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AUTONOMOUS COOPERATION – A CAPABLE WAY TO COPE WITH EXTERNAL RISKS IN INTERNATIONAL SUPPLY NETWORKS?*

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ABSTRACT

This paper intends to show possible contributions of the concept of autonomous cooperation (AC) to enable logistics management of International Supply Networks (ISN) to improve dealing with external risks caused by environmental complexity and dynamics. The concept of AC as one possible approach to cope with external risks of ISN will be analysed either from a theoretical and an empirical point of view.

IDENTIFICATION OF MANAGEMENT PROBLEMS IN ISN

In the course of globalization, a trend towards the development of ISN can be recognized. This trend can be detected by the tendency of different supply chains to interlink themselves (Hülsmann and Grapp 2005, p. 244) and is associated with the phenomenon of "hyper-linking". For organizations, hyper-linking connotes that they are interlinked not only with their direct business partners but as well indirectly with other logistic actors (Tapscott 1999) (e.g. its logistic service providers). From the perspective of strategic management, these multiple linkages represent the relevant environment of an organization (e.g. ISN) (Welge and Al-Laham 2003, p. 189). However, besides positive effects of cooperation in ISN (e.g. providing/exchanging logistic services) the relevant environment of ISN additionally holds negative effects such as potential external risks (e.g. non-predictable increasing quantity of logistic process data). Such external risks result from the characteristic complexity and dynamics of ISN induced by the cited phenomenon of hyper-linking. Its complexity originates from the large amount of involved organizations and relations between these organizations. Dynamics is caused by changes in involved organizations and relationships between organizations (Hülsmann and Wycisk 2005, pp. 4-5). Increasing complexity and dynamics simultaneously enlarge the amount of external risks ISN-Management is confronted with. Risk in an entrepreneurial view can be described as the impossibility to forecast the repercussions of decisions and the inherited uncertainty of future developments (e.g. order situation). The impossibility to forecast future developments results from a lack of information that is necessary to undertake a secure decision-making (Rosenkranz and Missler-Behr 2005, p. 20). Furthermore, it is difficult to manage external risks because of their volatility (e.g. fast changes of supplier-relationships and therefore permanently altering relevant environments). Volatility in an economic perspective is the fluctuation of an indicator around its trend or average value (Bruns and Meyer-Bullerdiek 2003).

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It can be concluded that ISN-Management has to face uncertainty regarding its decision-making because it has to process an increasing quantity of fluctuating information in its logistic processes (Hülsmann and Grapp 2005, p. 244). If the capacity of ISN-Management to process information is not sufficient to cope with all relevant information, problems in decision-making might occur (e.g. ineffective or inefficient management solutions). The informational basis for decision-making deteriorates with a rising amount of complexity and dynamics if the capacity of the system to handle information does not increase (Hülsmann and Wycisk 2005, pp. 4-9). This means, for every single logistic actor embedded in ISN, external risks connote challenges they have to cope with for ensuring their (logistic) goal achievement (e.g. right quantity, quality, time, space, costs) (Mikus 2003, p. 48).

Finally, this signifies the necessity for ISN-Management to deal with external risks that result from complexity and dynamics. Is there a capable way to deal with external risks? The main research question of this paper is to answer if and how far a management approach (e.g. AC) could contribute to cope with external risks of ISN. Firstly, it will be analysed if and how far AC might contribute to cope with the identified problems of ISN. The concept of AC will be introduced and its characteristics will be applied to the ISN-context **(Aim no. 1)**. Secondly, it will be evaluated empirically which method of AC is able to cope with external risks in ISN. A simulation and measurement model will be used to simulate the impacts of different methods of AC on the management of external risks in ISN **(Aim no. 2)**.

MANAGING EXTERNAL RISKS OF ISN BY AUTONOMOUS COOPERATION

One approach that has been discussed in the context of managing complexity and dynamics -here understood as causes for external risks- is the concept of AC (Hülsmann et. al. 2006). AC is based on the concept of self-organization which has its scientific roots in multiple fields of research (e.g. biology, physics, and chemistry). It belongs to the academic field of complexity science (Hülsmann and Wycisk 2005). AC aims at explaining how complex systems create ordered structures autonomously (Hülsmann and Wycisk 2005). According to Windt and Hülsmann AC "describes processes of decentralized decision-making in heterarchical structures. It presumes interacting elements in non-deterministic systems, which possess the capability and possibility to render decisions independently. The objective of Autonomous Control is the achievement of increased robustness and positive emergence of the total system due to distributed and flexible coping with dynamics and complexity (Windt and Hülsmann 2007, p. 8). According to this general understanding the main characteristic attributes of AC are decentralized decision-making, autonomy, interaction, heterarchy and non-determinism (Windt and Hülsmann 2007, pp. 8-10). The impacts of these attributes on logistics management of ISN shall be outlined in the following.

