DYNAMIC CAPABILITIES THROUGH AUTONOMOUS COOPERATION IN INTERNATIONAL SUPPLY NETWORKS?

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Abstract: *Logistics systems – understood as Complex Adaptive Logistics Systems – face the risk of dominant logics, path dependencies and resulting lock-in situations on both the level of the involved companies as well as the level of entire supply networks. The concept of dynamic capabilities is the current pre-dominant research paradigm for the explanation of organisational success and the ability to avoid such lock-ins, respectively to cope with them. Hence, the question arises, how the evolvement of dynamic capabilities in CALS can be fostered. Therefore, the paper discusses contributions and limitations resulting from the organisational principle of autonomous cooperation and its technological realisations (through e.g. RFID tags or sensor networks) for developing dynamic capabilities understood as the ability to replicate and reconfigure organisational resources.*

Keywords: Dynamic Capabilities, Supply Chain Flexibility, Strategic Flexibility, Knowledge Management, Complex Adaptive Logistics Systems, Autonomous Cooperation

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1. Introduction

The risk of being trapped in a lock-in situation – an inflexibility to leave an inefficient system state – is something that all kinds of companies in different branches encounter (e.g. David, 1994, Liebowitz and Margolis, 1995). Logistics companies are thereby no exception. According to SMITH, LANCIONI AND OLIVA (2005) *"[…] inertia in the management of supply chains can seriously affect the operational efficiency and productivity of a company"* (Smith, Lancioni and Oliva, 2005, p. 626). Moreover, today's logistics networks are not characterised by linear supply chain structures, but by the entanglement of several supply chains crossing each other. Therefore, several authors stated them to be complex adaptive systems (CAS) (Choi, Dooley and Rungtusanatham, 2001, Surana et al., 2005, Pathak, Dilts and Biswas, 2004, Pathak et al., 2007), wherefore they are also called complex adaptive logistics systems (CALS) (McKelvey, Wycisk and Hülsmann, 2009, Wycisk, Mckelvey and Hülsmann, 2008). These systems are characterised by the involvement of large amounts of autonomous, adaptive, heterogeneous companies (e.g. Wycisk, Mckelvey and Hülsmann, 2008), who however all face risks of path dependencies and resulting lock-ins. Therewith, not only the performance of the whole supply networks, but also of the single companies within the networks is endangered by the risk of managerial inertias.

The pre-dominant research paradigm for explaining a successful coping with such dominant logic-driven path dependencies and resulting lock-ins is the idea of dynamic capabilities (O'Reilly and Tushman, 2008, Schreyögg and Kliesch-Eberl, 2007). According to TEECE, PISANO AND SHUEN (1997) dynamic capabilities describe *"[…] the capacity to renew competences so as to achieve congruence with the changing business environment […]"* through "[…] *appropriately adapting, integrating, and reconfiguring internal and external organizational skills, resources and functional competences to match the requirements of a changing environment"* (Teece, Pisano and Shuen, 1997, p. 515). BURMANN (2002) operationalises this through transforming the underlying idea into the two dimensions: Replication ability (the ability to codify and transfer knowledge) and reconfiguration ability (the ability to abstract and absorb knowledge) (Burmann, 2002).

One approach that has been discussed in the associated literature for increasing the performance in logistics systems is the shift from a centralised control to a higher degree of the organisational principle autonomous cooperation via implementation of associated technologies, such as RFID-tags or sensor networks (e.g. Hülsmann, Grapp and Li, 2008, Hülsmann and Grapp, 2005). Suchlike technologies allow non-human logistics entities to interact with others autonomously (Jedermann and Lang, 2008), which led to the term of 'smart parts' in logistics (Wycisk, Mckelvey and Hülsmann, 2008). With an increasing usage of 'smart parts', the CAS-perspective would become not only useful on the interorganisational level – the supply network perspective – but also on the intraorganisational level: Organisations consisting of large amounts of heterogeneous, autonomous and interacting agents, capable of influencing the system's performance via learning algorithms can be regarded also as CALS. However, according to MCKELVEY ET AL. *"Real-world smart parts supply networks do not yet exist […]"* (Wycisk, Mckelvey and Hülsmann, 2008, p. 116); the CAS- perspective on the company level is still a vision. Therefore, the question arises, how the usage of 'smart parts' could contribute to a logistics company's or a supply network's ability to codify, transfer, abstract and absorb knowledge. In other words: How does the implementation of the organisational principle autonomous cooperation affect the evolvement of dynamic capabilities in a CALS?

In order to address this overarching research question, descriptive, analytical and practical objectives are pursued, which are guiding the further structure of this paper:

On a descriptive level the paper follows two sub goals: First, it intends to present the concept of dynamic capabilities as they are understood and operationalised by BURMANN (2002) and their necessity in logistics networks **(section 2)**. Second, the vision of supply networks and involved organisations as CALS and the concept of autonomous cooperation as the basis for technological and organisational possibilities for its realisation in the 'real world' shall be depicted **(section 3)**. Both serve as the descriptive basis for the analysis of effects that emanate from the constitutive characteristics of autonomous cooperation on the dimensions of dynamic capabilities. On an analytical level, the causal interrelations between the constitutive characteristics of autonomous cooperation and the dimensions of dynamic capabilities shall be addressed. This serves the revelation of contributions and limitations that arise from an increased degree of autonomous cooperation in a CALS on the evolvement of dynamic capabilities **(section 4)**. On a praxeological level, first managerial implications shall be deduced and further research requirements regarding a concretisation of the developed hypotheses and their empirical validation shall be derived **(section 5)**.

2. The Need for Dynamic Capabilities in International Supply Networks

2.1. Risks of Strategic Inflexibilities in International Supply Networks

Practitioners in supply chain management indicate that overcoming inertia is one of the biggest leadership problems CEOs of logistics companies face (Pellet, 2002). HANNAN AND FREEMAN (1984) describe structural inertia as follows: *"[…] structures of organizations have high inertia when the speed of reorganization is much lower than the rate at which environmental conditions change"* (Hannan and Freeman, 1984, p. 151). The underlying idea is that companies face the risk of behavioural lock-in situations based on evolving path dependencies.

In the path dependency literature, a lock-in situation describes a situation in which one particular technology has been adopted, whereas other technologies are unlikely to be chosen by the respective users, independent on their superiority or inferiority (David, 1985). Suchlike path dependencies and technological lock-ins are characterised by the peoples' increasing inflexibility to change technologies although others might be superior to the current one in use (David, 1985). In analogy to that, a behavioural lock-in describes a situation in which only a restricted amount of all theoretically thinkable managerial options is effectively or at least seems to be selectable (Dievernich, 2007, Schreyögg, Sydow and Koch, 2003, Ackermann, 2003). Hence, organisational lock-in situations are characterised by a strategic inflexibility.

