Risks Resulting from Autonomous Cooperation Technologies in Logistics

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***Abstract*—This paper provides a description of autonomous cooperation as a new organizational concept in order to cope with dynamics and complexity in current logistics systems. Accordingly, the effects of the implementation of autonomous cooperation technologies on general risks in logistics are outlined and exemplarily discussed, since the use of these technologies might influence existing risks or cause new risks in logistics system.**

Keywords-Autonomous Cooperation, Risks, Logistics, Supply Networks

I. Introduction

Recently more and more autonomous cooperation technologies are subject to scientific research [9, 10, 15, 29]. Plenty of benefits and positive outcomes have been identified so far (e.g. higher system robustness and flexibility) [9, 29]. However, beside these positive effects potential negative impacts through the application of autonomous cooperation technologies have to be addressed. These possible negative impacts might induce new or affect existing risks in logistics like the bullwhip effect, non-determinism of the underlying system etc. [15, 29]. Consequently, the following question has to be answered: How does the implementation and utilization of autonomous cooperation technologies affect risks in logistics?

For answering this question, the overarching aim of this paper is to identify effects on potential risks caused by the implementation and utilization of autonomous cooperation technologies. Therefore, the descriptive aim is to depict a framework comprised of the concept of autonomous cooperation as well as a general classification of risks in logistics. Next, the analytical aim strives for an illustration of potential effects between the implementation of autonomous cooperation technologies and the classes of risks in logistics. Finally, the praxeological aim is to obtain hypothesis about interrelations between the implementation of autonomous cooperation technologies and their influence on a company's risks as a starting point for further investigations.

To achieve the mentioned aims, the paper proceeds as follows: First, after constituting the general problem, deducing the research question and the paper's structure in section I, section II describes the concept of autonomous cooperation and its constitutive characteristics. In section III, general risks of logistics will be identified and described in order to obtain a suitable classification. Section IV discusses potential interrelations between the implementation of autonomous cooperation technologies and the classes of risks. Finally, section V will subsume the results and deduce further research requirements.

II. Autonomous Cooperation Technologies In Logistics

Autonomous cooperation bases upon the idea of self-organization, which originates from different scientific disciplines [10]. Originally, self-organization was part of research in cybernetics, chemistry, physics, biology, and mathematics [11]. The associated research deals with the study of the creation of ordered structures in complex systems [11]. According to Windt and Hülsmann [28] the following assumption constitutes the basis for the investigation of autonomous cooperation in logistics: "The implementation of autonomous logistics processes provides a better accomplishment of logistics objectives in comparison to conventionally managed processes despite increasing complexity. […] Autonomous cooperation and control is one factor to guarantee the necessary changeability of logistics processes" [28, p. 3]. To provide a general understanding of the term autonomous cooperation or autonomous control respectively, it is necessary to give a comprehensive definition: "Autonomous Control 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. 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" [28, p. 8]. The definition includes five characteristics of autonomous control, which shall be described in detail: Decentralized decision-making, heterarchy, interaction, non-determinism, and autonomy.

Decentralized decision-making means that the logistics objects (e.g. container) are able to render own decisions under consideration of available information and determinants (e.g. decision rules) [9]. As a result, these objects act **autonomously** and perform **interaction** with other elements in order to receive relevant information [25] (e.g. traffic conditions). An adequate information supply is very important in this context, since information constitutes a basis for a decision making process. Moreover, **heterarchical structures** are required [26] in order to ensure information sharing and interaction of logistics objects [3].

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That means that all objects strive for their own goals (which must not constitute the global optimum of the whole system but in some cases the local optimum of the objects) by rendering their own decisions and those objects are independent from higher control entities. Additionally, rendering own decisions leads to a high number of decision alternatives. Thereby, the predictability of the overall system's behavior is nearly impossible, which is constituted by **non-determinism** [3].