In the context of AC **decentralized decision-making** connotes the delegation of decision power from a centralized entity to individual elements of the system (e.g. packages, industrial trucks) (Windt and Hülsmann 2007, pp. 8-9). From an ISN-perspective, more elements that are enabled to undertake decision-making signify an increasing decision-making capacity because they contribute to the organization's decision-making capability. For ISN-Management this implies that the thread of external risks could be reduced, because the total ability to manage external risks increases. **Autonomy** is the result of processes of decentralization and delegation (Kappler 1992). It connotes that an element is responsible for its own system design, development and direction (Probst 1987). For logistics management of ISN autonomy implies that a suitable degree of autonomy can enable the system to develop itself and therefore develop suitable structures for given and for changing situations. This emergent behaviour may lead to structures that are superior in processing complexity and dynamics and therefore reduce external risks (e.g. new channels of informational exchange). **Interaction** in systems that cooperate autonomously is assumed if the elements are able to communicate directly with each other and therefore are able to exchange information that is needed for decision-making of the individual elements (Windt and Hülsmann 2007, p. 9). Interaction of the elements (e.g. either persons, logistic actors or AC-technologies) in ISN might imply a more target-oriented exchange of information. Because the single elements (e.g. RFID tags) might be -e.g. from a technical point of view- capable to absorb and process information they need for an upcoming decision. Therefore the overall amount of information an organization has to process might be reduced because only the needed portion of information is exchanged. This reduced amount and the more target-oriented exchange of information may reduce the uncertainty in decision-making and therefore the problems if external risks in ISN occur. A **heterarchic** system is a system that does not feature a permanently dominant control entity. The system can be characterized by growing independencies between single elements and a central logistic co-ordination entity (Windt and Hülsmann 2007, p. 9). For logistic management heterarchic structures imply that the structure of the organization itself might become more complex and dynamic due to more elements that have to be taken into account. This might lead to redundancy of decisions different elements undertake, but it might also enlarge the capacity of decision-making. Therefore heterarchy in general might lead to more internal complexity and dynamics but in turn might enlarge the capacity to handle external risks. **Non-determinism** is a further AC-characteristic. Non-determinism implies that the behaviour of a system can not be predicted over a longer period of time (Fläming 1998). With the characteristic of non-determinism, AC aims at higher efficiency for dealing with complexity and uncertainty within processes (Windt and Hülsmann 2007, p. 10). For the management of ISN non-determinism might imply that the processing of information and therefore processes can be handled more flexible. It enables the system to react to changes in the structure of ISN and the resulting problems. Accordingly, non-determinism might increase the ability of logistics management of ISN to cope with external risks, especially risks that result from dynamics (e.g. changing of supplier-relationships). Generally, implementing AC-technologies or concepts in ISN might advance the ability to cope with an increasing quantity of information, because it might enlarge its ability to process information. In turn, this might lead to an improved decision-making and reduced uncertainty. Therefore, AC seems to be able to improve the ability of logistics management to deal with external risks of ISN.

EMPIRICAL ANALYSIS OF EXTERNAL RISKS OF ISN

To measure the effects of AC on a systems ability to cope with complexity and dynamics a simulation and measurement system has been developed (Hülsmann et.

al. 2006). A similar approach will be used to simulate the impact of AC in ISN. Figure 1 shows the developed simulation model of an ISN in order to show different levels of complexity and dynamics. The complexity can be varied by different numbers of processing units within the ISN and different numbers of sources (e.g. for information, resources and orders) as shown before complexity and dynamics of an ISN may represent external risks for logistics management in ISN. In this scenario, AC is implemented by autonomous orders that render decisions about their processing autonomously. The orders enter the system at the sources. Each order has a specific processing plan i.e. a list of processing steps that have to be undertaken to produce goods or services. The finalised goods or services leave the system at the drain. Depending on different autonomous control methods (Queue length estimator, Pheromone method and Due Date method), the overall system shows altered behaviour and dynamics. The first AC method called Queue Length Estimator compares the actual buffer level at all parallel processing units that are able to perform the next production steps, i.e. the direct successor referring to the production plan (Scholz-Reiter et al. 2006). The second method, the Pheromone method, is inspired by the behaviour of foraging ants that leave a pheromone trail on their way to the food. Following ants use the pheromone trail with the highest concentration of pheromone to find the shortest path to the food. In the simulation this behaviour is imitated in a way that whenever a part leaves a processing unit the part leaves information about the duration of processing and waiting time at the respective processing unit. The following parts use the data stored at the machine to render the decision about the next production step (Scholz-Reiter et al. 2006). The due date method is a two-step method. When the parts leave a processing unit they use the queue length estimator to choose the subsequent processing unit with the lowest buffer level. The second step is performed by the processing units. The due dates of the parts within the buffer are compared and the part with the most urgent due date is chosen to be the next product to be processed (Scholz-Reiter et. al. 2007).