AAKER AND MASCARENHAS (1984) define **strategic flexibility** as *"[…] the ability of the organisation to adapt to substantial, uncertain and fast-occurring (relative to required reaction time) environmental changes that have a meaningful impact on the organisation's performance"* (Aaker and Mascarenhas, 1984, p. 74). That is, according to ANSOFF (1984) as well as THOMPSON AND STRICKLAND (1983), the extent to which an organisation is free to change its strategies and policies (Ansoff, 1984, Thompson and Strickland, 1983.). It can be assumed that the changes in organisational environments have accelerated in the last decades due to – beside others – continuous and fast developments in information and communication technologies, like RFID or sensor networks (e.g. Angeles, 2005, Spekman and Sweeney II, 2006, Ngai et al., 2008). Hence, organisations are required to perpetually adapt their choices of actions to realise long-term organisational goals. This includes the need for a continuous adaptation of the organisations themselves (e.g. Hedberg, Bystrom and Starbuck, 1976, Nadler and Tushman, 1986, Kilmann and Covin, 1990).

If in a lock-in situation the extant managerial options – the organisational strategy – fit perfectly to the organisation's environmental requirements, a lack of flexibility respectively a lock-in situation does not have any negative effects on the organisational performance. In such a situation new competences would not have to be developed or regenerated; alternative strategic logics are not necessary, and so forth. However, logistics companies face highly dynamic competitive surroundings (Klaus and Kille, 2008), which makes such a situation – regarded over time – very unlikely. Hence, organisations, which are unable to alter their strategic behaviour according to environmental requirements, run the risk of becoming inefficient. This conforms to BARNES, GARTLAND AND STACK (2004) who describe behavioural lock-ins as situations in which the respective agent – a certain decision maker or a whole organisation – is unable to alter her/its behaviour, which *"[…] is 'stuck' in some sort of inefficiency or sub-optimality"* (Barnes, Gartland and Stack, 2004, p. 372). Consequently, an organisational lock-in situation can be defined as an inflexibility to leave an inefficient organisational state.

Logistics companies are usually not only involved in one or two single linear but in manifold different supply chains. Therefore, the resulting risk of inertias and lock-ins affects not only single companies but might affect also the whole underlying network of supply chains. These manifold supply chains create together highly complex and non-linear webs of logistics activities where information, products and finances are transferred between various suppliers, manufacturers, distributors, retailers and customers (Surana et al., 2005).

One example: Daimler Chrysler works with about 1500 suppliers. One of their main first-tier suppliers for the "Grand Cherokee" Textron Trim, in turn, has about 300 suppliers and provides besides Daimler Chrysler its competitors such as BMW, Nissan, Toyota and Honda (Choi and Hong, 2002). The involved supply chains are crossing each other at some points in the single value adding steps, which leads not only to direct interdependencies between the involved organisations, but as well to indirect ones (Hülsmann and Berry, 2004). To take on the chosen example, in 2002 Textron Trim made 50% of their sales with Daimler Chrysler (Choi and Hong, 2002). If Daimler Chrysler would, for some reasons, change its main first tier supplier for the "Grand Cherokee", Textron Trim would probably have to decrease production units, which, in turn, might influence their costs- and therewith their price structures. Hence, other customers of Textron Trim, such as BMW, would be indirectly affected by the supplier decision of Daimler Chrysler. The manifoldness of existent, and potential interdependencies between involved organisations in supply networks is boosted by an ongoing trend of an increasing internationalisation of firm's activities (e.g. Hülsmann and Berry, 2004, Whitley, 1994, Lado and Maydeu- Olivares, 2001). HÜLSMANN AND GRAPP (2005) speak in this context of international supply networks (Hülsmann and Grapp, 2005).

Assuming the risk of inertia occurs in at least some of the participating companies, the resulting inflexibilities to leave an inefficient system state might affect also the efficiency of the whole international supply networks. Consequently, the question arises, how logistics companies and whole international supply networks can avoid and cope with lock-ins and underlying path dependencies.

2.2. Dynamic Capabilities for Overcoming Lock-Ins in International Supply Networks

O'REILLY AND TUSHMAN (2008) state that overcoming *"[…] inertia and path dependencies is at the core of dynamic capabilities"* (O'Reilly and Tushman, 2008, p. 187). In its original concept TEECE AND PISANO (1994) and TEECE, PISANO AND SHUEN (1997) picked up the main assumptions of the resource-based view (based on Selznick, 1957, Penrose, 1959, Wernerfelt, 1984, Barney, 1991) and the competence-based view (Teece, Pisano and Shuen, 1997, based on Sanchez, 2004, Prahalad and Hamel, 1990) but argued that competitive advantages do not primarily originate from the resources and competences themselves (Teece, Pisano and Shuen, 1997, Teece and Pisano, 1994). Instead, a firm's long-term success is dependent on the capabilities to *"[...] shape, re- shape, configure and reconfigure the firm's asset base so as to respond to changing technologies and markets"* (Augier and Teece, 2007, p. 179).

BURMANN (2002) took on these considerations and conceptualised dynamic capabilities as managerial and organisational processes that represent an organisation's ability to **replicate** (in TEECE ET AL.`S (1997) words: to integrate) and **reconfigure** its resource base. The ability to learn in turn is regarded as an important component of replication and reconfiguration abilities. By managerial and organisational processes TEECE ET AL. (1997) refer to *"[…] the way things are done in the firm, or what might be referred to as its routines, or patterns of current practice and learning."* (Teece, Pisano and Shuen, 1997, p. 518). These *processes* are influenced by and influence on the one hand the evolutionary *paths* of dynamic capabilities and on the other hand by the underlying resource *positions.*

The resource *positions* of an organisation determine its routines of actions, since they in turn develop out of repeatable combinations of resources (Burmann, 2002). Thereby, TEECE

ET AL. (1997) deploy a wide definition of resources, which include material assets such as certain technology resources, but also a wide range of immaterial resources such as reputational, structural or institutional resources (Teece, Pisano and Shuen, 1997). The interplay between replication and reconfiguration abilities is regarded as a meta-ability, which determines the adaptivity, therewith the competitive advantages of an organisation and hence, its performance (Burmann, 2002) (see Figure 1).

