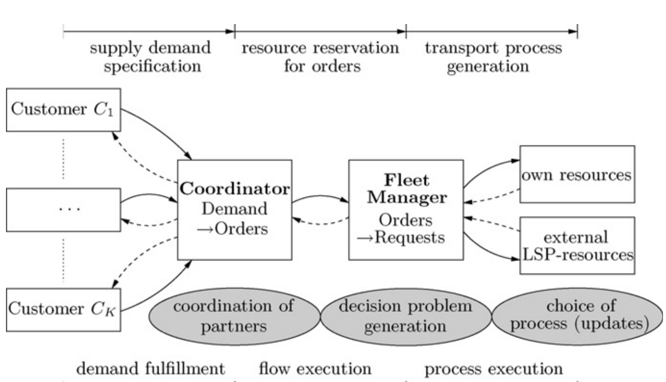

Fig. 1. Transport process planning scheme.

A release of one or more additional requests initiates the revision of the so far constructed routes for the own vehicles. If needed some requests are excluded from the routes of the own vehicles and forwarded to an LSP. A re-assignment of requests formerly given away to an LSP to an own vehicle is impossible.

The fleet managing agent receives a certain amount as budget from the coordinator for covering all expenses associated with the transport order fulfillment. From this budget he has to pay his costs for fulfilling the necessary transport orders (travel expenditures and fees to be paid for subcontracted shipments). The difference between the overall budget and the request fulfillment costs remains as surplus at the fleet managing agent.

A service degree is fixed in the contract agreed between the coordinator and the fleet manager, e.g. a given percentage p^{target} of the customers' transport demand has to be fulfilled within the customer-specified time restrictions. At a certain time t, there are f_t requests whose completion times (already realized or scheduled) fall into the period $[t-500,\ t+500]$ (moving time window). Among these f_t requests the number of f_t^{punc} requests is completed (or expected to be completed) within the previously agreed time windows. The current process punctuality rate p_t is defined by $p_t := (f_t^{punc})/(f_t)$ (representing the current reliability of the transport system). When the quotient p_t does not fall below the threshold value p^{target} the reliability requirement is met. This quote can be explained as follows: Each demand comprises goods necessary to keep the production processes at the customers' factories running and goods used to build up security stocks. The first kind of goods must be provided in time while the second kind of goods can be delivered later without causing corruption on the running production processes. In a *high quality (HQ) period* the requirement for the least punctuality is fulfilled ($p_t \geq p^{target}$) but in a *low quality (LQ) period* the required punctuality rate is not attained ($p_t < p^{target}$).

For the reason of simplicity, we assume that each transport order is an executable task and it is converted 1:1 into a transportation request and added to the request pool of the fleet managing agent. A request instructs a transport resource to visit a given location during a customer specified time window. Examples in which such a kind of request occurs are related to situations in which a large number of small-sized packages are loaded at the beginning of a day-trip so that packages (like spare parts) can be delivered to a large number of customers without the necessity to re-visit a loading berth. Other applications are the collection of used consumable items (collection of used laser or ink-cartridges during office-hours) and the dispatching of service crews or repairmen [8]. For a summary of further related scenarios we refer to [9]. If the number of additionally released requests temporarily increases so high that it is not possible to serve the additional requests immediately, then a workload peak occurs.

Whenever an additional request corrupts the execution of the so far followed processes a process revision (re-planning) becomes necessary. The arrival times at some customer sites may be