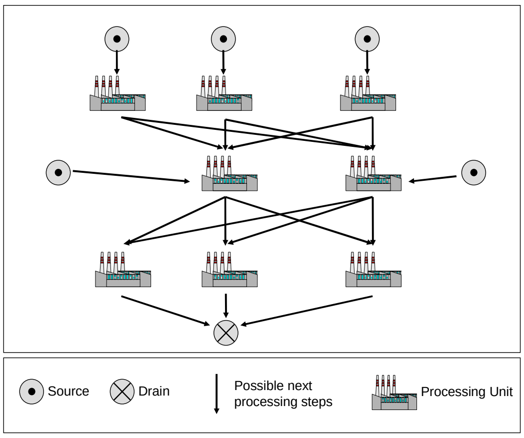

Fig. 1. Simulation Model of an ISN.

The following simulation analyses the overall systems ability to cope with rising structural complexity and rising dynamics using different autonomous control methods. At each source the arrival rate of the orders is set as a periodically fluctuating function. Therefore, the external risks rise with increasing complexity of the ISN. The logistical goal achievement is measured using the key figure throughput time for different levels of complexity and different AC methods. Figure 2 shows the results i.e. the mean throughput times for the three different autonomous control methods in dependence of the systems complexity and the minimal throughput time. The systems complexity is increased by enlarging the amount of processing units as well as the number of sources. It has been found that the Due Date method and the Queue Length Estimator show almost the same results. The Due Date method shows a slightly worse performance because of sequence reordering, while the Pheromone method shows inferior goal achievement. The first two curves are almost parallel to the minimal throughput time. This means that a constant logistical goal achievement is accomplished all through rising complexity and rising dynamics. Therefore it seems that an organization might be able of deal with increasing external risks by using AC methods. The pheromone method shows an inferior behaviour. In this scenario, the dynamics is too high and the boundary conditions change faster than the pheromones are updated.

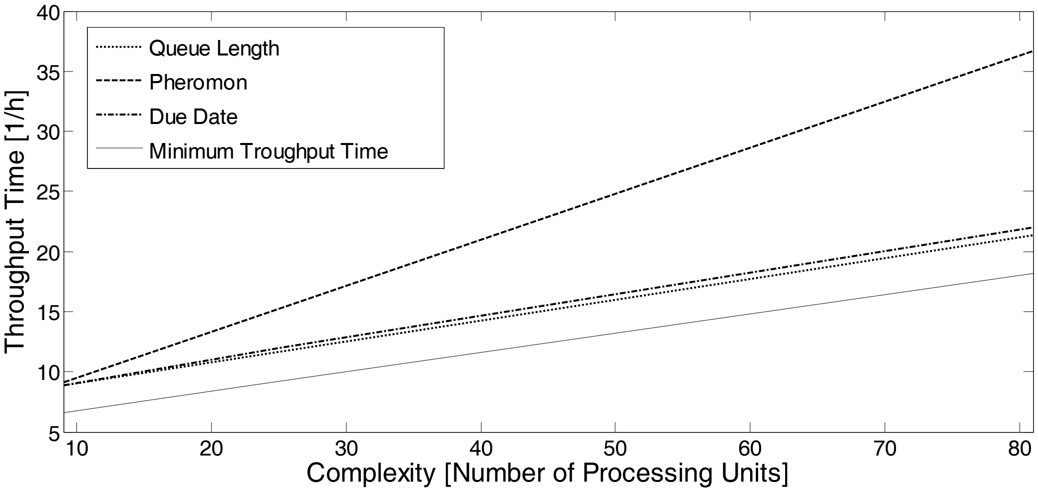

Fig. 2. Logistical goal achievement for different organisational level of complexity and multiple autonomous control methods.

It has been shown that for this kind of scenario, representing rising levels of external risks, the queue length estimator is an appropriate autonomous control method and represents the adequate degree of AC. Because of high dynamics, the pheromone method has not been able to adapt to the changing boundary conditions. The empirical findings imply that a suitable degree of AC might enable logistics management in ISN to handle external risks and therefore ensure logistical goal achievement.

CONCLUSION & FUTURE RESEARCH TASKS

On the one hand, it has been outlined that AC might enable logistics management of ISN to cope with external risks by enlarging the capacity to process information. Especially interaction and communication activities among ISN-actors in logistic processes might be optimized (e.g. information accessible when needed for achieving a specific logistical goal) and correspondingly possible external risks could be anticipated early enough (e.g. adequate package of data is available). Further research should focus on setting up a consistent system of hypotheses regarding the management of risks in ISN through AC. Moreover, this has to be reflected and considered for an optimization of existing AC-measurement concepts (Hülsmann and Grapp 2006). On the other hand, the empirical findings have shown that a suitable degree of AC can enable an organization to deal with external risks in ISN. However, future research needs a more detailed analysis of the impacts of AC on the handling of risks in ISN. For example, empirically other degrees and therefore other methods of AC should be analysed.

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