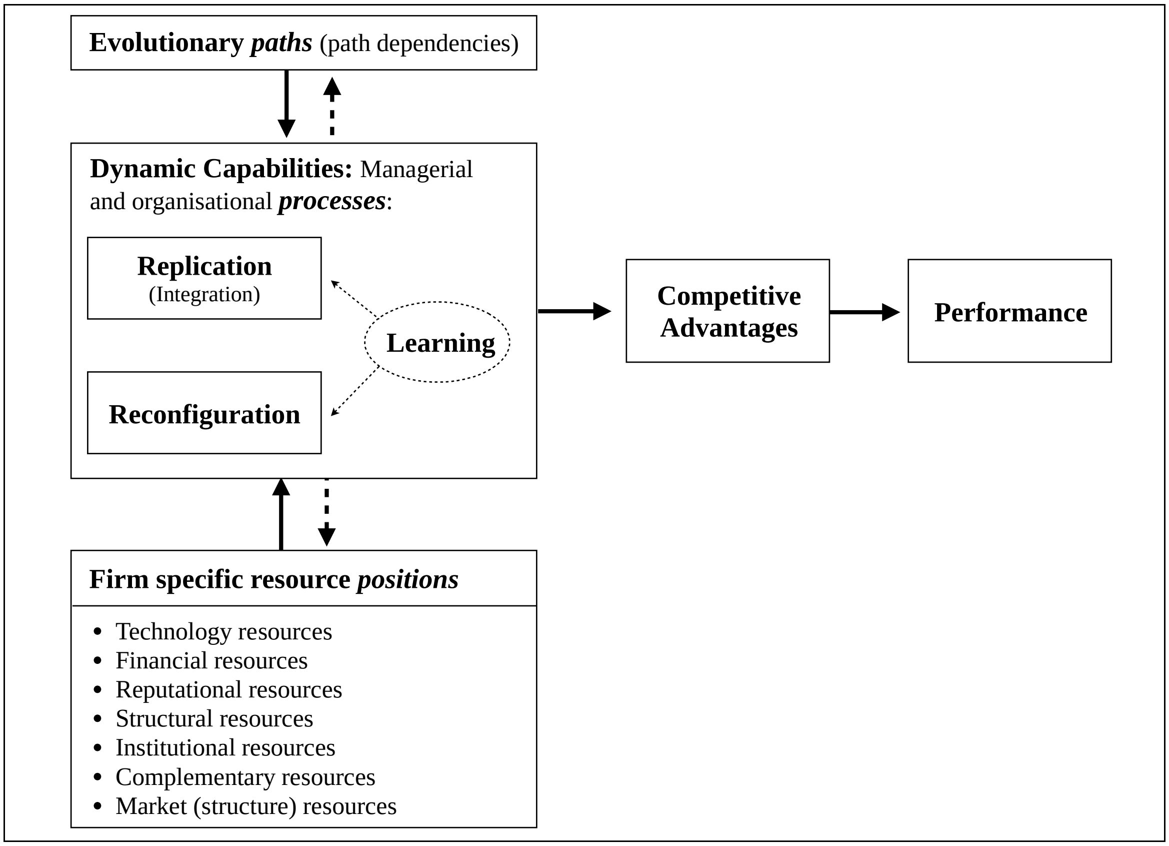

Figure 1: Dynamic capabilities approach as an overview (based on Teece, Pisano and Shuen, 1997, Burmann, 2002)

The underlying meta-ability of dynamic capabilities, in turn, is based on knowledge of and within organisations, which is assumed to play a vital role for organisational success by a multitude of authors (e.g. Quinn, 1992, Drucker, 1993, Spender and Grant, 1996, Kusunoki, Nonaka and Nagata, 1998, Grant, 2002). Therewith, dynamic capabilities can be defined as knowledge-based path dependent managerial and organisational processes of replicating and reconfiguring resources.

Replication Ability

Replication ability is described as the ability to replicate existent operative process-related abilities of the organisation's on-going operations. This enables first, a fast and efficient growth of firms. Second, it shows to what extent a firm is able to comprehensively understand the configuration and functionality of its capabilities (Burmann, 2002), which in turn is the basis for their improvement and further development (Teece, Pisano and Shuen, 1997).

Referring to empirical studies such as NOBEOKA AND CUSUMANO (1997) and TEECE (1987), BURMANN (2002) states that a high replication-ability results in a higher **velocity of organisational (re-)actions** (Burmann, 2002, referring to Nobeoka and Cusumano, 1997, Teece, 1977). If an organisation is able to replicate patterns of action (i.e. routines) that proved successful in the past, it can react faster on environmental circumstances that demand for these patterns, compared to an organisation that needs to develop them first.

BURMANN (2002) identifies two dimension of replication ability:

- Knowledge Codification
- Knowledge Transfer (Burmann, 2002).

Knowledge Codification

ANCORI ET AL. (2000) state that *"to be treated as an economic good, knowledge must be put in a form that allows it to circulate and be exchanged."* (Ancori, Bureth and Cohendet, 2000, pp. 255-256). Hence, successful codification means to transform implicit (tacit) knowledge, which evolves over time through absorption of data, information and practical experiences (Burmann, 2002), into explicit knowledge (Nonaka, Mader and Takeuchi, 1997). TEECE (1981) therefore understands the codification of knowledge as *"[…] the transformation of experience and information into symbolic form"* (Teece, 1981, p. 83).

Codifying knowledge in a way that individuals can learn from it in turn requires that the information receiver is able to understand the information. With recourse to the action-orientation of relevant knowledge (Zahn and Tilebein, 2000), ZOLLO AND WINTER (2002) point out that the main effort of knowledge codification is "[…] *to understand the causal links between the decisions to be made and the performance outcomes to be expected"* (Zollo and Winter, 2002, p. 342). In the words of DAFT AND WEICK (1984) this corresponds to the ability of giving the data a meaning – an interpretation (Daft and Weick, 1984). Hence, knowledge codification requires a shared understanding and interpretation of the messages within the organisation. Consequently, knowledge codification can be defined as the transformation of available knowledge into symbolic forms that are understandable and interpretable in the same way by the entire organisation and its members.

Knowledge Transfer

ARGOTE AND INGRAM (2000) describe knowledge transfer in organisations as *"[…] the process through which one unit (e.g., group, department, or division) is affected by the experience of another"* (Argote and Ingram, 2000, p. 151). However, this understanding implies that knowledge is only based on experience. Simple information on cause-effects-relations, without personal experience would therewith be excluded from the transfer of knowledge. SZULANSKI (2000) refers to knowledge transfer *"[…] as a process in which an organization recreates and maintains a complex, causally ambiguous set of routines in a new setting"* (Szulanski, 2000, p. 10). This understanding focuses on routines as a special kind of knowledge and is therefore an also too narrow view, since it excludes knowledge that has not been solidified in routines yet.