The creation of innovation and the use of technologies respectively have become critical and important factors for the success of companies in general [1] as well as for logistics service providers [6]. In logistics, the competitiveness of companies depends on their ability to create and use innovations (e.g. technologies), which add value to customers [6]. Thus, own services can be distinguished from those of competitors and competitive advantages are obtained. To achieve this, a product or service has to be unique in order to find the acceptance of the customer [4]. In addition, some requirements might hamper the implementation of autonomous cooperation technologies in logistics if not fulfilled. First, being a "Pioneer" in introducing a new technology might be desirable since this creates an advance for the "First Mover". Even if competitors imitate the "Pioneer", the first mover advantage will lead to potential advantages in cost or differentiation [21]. Second, innovations base on investments in fixed capital, which automatically tie liquidity and have to amortize after a period of time [19]. Third, an implementation of technologies requires an appropriate infrastructure, which contains compatible interfaces to customers as well as to own suppliers. That demands for a former establishment of a technical environment in order to allow for an optimal use of these new technologies. All requirements mentioned above can also constitute barriers for the use of autonomous cooperation technologies in logistics.

In the context of logistics technologies the use of autonomous cooperation technologies has become a more and more discussed and investigated option in order to adapt to new and changing requirements in logistics [10]. These new and altered requirements result from shorter product-life cycles, a decreasing number of lots in production processes [11] as well as an increasing demand for flexibility in processes of logistics service providers (e.g. act to unforeseen events like changes in a customer's order). Autonomous cooperation, which constitutes an approach of decentralized planning and control by intelligent logistics objects, is discussed as one possibility to cope with these new requirements [10, 11]. The idea of suchlike new technologies is to enable logistics objects (e.g. containers) to render their own decisions in order to adapt to a dynamic and complex environment [11]. According to Jedermann et al. [13] the Intelligent Container constitutes one example for an autonomous cooperation technology. It consists of RFID tags and sensor networks as well as software agents. The software agents are equipped with individual transport and monitoring instructions. A sensor network measures goods conditions and a RFID system ensures the transfer of the mobile agents. Thereby, the intelligent container is able to react autonomously to critical events like an exceeding of goods temperature thresholds during a transport process or traffic-jams under the consideration of pre-defined decision rules (fixed by the customer) [13]. In other words: It reacts without the intervention of human being.

Beside these technologies, McKelvey, Wycisk and Hülsmann mention that the use of autonomous cooperation technologies can lead to different possible outcomes, which are for example the bullwhip-effect and robustness [29]. The bullwhip-effect might occur through the use of autonomous cooperation technologies due to insignificant events (e.g. little shifts in customer demand which affects the whole logistics process). This effect grows between the processes and can lead to extreme events. The robustness in logistics processes can be understood as its resistibility against critical incidents as well its adaptation to changing environmental requirements. That means that both the flexibility as well as the stability in logistics processes has to be balanced [9].

Since this paradigm shift from centralized to decentralized decision making in logistics appears [28], it can be assumed that suchlike organizational changes originate risks, based on the characteristics of autonomous co-operating logistics objects. A classification of those possible risks shall be given in the next section.

III. Risks In Logistics

Many general definitions of risk in a scientific context are available (e.g. [12, 17, 20]). Mitchell [17] defines a risk as "*… the probability of loss and the significance of that loss to the organization or individual*". However, following these academic definitions, Hunt mentions that academia lags behind business due to the fact that business now considers risk in a much broader perspective [12]. Companies increasingly move forward to inter-firm cooperations in order to gain and maintain competitive advantages [14, 28]. Therefore, risk management more and more focuses on the level of supply chains and networks in order to cope with risks on this inter-firm level [18].

Consequently, existing risks from both theory and practice have to be identified and integrated in order to close the gap between theory and real business. Thereby, a broad perspective on risks can be applied. The idea is to categorize risks in order to obtain a framework containing classes of risks. As a result, risks can be arranged and described systematically within these classes. Moreover, the framework can be expanded, if new risks are revealed, which are not appropriate to any existing category. Thus, interrelations between a risk category and the characteristics of autonomous cooperation can be described and explained.

This paper follows the risk categorization of Harland, Brenchley and Walker [7], since they summarize various aspects to provide a comprehensive and broader multi-perspective view on risks. According to them risks can be divided into different types with regard to their impact on a business and its environment. They introduce eleven general risks in the context of logistics:

- **Strategic risks** are according to [23] effects influencing a company's business strategy.

Managers must determine what actions or behaviors might damage the company's strategic goals and release codes of conduct in order to avoid any damages to their business [23].