In order to avoid such exclusions, it is reasonable to select a wider perspective. BOU-LLUSAR AND SEGARRA-CIPRÉS (2006) refers to knowledge transfer as *"[…] the exchange of knowledge between units within a firm (internal transfer) or between different firms (external transfer)"* (Bou-Llusar and Segarra-Ciprés, 2006, p. 105). Furthermore, SZULANSKI (1996) argues that a transfer of knowledge has to pass different stages until it is completed: First, the transfer has to be initiated through a managerial decision. Second, the transfer has to be implemented through exchanges of resources between the source and the recipient of the knowledge. Third, in the ramp-up stage the recipient utilises the knowledge. Fourth, the received knowledge is integrated once first satisfactory results with the new knowledge have been achieved (Szulanski, 1996, pp. 28-29). Not until all four stages have been passed one can speak of a successful knowledge transfer. Furthermore, ZHAO AND ANAND (2009) state that *"when firms transfer organizational capabilities from one unit to another, they transfer not only individually held skills, but also organizationally embedded knowledge or collective knowledge"* (Jane Zhao and Anand, 2009, p. 960). Following this understanding, knowledge transfer can be defined as the devolvement process of individual or collective knowledge from one application place to another within an organisation or within a cooperation between organisations, initiated by an organisation (Burmann, 2002).

Reconfiguration Ability

According to LAVIE (2006), a reconfiguration process entails the substitution of capabilities (Lavie, 2006). Similarly, TUSHMAN AND ANDERSON (1986) advocate the evolutionary mechanisms variation-selection-retention in the course of competence-destroying or competence-enhancing processes for the initiation of organisational change (Tushman and Anderson, 1986). Old capabilities that become obsolete in a changed organisational environment are replaced by either entirely new capabilities or old capabilities that have been adapted. Hence, **the ability to reconfigure organisational capabilities results in a higher scope of managerial options** (Lavie, 2006), since the higher scope of potential new or old and adapted capabilities enable the organisation's management to choose from a wider pool of managerial actions, based on potential capabilities.

BURMANN (2002) identifies two dimension of reconfiguration ability:

- Knowledge Abstraction
- Knowledge Absorption (Burmann, 2002).

Knowledge Abstraction

BOISOT (1998) describes knowledge abstraction as the ability to generalise knowledge suitable for a limited number of applications to a wider range of applications (Boisot, 1998). In order to do so, the knowledge has to be reduced to its essentials, i.e. its underlying structure, which reveals certain cause-and-effect relationships (Burmann, 2002) that are not directly observable in the knowledge's codification (Boisot, 1998). BURMANN (2002) states therefore that knowledge abstraction means to disengage knowledge from its prior context in order to make it applicable in other contexts. In its pure form, it leads to a complete decontextualisation (Burmann, 2002). According to NAHAPIET AND GHOSHAL (1998) the abstraction as well as the reflection of knowledge is the key to transform experience-based knowledge into theoretical knowledge on cause-and-effect-relations (Nahapiet and Ghoshal, 1998).

Therefore, the essence of the ability to abstract knowledge can be interpreted as the flexibility to engage the underlying scheme of certain knowledge – whether it is on strategic logics, management processes, chains of resources, operations or application fields for skills and capabilities – to other fields of appliance than its original one. In other words, knowledge abstraction can be defined as the ability to disengage knowledge from their contexts and engage it to other contexts.

Knowledge Absorption

The origins of the idea of knowledge absorption can be found in the work of COHEN AND LEVINTHAL (1990) on absorptive capacity. That is *"[…] the ability of a firm to recognize the value of new external information, assimilate it, and apply it to commercial ends"* (Cohen and Levinthal, 1990, p. 128). They distinguish further between the absorptive capacity of an individual and an organisation (Cohen and Levinthal, 1990). ZAHRA AND GEORGE (2002) identified four dimensions of absorptive capacity: Acquisition, assimilation, transformation and exploitation of knowledge (Zahra and George, 2002).

Thereby, the ability to acquire knowledge refers to *"[…] a firm's capability to identify and acquire externally generated knowledge that is critical to its operations."* The ability to assimilate knowledge describes the organisation's ability to analyse, process, interpret and understand externally obtained information (Zahra and George, 2002, p. 189). The ability to transform knowledge reflects an organisation's capability to *"[…] develop and refine the routines that facilitate combining existing knowledge and the newly acquired and assimilated knowledge."* Finally, the ability to exploit knowledge refers to the capability to incorporate acquired or transformed knowledge into the operations of an organisation in order to *"[…] refine, extend, and leverage existing competencies or to create new ones"* (Zahra and George, 2002, p. 190).

Subsuming, these processes of knowledge acquisition, assimilation, transformation and exploitation lead to an internalisation of knowledge. According to BOISOT (1995) that is the key element of knowledge absorption (Boisot, 1995). Hence, knowledge absorption can be defined as the organisational process of internalising knowledge through its acquisition, assimilation, transformation and exploitation (Zahra and George, 2002, Boisot, 1995).

Figure 2 subsumes the dimensions and sub-dimensions of dynamic capabilities and their definitions.

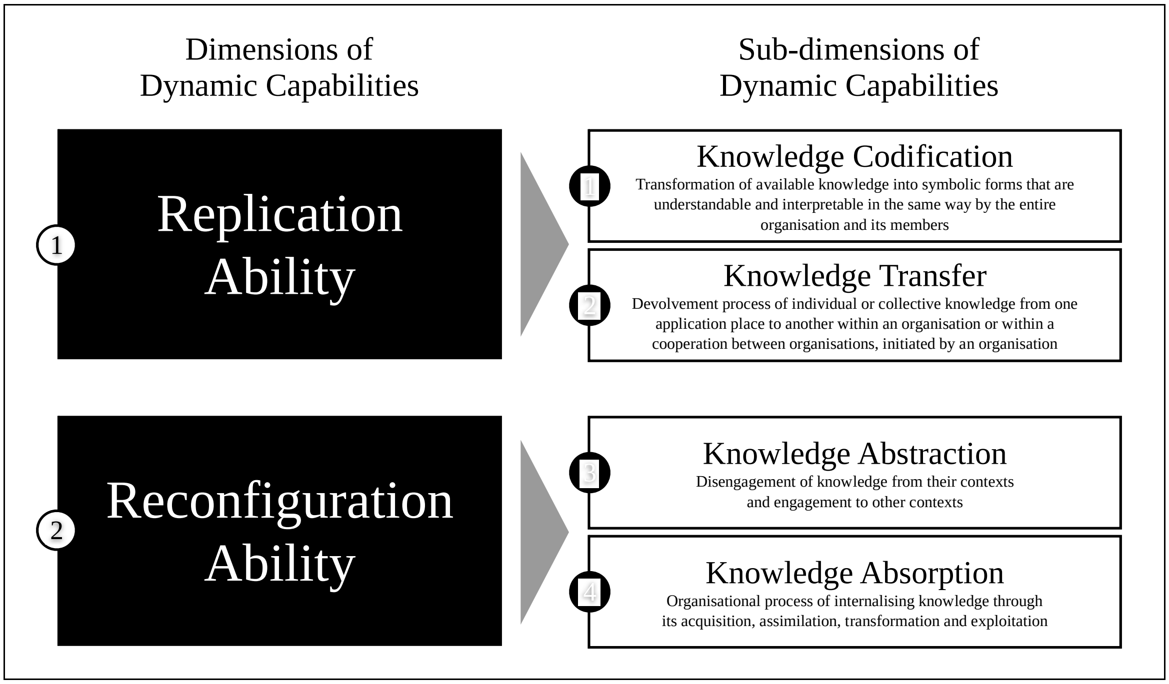

Figure 2: Dimensions and sub-dimensions of dynamic capabilities (based on Burmann 2002).

Two developments illustrate the increasing necessity for logistics companies to develop dynamic capabilities in terms of replication and reconfiguration abilities: First, the risk of lock-ins is generally a large problem in the leadership of supply chains (Smith, Lancioni and Oliva, 2005, Pellet, 2002). Managers are always faced with the risk that the “way things are done” solidify without a contextual reason (Prahalad and Bettis, 1986, Bettis and Prahalad, 1995, Bettis and Wong, 2003). Second, the performance of a logistics companies is often largely dependent on the performance of the supply networks in which they are operating. Ergo, logistics companies are not only endangered by inertias of their own managers, but also by inertias of other participants in the supply networks.

Hence, one important task for supply chain management is to enable both the own company as well as the whole supply network in which it is operating to avoid and to cope with the risk of lock-ins. Following BURMANN (2002), it is therefore necessary that knowledge codification, transfer, abstraction and absorption happen on both levels: Intraorganisational, to keep the company competitive within a supply network, as well as interorganisational, to keep the whole international supply network competitive against other supply networks.

Consequently, the question arises, which determinants influence the evolvement of dynamic capabilities not only on one, but on two levels of perspective at the same time. More specific: How can logistics companies ensure that knowledge-based activities (codification, transfer, abstraction and absorption) are carried out within the company and between the company and their business partners in the supply network, without unwanted spillovers of knowledge (Ibrahim, Fallah and Reilly, 2009) to supply network participants that are at the same time competitors?

In order to address this research question, a complex adaptive systems perspective will be applied in order to reveal determinants of a modern supply network's structure, which can be varied by implementing technologies like RFID or sensor networks.

3. Autonomous Cooperation for Realising Complex Adaptive Logistics Systems (CALS)

3.1. Dimensionalities of CALS

Modern perspectives on logistics systems look less on individual and isolated supply chains than on the underlying networks in which these supply chains are integrated (e.g. Choi, Dooley and Rungtusanatham, 2001, Surana et al., 2005, Pathak, Dilts and Biswas, 2004, Pathak et al., 2007, McKelvey, Wycisk and Hülsmann, 2009, Wycisk, Mckelvey and Hülsmann, 2008, Choi and Hong, 2002). Several authors argue that supply networks can be regarded as Complex Adaptive Systems (Choi, Dooley and Rungtusanatham, 2001, Surana et al., 2005, Pathak, Dilts and Biswas, 2004, Pathak et al., 2007, McKelvey, Wycisk and Hülsmann, 2009, Wycisk, Mckelvey and Hülsmann, 2008). Thereby, it can be distinguished between the following two dimensionalities: the whole *supply network*, consisting of the involved companies and the single *companies*, consisting of single organisational entities.

Supply network dimensionality:

This dimensionality describes logistics systems as international supply networks, consisting of a multitude of companies involved in national and cross-border logistics processes (Hülsmann and Grapp, 2005).

On an **individual level**, many organisations **interact** with each other (Choi, Dooley and Rungtusanatham, 2001, Surana et al., 2005) (e.g. exchange of goods and finances between Daimler Chrysler and its 1500 suppliers), they are **heterogeneous** (e.g. different suppliers have different resources, competences and goals) and they are **able to learn** (e.g. Daimler Chrysler would probably cut prices or change the supplier if the supplied products were of bad quality) (McKelvey, Wycisk and Hülsmann, 2009, Wycisk, Mckelvey and Hülsmann, 2008).

On an **intra-systemic level**, the involved companies initiate their actions by themselves, as far as they are not controlled by another entity or organisation in the supply network (e.g. Daimlers first tie suppliers choose their suppliers without Daimlers direct control) - they are **autonomous**. Hence, the whole supply network **organises itself** without any top-down orders regarding its structure (Choi, Dooley and Rungtusanatham, 2001, Surana et al., 2005). Despite the absence of a central control entity of the network, it is neither in a state of total uncontrolled chaos nor leads the self-organisation to a state of total predetermined control. Rather, it exists in a so-called **‘melting zone’** between the “edge of chaos” and the “edge of order” (Kauffman, 1993) (e.g. although the supply network of Daimler is not fully controllable a supply network structure emerges at any time that ensures its operational capability).

On an **inter-systemic level**, it has to be taken into consideration that supply networks are not isolated from the rest of the world. Rather, they **co-evolve** with other logistics systems (McKelvey, Wycisk and Hülsmann, 2009, Wycisk, Mckelvey and Hülsmann, 2008) (e.g. Textron’s other supply networks) as well as non-logistics systems (e.g. the banking sector). New structures emerge and elapse all the time without any super ordinate controlling entity; in other words: **self-organisation** takes place (Choi, Dooley and Rungtusanatham, 2001, Surana et al., 2005, McKelvey, Wycisk and Hülsmann, 2009, Wycisk, Mckelvey and Hülsmann, 2008). Therefore, suchlike logistics networks can be called **Complex Adaptive Logistics Systems (CALS)**.

Company dimensionality:

By zooming the perspective in the hitherto regarded individual level on which the single companies constitute the logistics system’s elements, they, in turn, can also be regarded as Complex Adaptive Systems: Beside employees, the organisation-system’s elements in a logistics context are the so-called ‘smart parts’. According to MCKELVEY, WYCISK AND HÜLSMANN (2009) ‘smart parts’ describe *“[...] logistics entities, which posses the capabilities of interaction and autonomous decision-making through the usage of modern communication and information technologies, such as RFID, GPS, sensor networks and electronic markets [...]”* (McKelvey, Wycisk and Hülsmann, 2009, p. 478).

On an **individual level**, these technologies enable logistics entities like ships, containers or even single products to exchange information with each other (e.g. a RFID-tagged product sends its routing goals to containers, whereas they, in turn, respond whether they fit into their routing plans or not); in other words, they **interact**. Differing characteristics (e.g. space of containers) or behavioural programming (e.g. preferring of fast vs. cheap routes) leads to certain **heterogeneity** between them. 'Intelligent features' implemented in the programming of the 'smart part's behavioural rules might **enable them to learn** to a certain degree (e.g. a RFID-tagged container equipped with the goal to go after the fastest route might remember previous routes and learn from whether they were fast or slow) (McKelvey, Wycisk and Hülsmann, 2009, Wycisk, Mckelvey and Hülsmann, 2008).