- **Operations risks** are following Meulbroek [16] events affecting a firm's internal ability to produce goods and provide services on an operational level (e.g. machine breakdowns or employees absenteeism). Simons [23] constitutes operations risks as "… results from the consequences of a breakdown in a core operating, manufacturing or processing capability".
- **Supply risks** (also input risks) negatively affect inward flows of any type of resource necessary for operations to take place (e.g. loss of raw materials delivery) [16].
- **Customer risks** impact the likelihood of customers placing orders and can be grouped with factors like product obsolescence (e.g. incertitude if customers place an order) [16].
- **Asset impairment risks** arise from a reduced utilization of an asset and can occur when the ability of the asset to generate income is reduced (e.g. technical machine lifespan is exhausted) [23].
- **Competitive risks** result from a limited ability of a firm to differentiate its products/services from those of competitors (e.g. the more standardized products / services are the harder differentiation becomes) [23].
- **Reputation risks** are based on Schwartz and Gibb [22] a decrease of a company's value due to losses of confidence among customers (e.g. contamination of the environment caused by a firm's production).
- **Financial risks** expose a firm to potential loss caused by changes in financial markets (e.g. changes in currency rates). They can also occur due to debtors' default (e.g. insolvency of a debtor) [16].
- **Fiscal risks** arise through changes in taxation, which influence a company's financial situation (e.g. increase of sales tax or release of new taxes) [16].
- **Regulatory risks** are corresponding to Bowen et al. [5], Smallman [24] and Meulbrook [16] risks affecting a firm's business due to changes in regulations like environmental regulation (e.g. limitation of CO_2-emission).
- **Legal risks** expose a firm to litigations with potential conflicts arising from customers, suppliers, shareholders, or employees (e.g. customer intoxication through insufficient tested medicine) [16].

After these risk classes have been briefly described they have to be discussed according to their sensitivity to the implementation of autonomous cooperation technologies.

IV. Autonomous Cooperation Technologies' Effects On Risks In Logistics

This section exemplarily discusses potential positive and negative effects on the introduced risks caused by the implementation and application of autonomous cooperation technologies in logistics.

Strategic risks might be reduced through the application of autonomous cooperation technologies due to enhanced potentials for a better differentiation from competitors. This can exemplarily be obtained through higher system adaptivity [9]. Adaptivity is increased because of interaction and autonomy of a system [9]. Contrary, since a company acts as a first mover in introducing these technologies, it bears all the risks and costs caused by the implementation. If these technologies are easily imitable, the innovating company has tremendous initial costs whereas the contributions are shared also to competitors to a certain degree if the technologies are successful on the long run [8]. This increases strategic risks of a company.

Operations risks could be positively affected by improved handling of e.g. machine breakdowns through a higher flexibility in the whole system [29]. A part in a production environment can e.g. autonomously change its route and take a different machine (if one is available), if the machine on the part's current route is down. Negative effects are caused by the fact that agents in a system and therewith the whole system might strive for local optima without being aware of it. This is caused by a decentralized decision making process achieved by autonomous cooperation. Agents have local decision rules they follow. They must not necessarily accord global goals of a system. Consequently, the global optimum of the system could be unknown to a single agent or it is not a high priority goal and therefore the agent might follow another goal.

Supply risks should be reduced by a faster reaction time to e.g. supplier unavailability. A system would automatically change a supplier if necessary in order to ensure the incoming flow of required goods and materials. On the other hand Wycisk et al. [29] mention the Bullwhip effect, which can occur in logistics processes and could be increased through the application of autonomous cooperation technologies. In combination with autonomous cooperation this effect is amplified because frequencies of feedback loops, reaction times and communication are shorter causing stronger extreme events [29]. Consequently, supply risks are boosted and high inventory in supplies becomes more likely.

Customer risks can be affected positively through autonomous cooperation. Through higher system flexibility a company is enabled to offer more customized and individualized products. This might attract more customers leading to more frequent orders. Consequently, customer risk is reduced because more frequent orders facilitate planning and reduce peak demands through better balanced machine utilization based on the better planning [2]. On the other hand customers might have to adapt to new technologies and interfaces in order to stay compatible with the standards and technologies used by a company (e.g. RFID requires suitable reader). This might cause denial among customers finally resulting in higher customer risks because order frequency decreases and planning is hampered.