On an **intra-systemic level**, logistics entities can be enabled to render their decisions about their next steps on their own (e.g. a RFID-tagged product might be allowed to render the decision about which routing option to take without the need for a confirmation of a central control entity) - hence, they are **autonomous**. A company that allows its elements to act autonomously, in turn, allows a certain degree of **self-organisation** (e.g. the evolvement of certain standard routes and routing alternatives for its products). A pre-condition for this is that the structure of the transportation system is neither pre-configured (e.g. the products are forced to take given routes or take pre-determined logistics service-providers) nor that it is totally uncontrolled (e.g. products take whatever routes they want and cannot be traced back) – rather it exists within the **'melting zone'**. Hence, companies, which feature these characteristics, can also be called **Complex Adaptive Logistics Systems (CALS)** (McKelvey, Wycisk and Hülsmann, 2009, Wycisk, Mckelvey and Hülsmann, 2008).

According to authors like CHOI, DOOLEY AND RUNGTUSANATHAM (2001), SURANA ET AL. (2005), PATHAK, DILTS AND BISWAS (2004), PATHAK ET AL. (2007), MCKELVEY, WYCISK AND HÜLSMANN (2009) and WYCISK, MCKELVEY AND HÜLSMANN (2008) is the existence of these characteristics in the supply network dimensionality not questionable. In the company dimensionality and especially referring to non-human logistics entities on the contrary this is largely dependent on two aspects: First, how much interaction, learning-abilities, heterogeneity, autonomy and self-organisation is firstly possible from a technological as well as from an organisational point of view? Second, how much is allowed by the management of the respective company or supply network?

3.2. Technological and Organisational Realisation of CALS through Autonomous Cooperation

The technological realisation refers to the »possible smartness« of logistics entities in the real world. Although there are restrictions in, for instance, the parts' abilities to learn (Wycisk, Mckelvey and Hülsmann, 2008), ongoing developments in associated communication and information technologies lead to the assumption that these restrictions will more and more disappear in the future. This refers especially to developments in the logistics elements' abilities to process information, to render and to execute decisions on their own. The basis for suchlike artificial decision-making abilities is given by the use of technologies that enable logistic elements to get information about their environment: For the logistics objects' identification RFID (radio frequency identification) can be used, for the positioning GPS (global positioning systems) and for the communication between them UMTS (universal mobile telecommunications system) or WLAN (wireless local area network) (Scholz-Reiter, Windt and Freitag, 2004).

The underlying organisational principle is the idea of autonomous cooperation (Wycisk, Mckelvey and Hülsmann, 2008, Hülsmann and Grapp, 2005, e.g. Scholz-Reiter, Windt and Freitag, 2004, Hülsmann and Wycisk, 2005, Philipp, Böse and Windt, 2006, Windt and Hülsmann, 2007). According to WINDT AND HÜLSMANN autonomous cooperation can be described as *"[...] processes of decentralised decision-making in heterarchical structures. It presumes interacting elements in non-deterministic systems, which possess the capability and possibility to render decisions."* (Windt and Hülsmann, 2007, p. 8). Hence, certain degrees of the following five constitutive characteristics can be observed in autonomously controlled logistics processes:

- Decentralised decision-making,
- Autonomy,
- Interaction,
- Heterarchy, and
- Non-determinism.

Decentralised Decision-making: FRESE (1993) and LAUX (1998) describe decision-making as the goal-oriented selection between action alternatives (Frese, 1993, Laux, 1998). In contrast to externally controlled systems, in which this selection is made by a centralised control entity (e.g. the supply chain management), in autonomously controlled systems single logistics entities (e.g. products, containers or ships) are technologically enabled and organisationally empowered to render decisions by themselves (e.g. selecting from different routing alternatives) (Windt and Hülsmann, 2007).

Autonomy: PROBST (1987) describes autonomy of a system's element as its ability to render decisions without having to ask a central, super-ordinate entity (Probst, 1987). Hence, a certain degree of decentralisation of decision-making processes in a logistics system results directly in a certain degree of autonomy of the respective logistics entities (Windt and Hülsmann, 2007).

Interaction: STAEHLE (1999) describes interaction as contacts between systems' elements in a way that certain reactions are induced (Staehle, 1999). Hence, in autonomously controlled logistics processes information flows take not or not only place from top to the bottom and back (e.g. data that is sent from the supply chain management to containers in order to pre-configure their transportation routes), but also between the involved elements (e.g. data that is sent by products to containers in order to let them know about their desired destinations). This information, in turn, is the basis for their ability to decide on their own upon their next actions (Windt and Hülsmann, 2007).

Heterarchy: GOLDAMMER (2003) describes Heterarchy following MCCULLOCH (McCulloch, 1945) and in distinction to hierarchy as co-subordination (Goldammer, 2003). PROBST AND MERCIER (1992) points out that heterarchical systems are characterised by the absence of a permanently dominant entity (Probst and Mercier, 1992). Hence, autonomously controlled logistics systems featuring a certain degree of heterarchy are therefore characterised by less dependencies of single elements (e.g. goods or containers) on central controlling entities (e.g. the supply chain management), and more interdependencies between the single elements with each other (Windt and Hülsmann, 2007).

Non-determinism: FLÄMIG (1998) describes non-deterministic systems as systems whose behaviours are impossible to predict although all system laws are known and current system states can be measured (Flaemig, 1998). This does also mean that it is impossible to pre-configure autonomously controlled logistics systems, which allows for a certain degree of flexibility (Hülsmann, Grapp and Li, 2006).

Whereas the technological development determines the »possible smartness« of logistics objects, the economic reasonability of a high »smartness« is still a not fully explored research field. Recurring to section 2 in which the risk of lock-ins in logistics systems has been shown and the necessity for dynamic capabilities has been deduced, the following research question arises: How does an increase of autonomous cooperation through an implementation of associated technologies affect the evolvement of dynamic capabilities on both the company as well as the supply network dimensionality?

More specific, the question can be divided into a set of sub questions that represent on the one side the dimensions of dynamic capabilities and on the other side the constitutive characteristics of autonomous cooperation as a driver for the realisation of CALS. Therefore and in order to avoid redundancies it seems to be reasonable to build groups of characteristics: First, a decentralised decision-making results directly in autonomy of the system's elements. Therefore, the first group consolidates the constitutive characteristics decentralised decision-making and autonomy. Second, if the elements within a system are enabled to interact directly without having to rely on the indirect connections between them, a central entity and other elements, a heterarchic structure of exchange processes occurs. Therefore, in the second group, the constitutive characteristics interaction and heterarchy are consolidated. The last group entails finally the characteristic non-determinism.

Therewith, a new set of sub questions arises. Two examples: How does an increased decentralised decision-making and resulting autonomy of the system's elements affect the abilities for an effective and efficient knowledge transfer within and between companies within an international supply network? Or: How does an increased interaction between the logistics system's elements and a resulting heterarchy affect the abilities of an efficient and effective knowledge abstraction? With four dimensions of dynamic capabilities and three groups of constitutive characteristics of autonomous cooperation, there are six causal interrelations, which have to be analysed in order to reveal the effects of autonomous cooperation in logistics on the evolvement of dynamic capabilities (see Figure 3).

		Dimensions of Dynamic Capabilities	
		Replication Ability	**Reconfiguration Ability**
Groups of Constitutive Characteristics of Autonomous Cooperation	**Decentralised Decision-Making & Autonomy**	1	4
	Interaction in Heterachical Systems	2	5
	Non-Determinism	3	6

Figure 3: Interrelations to be analysed for investigating the effects of autonomous cooperation on dynamic capabilities.

4. Contributions and Limitations of Autonomous Cooperation for the Evolvement of Dynamic Capabilities in CALS

4.1. Contributions and Limitations of Autonomous Cooperation to the Replication Ability in CALS

1. Decentralised decision-making and autonomy of the elements within a CALS means for the replication ability that the system's elements (i.e. employees, smart parts) can decide on their own, if they codify and transfer knowledge and if they do so, which knowledge they codify and transfer how. They do not have to ask a hierarchically higher super-ordinate entity for allowance to transform their knowledge into symbolic forms and therewith making it understandable, interpretable and achievable for other elements. Furthermore, the elements can select the form of codification on their own. Therewith they also determine to which other elements the knowledge will be transferred and if they will be able to understand and interpret the knowledge in the same way.

A resulting *contribution* to the replication ability of organisations and supply networks is based on the following assumption: The single elements of a logistics system know better, which of their knowledge would contribute to the organisation's goals when they are codified and transferred to other application fields, than a central management. The reason is that the single elements are “nearer” at the operational tasks and have therefore a deeper knowledge about it compared to a management, which does not accomplish the tasks itself (Burmann, 2002). Hence, the effectiveness of knowledge codification and transfer increases with an increasing decentralisation of decision-making processes.

A resulting *limitation* is based on the risk of local optima: It might not be in the interest of the elements that their knowledge is understandable and interpretable by all other elements in the system and that it is transferred to them and other application fields, especially when the elements are in competition to each other. This is normally the case with companies within supply networks that can overtake the same tasks (e.g. transportation) (Hülsmann and Cordes, 2009). On the company dimensionality, certain employees are in competition to each other and might not be interested in sharing their knowledge due to career intentions, which leads to “internal stickiness” and impedes the transfer of best practices within firms (Szulanski, 1996). On the smart part level this is dependent on the respective design of the CALS. MCKELVEY ET AL. (2009) developed a system of design options that is derived from the financial market. Logistics objects act like they were traders and hence, are in competition to each other (McKelvey, Wycisk and Hülsmann, 2009). Consequently, the risk of non-willingness to codify and transfer knowledge occurs.

2. Interaction between elements in a **heterarchic** CALS means for the replication ability first that the elements can learn from other elements how to codify knowledge and how to understand other symbolic forms. They do not rely on a central management and its willingness as well as ability to transfer knowledge on how to codify and read knowledge from other elements in the system. Second, knowledge transfer requires interaction. Whereas a system with non-interacting elements would need to transfer all available knowledge through a hierarchically higher entity, with interacting elements knowledge transfer can happen both on a vertical as well a horizontal level and cross lateral.

A resulting *contribution* is that the amount of knowledge that can potentially be codified and transferred will be higher. The reason is that a central management has restricted information processing capacities (Hülsmann, Grapp and Li, 2008) due to bounded rationalities (Simon, 1991). Therewith, it has also restricted capacities for knowledge codification and transfer. Furthermore, the »distance« between elements might be smaller than between an element, a central entity and another element. Therefore, the costs of knowledge transfer can be assumed to be lower if the transfer can happen on a direct way.

A resulting *limitation* is based on the postulation that the benefits of knowledge codification and transfer should exceed their costs (Burmann, 2002). Otherwise the knowledge codification and transfer would be inefficient. Thereby, the benefits ensue through the contribution of the knowledge codification or transfer to the achievement of the organisation's goals. If too much knowledge is codified and transferred, which would not contribute anymore to these goals, the associated costs are not fronted by associated benefits. Hence, a high interaction and resulting exchange of knowledge through codification and transfer could cause an excessive amount of costs without associated benefits.

3. Non-Determinism means for the replication ability of and within a CALS that neither the amount of knowledge that is codified and transferred, nor the way in which it is codified and transferred is in any way predictable. Even when the knowledge state of each single element and their abilities to codify and transfer that knowledge are known, the amount of knowledge that is codified and transferred as well as the way of codification and transfer is not foreseeable.

One *contribution* to dynamic capabilities in a CALS resulting from a non-deterministic system structure is a higher flexibility to adapt the amount of codified and transferred knowledge to the environmental conditions. The reason is that less dynamic situations might require less knowledge transfer than highly dynamic situations in which it might be reasonable to accept high costs of knowledge codification and transfer. When more knowledge codification and transfer is all of a sudden necessary, the system can immediately adapt in contrary to a deterministic system, in which the amount and the way of knowledge based activities is fixed for a certain period.

An associated *limitation* is that a non-deterministic system structure precludes a planning of costs and resource requirements that will occur in the near future. Hence, the management of a CALS or a logistics company within a CALS has to rely on the adaptability of the non-deterministic system; that it always allocates the right amount of resources to the right resource positions. However, a long term planning of a company's future development is unfeasible.

4.2. Contributions and Limitations of Autonomous Cooperation to the Reconfiguration Ability in CALS

4. Decentralised decision-making and autonomy of the elements within a CALS means for the system's reconfiguration ability that its elements are enabled to decide by themselves, whether or not they decontextualise any knowledge and apply the underlying causal interrelations to other application fields and if as well as how they absorb any information from the organisational environment. In other words: The decisions, how much knowledge is absorbed and abstracted, which knowledge is absorbed and abstracted and in which depth processes of absorption and abstraction occur are no longer in the hands of a central management. Instead, the single employees and smart parts within a CALS decide on their own, e.g. which external knowledge sources they use and for which other application fields this knowledge might be useful.