Asset impairment risks are reduced through the application of some autonomous cooperation technologies. Considering e.g. software of agents comprised of algorithms, the risk of asset impairment is diminished through adaptability and expandability of software in general. However, this leads directly to a negative effect. As software is easily expandable it is simultaneously also easily to copy what significantly enhances the risk of asset impairment. Therefore, patents could protect innovations connected to autonomous cooperation affecting assets.

Competitive risks might be downsized by reason that new competitive advantages can be obtained through increased strategic adaptivity of a system [9]. Agents of a system equipped with autonomous cooperation technologies can autonomously change their structures based on information obtained through their interaction. Thereby, a system can perform required changes in its structures in order to react to e.g. environmental changes (e.g. new laws). As a result, competitive risks are reduced. Contrariwise, this enhanced strategic adaptivity might also increase competitive risks. The reason is that system structures change in a non-predictable manner. Consequently, a system might move into local optima, what cannot be determined or even fixed by human interventions due to the autonomy of the system. Thus, a company might become less competitive.

Reputation risks could be affected positively through the innovative stand of autonomous cooperation technologies. Thus, a company might derive benefits regarding its reputation decreasing reputation risks because the company is perceived as an innovative one. Otherwise, customers might be skeptical and decline a new technology due to missing experience in daily life. Furthermore, the error rate, which can occur by the use of new technologies, can be higher according to established technologies. This causes dissatisfactions among customers and reputation of a company is compromised. Hence, reputation risks could also be amplified.

Fiscal risks might be influenced both positive and negative but this is hardly determinable. Since autonomous cooperation is relatively new and application is not wide spread in practice by now, fiscal issues are not known so far. However, there might be fiscal risks (positive or negative), which might occur due to e.g. the investment costs into autonomous cooperation technologies. Therefore, this class has to be considered within an overall risk framework in order to assign potential prospective fiscal risks adequately if they come up.

Financial risks may be diminished because autonomous cooperation enables a system to shorten throughput and react more flexible to changes, since agents equipped with e.g. RFID tags within sensor networks are able to interact and act autonomously [27]. Thus, the time a unit is in production as well as stocks might be decreased and less capital is tied in production. Consequently, financial risks decrease. On the other hand, new technologies as autonomous cooperation technologies require high implementation and maintenance costs. Since outcomes of suchlike technologies are partially still hidden and not just beneficial, resulting effects might also be negative. Thereby, financial risks are increased as the costs are incurred and the consequences are not fully known.

Regarding **regulatory risks**, through autonomous cooperation a company could not only monitor and track the exact environmental conditions during transportation of goods with the help of sensor networks. It can also react autonomously if temperature thresholds are exceeded (e.g. intelligent container). Thereby, an e.g. continuous cooling level of perishable goods can be guaranteed and also proofed reducing regulatory risks. However, through the non-determinism of suchlike systems their behavior cannot be estimated in advance. Consequently, the risk of unauthorized sharing of sensitive data and information can happen. Thus, conflicts regarding privacy or compromised information can arise negatively affecting regulatory risks.

Finally, **legal risks** can be reduced due to the fact that a complete tracking becomes possible. Thus, in the case of litigation a company can proof all actions of a related process. Legal risks might also be enhanced because lots of data is collected. Thereby, privacy issues might emerge leading to litigations. Thus, legal risks would be increased due to the fact that customers do not know the intention of data utilization. Therefore, they might sue a company in order to force it to formulate clear rules about what data to collect and safe and what not.

In conclusion, a net effect (neither positive nor negative) between the implementation of autonomous cooperation technologies and the risk classes in logistics cannot be determined. However, some hypothetic effects are revealed and exposed to the reader.

V. Conclusions

The overarching aim of this paper was to identify effects on potential risks caused by the implementation and utilization of autonomous cooperation technologies. Some exemplary hypotheses according to the overarching aim were stated and briefly discussed in section IV. There are on the one hand several potential positive effects of the implementation of autonomous cooperation reducing risks in logistics. On the other hand also negative effects were introduced leading to increased risks in logistics. In summary, effects (positive and negative) might be induced but net effects are just discussed but not measured. Furthermore, the hypotheses generated in this paper are only exemplary and give rise to the necessity of further developments of hypotheses and following verifications in future research. Hence, further theoretical investigations as well as an empirical study should be applied in order to verify the risen hypotheses, reveal new hypothesis and transfer them into a practical risk management. Thus, the overall risk a logistics company is exposed to can be diminished.

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