A resulting *contribution* to the reconfiguration ability of organisations and supply networks is that in analogy to the given point 1, the single elements of a logistics system might know better, how to absorb external knowledge and how to decontextualise its underlying causal relations than a central management (Burmann, 2002). The employees as well as the smart parts are in direct contact and interaction with employees and smart parts of other companies within a supply network. Hence, the absorption capacity and the capacity to abstract externally absorbed information might be greater compared to a central management, which is “farther” from the real knowledge absorption and abstraction processes and has a restricted capacity to absorb and abstract knowledge.

One associated *limitation* is, in analogy to point 1, based on the risk of local optima: the elements might not be interested in absorbing new knowledge or in abstracting their existing knowledge to other contexts. Employees might not be willing to change their working environment and hence, might fear that their knowledge is more useful in another context. In this case, they could prefer to keep the underlying causal relations to themselves instead of trying to unhinge it from its original context (based on Szulanski, 2000, Szulanski, 1996). Consequently, an appropriate system of incentives for both the decision rules in a system’s smart parts as well as the employees is necessary in order to avoid suchlike limitations.

5. Interaction in a **heterarchic** system means for the reconfiguration ability first that the elements can learn from other elements how to abstract knowledge and how to absorb information from the organisational environment. Second, elements in a heterarchic CALS do not only interact with other elements in the same company but also with elements from other companies. That is the case for both, for employees that have to coordinate cooperative activities and resource exchanges in inter-organisational business operations, as well as for smart parts that have to interact with other smart parts in inter-organisational supply chains.

A *contribution* to the reconfiguration ability of a CALS or of organisations within a CALS arises from the restricted absorptive capacity of a central management: If all the elements are enabled to interact with other elements outside the organisation they belong to, the amount of knowledge that can be absorbed can be assumed to be higher than the amount a central management can absorb. The same is true for the abstraction: A central management has firstly restricted abilities to abstract knowledge by itself, and secondly, to give reasonable instructions to all the single elements, which information they should absorb and abstract and how to do it.

One possible *limitation* is that the elements might start to interact in order to absorb and abstract external knowledge without adequate opposite benefits. Since knowledge absorption and abstraction is time consuming and hence, generate costs or alternative costs, the processes might get inefficient without recognition of the elements. For instance, although a central management might be less capable to absorb as much knowledge as the whole population of smart parts, it might be more capable of appraising the reasonability of spending time and resources on information absorption processes, compared to single elements – i.e. smart parts or employees.

6. Non-Determinism implies that there is no possibility to forecast future needs of new externally absorbed knowledge or of decontextualising existing knowledge and apply it in other contexts. For the reconfiguration ability of a CALS or of a company within a CALS this means that all activities on knowledge absorption and abstraction emerge from the current interactions between the system's elements and not from a previously elaborated plan.

A *contribution* to dynamic capabilities in a CALS resulting from this is that the system is more flexible to adapt the abstraction and absorption processes to current needs based on environmental changes. In analogy to point 3, it can be assumed that some competitive situations require more information from the environment than others. Therefore, in these situations it is reasonable to accept also higher costs of knowledge absorption and abstraction processes in favour of the associated benefits of being able to cope with the environmental dynamics. A non-deterministic system structure enables an invariable ability to adapt knowledge-based activities to current needs.

One *limitation* is that in a non-deterministic system structure it is impossible to plan how much costs will occur and how many as well as what kind of resources are needed in the near future for knowledge-based activities and therewith, how much capital has to be employed.

Since capital acquisition might not be as fast as the development of the system and its needs for capital, the risk occurs that the system is not able to provide its employees and smart parts with the resources they require for enabling a fully adaptive system of reconfiguration processes.

5. Conclusions

Since logistics companies are – just as every other company – faced with the risk of dominant management logics, path dependencies and resulting lock-ins, there is a need for them to develop dynamic capabilities that allow to avoid or to cope with managerial inertia. One approach that has received increasing advertency in the logistics research (e.g. Hülsmann and Grapp, 2005, Scholz-Reiter, Windt and Freitag, 2004, Hülsmann and Wycisk, 2005, Philipp, Böse and Windt, 2006, Windt and Hülsmann, 2007) and that might influence the development of dynamic capabilities is the concept of autonomous cooperation. Based on technological developments such as RFID tags or sensor networks does an increase of the degree of autonomous cooperation allow single logistics entities to interact with each other and to render decisions by themselves. Authors speak therefore of logistics networks as complex adaptive logistics systems (CALS) that consist of a large amount of heterogeneous agents (e.g. smart parts or employees) that interact in a self-organised system structure (an international supply network) (McKelvey, Wycisk and Hülsmann, 2009, Wycisk, Mckelvey and Hülsmann, 2008). Consequently, the overarching objective of this paper was to identify contributions and limitations of increasing the degree of autonomous cooperation to the evolvement of dynamic capabilities.

The qualitative analysis of the question how autonomous cooperation and an associate technological realisation would affect the evolvement of dynamic capabilities in CALS – understood as managerial processes of replication (knowledge codification and transfer) and reconfiguration (knowledge abstraction and absorption) of organisational resources (Burmann, 2002) – reveals both contributions and limitations. Two examples: On the one hand it can be assumed that the amount of knowledge that can potentially be codified and transferred will be higher if the degree of autonomous cooperation increases. The reason lies in a restricted information processing capacity and hence, restricted ability to codify and transfer knowledge of a central management. On the other hand, an autonomous cooperating logistics system entails a non-deterministic system structure. That makes it impossible to plan the amount of capital that has to be employed in the near future in forms of resources and resource allocations.

However, the analysis followed a solely qualitative approach with the aim to develop first considerations about underlying hypotheses that in total reflect the causal relationship between autonomous cooperation and the evolvement of dynamic capabilities. Hence, neither does the list of contributions and limitations claim for completeness nor have they been operationalised and empirically validated. A net effect, whether or not autonomous cooperation increases the replication and reconfiguration ability in a CALS has not been shown. Therewith further research requirements result from the demand for a further concretisation into operationalisable hypotheses that can be empirically validated. Not until then, the economic reasonability of investing in an increasing degree of autonomous cooperation in CALS can be finally evaluated with regards to the aim of an increasing competitiveness through dynamic capabilities.

Hence, managerial decisions about investments in technologies that enable autonomous cooperation or in organisational restructurings, which increase the constitutive characteristics of autonomous cooperation – decentralised decision-making, autonomy, interaction, heterarchy, non-determinism – have to consider both sides: The potential benefits that arise from an improved ability to codify, transfer, abstract and absorb knowledge, such as a higher flexibility on changing business environments; and associated direct costs, e.g. through purchasing and maintenance of technologies as well as indirect costs, e.g. risks of local optima and resulting sub-optimal system behaviour.

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