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1.1 Strategic decisions for autonomous logistics systems

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1.1.1 Introduction

Logistics management is currently facing major challenges. The integration of the value chain and the growing importance of spatially and organisationally distributed production networks strongly increase the need for logistical coordination. Growing customer orientation requires product customization and increased responsiveness in order delivery, thereby raising flexibility and reactivity requirements within the whole supply chain. These developments contribute to the increase in structural and dynamic complexity of logistics systems, thus complicating central planning and control of logistics processes.

Research on autonomous cooperating logistics processes confronts these challenges by proposing to replace central planning and control with decentral, autonomous coordination. While former concepts of organisational decentralisation implied an increase in the autonomy of employees, autonomous cooperation in logistics is primarily based on the capability of logistics objects to decide and coordinate themselves. Scholz-Reiter et al. describe the scenario of autonomous cooperation in logistics as follows:

"Imagine decentralized distributed architectures of intelligent and communicating objects instead of today's centralized control of non-intelligent objects in hierarchical structures (…). The flow of goods is no longer controlled by a central instance. Instead, the package is finding its way through the transport network to the destination autonomously while constantly communicating with conveyances and nodes and considering demands, e.g. concerning delivery date and costs." (2004: 358)

Autonomous cooperation in logistics promises higher efficiency as well as increased flexibility and robustness even in complex logistics systems. While it is based on the application of several new technologies (cp. Scholz-Reiter et al. 2004), multi-agent technology plays the most promi-

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nent role in regard to the actual ability of local self-coordination. Although this technology is already applied on several layers of the supply chain, e.g. in industrial production (e.g. Van Dyke Parunak 2000) or in transport logistics (e.g. Graudina and Grundspenkis 2005; Davidsson et al. 2005), a comprehensive and integrative automation of decision making in the supply chain is still a vision for the future. Not only remaining technical restrictions but also organisational factors act as constraints on the application of multi-agent technology in practice. As Janssen notes, "the prospect of delegating routine supply chain decisions to software agents still makes many managers nervous" (Janssen 2005: 316).

While the question how to convince managers of the advantages of multi-agent technology has been addressed by several authors (e.g. Van Dyke Parunak 2000; Janssen 2005), the character of the underlying decision problem remains unclear. In this article, we deal with this decision problem by elaborating on its strategic nature, which has to be appropriately comprehended in order to understand the difficulties related to the decision about autonomous cooperation and possible ways to address them. For these purposes, this article

- describes autonomous cooperation in logistics as a particular form of delegation of decision making
- attributes the strategic character of this delegation process to the necessity for organisations to open their boundaries
- outlines a concept of boundary management in order to foster and regulate the boundary opening and thus to provide the appropriate organisational context for the decision to implement autonomous cooperation.

1.1.2 Autonomous cooperation in logistics as delegation of decision making

In this article, we suggest that it is not possible to capture the strategic relevance of autonomous cooperation by comprehending it as a mere technological innovation potentially providing a competitive advantage. Instead, we propose to focus on the issue of delegation of decision making, which shall be explained in the following.

It has already been indicated that multi-agent systems (MAS) play a crucial role in regard to the ability of logistics objects to coordinate and decide for themselves. MAS consist of interacting, intelligent agents, i.e. of „autonomous, computational entities that can be viewed as perceiving their environment through sensors and acting upon their environment through effectors" (Weiss 1999: 2) and which are able to "pursue their goals and execute their tasks such that they optimize some given perform-

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ance measures" (ibidem). Intelligent agents can fulfil different functions in logistics processes like representing individual logistics objects and the related objectives or mediating the coordination process between other agents. The possibility to represent distinct entities with potentially conflicting interests and the ability to act on the basis of local knowledge make MAS an attractive solution for the decentral coordination of logistics processes. Besides the agents' ability to learn, the particular problem solving capability of MAS is mainly based on the agents' cooperation, i.e. it emerges through their interactions (cp. Chainbi et al. 2001; Odell 2002).

Considering the ability to learn and the emergence of the problem solving capability, the notion of technology reaches its limits in the context of MAS. Understanding technology ("Technik") as tight coupling of causal elements (Luhmann 2000), it is obvious that the notion of a technical system does not describe agent-based autonomous cooperation appropriately. Technology refers to the use of isolated causal relations in order to achieve some intended effects on the basis of defined preconditions (cp. Baecker 2005). Autonomous cooperation, however, is supposed to enable problem solving in situations, where technology reaches its limits, i.e. where neither causal relations nor preconditions can be operationalised unambiguously and the intended effects are themselves dependent on the former.

From the perspective of the organisation, operations of MAS are characterized by a high degree of contingency[1] untypical for technology. Contingency refers to the large number of possible results these operations can achieve. Consequently, the organisation is confronted with uncertainty with regard to their outcomes and thus with a loss of control similar to the case of delegation of decision making to human agents (cp. Laux and Liermann 2003). In order to substantiate this similarity we briefly address the question, whether agents' operations can be perceived as decision making[2]. In this article, we refer to the notion of decision brought forward by the sociologist Niklas Luhmann (e.g. Luhmann 2000). According to Luhmann, decision making can be comprehended as a basic form of dealing with the contingencies organisations face in their everyday operations. Organisations use decisions to transform open contingency, i.e. the existence of several alternatives to act before the decision, into closed contigency after the decision, when one alternative has been chosen and the

[1] The issue of contingency in the context of MAS is e.g. discussed in Dryer (1999) and Paetow and Schmitt (2002).

[2] The terms 'decision' and 'delegation' are sometimes referred to in the literature on MAS (e.g. Castelfranchi and Falcone 1998). However, we do not intend to review these discussions here. For our purpose, it is sufficient to understand how the related problems are perceived from an organisational perspective.

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others remain in the background as excluded possibilities only (Luhmann 2000). Referring to this understanding, it can be argued that decisions process contingency. Technology as a causal simplification, in contrast, only works if these contingencies are suppressed. In order to successfully utilise technology, contingency has to be eliminated first. Yet, MAS function in a different manner; they actively and adaptively develop situation-aware methods to address contingency and uncertainty. This implies, however, that their actual behaviour cannot be easily predicted by an external observer. Paetow and Schmitt (2002) thus refer to MAS as technical systems with non-technical properties.

Consequently, from the point of view of the organisation, implementation of autonomous cooperation in logistics indeed can be viewed as a process of delegation of decision making, accompanied by a loss of control as a typical side effect, which is likely to be one of the main problems in the context of the decision about autonomous cooperation.

In the following, we use concepts from New Systems Theory (especially Luhmann's theory of social systems) to further analyse autonomous cooperation as delegation of decision making. We show that the strategic character of this delegation is based on the necessity for organisations to open their boundaries. In comparison with economic theories addressing the issue of delegation, like the agency theory, Luhmann's theory offers two advantages. Firstly, it relieves us from the necessity to deal with the applicability of restrictive theoretical assumptions (e.g. the agency theory's notion of bounded rational, opportunistic, self-interested agents) to MAS. Secondly, Luhmann understands organisations as recursive unities of decisions and connects the way these unities structure decision making processes to their ability to reproduce themselves. This understanding seems especially appropriate when dealing with the strategic nature of the delegation of decision making.

1.1.3 Delegation of decision making as a process of boundary opening and its strategic relevance

Speaking of boundary opening, we first have to address basic concepts of openness and closeness of organisations. The idea of organisations being open systems has a long tradition in organisation theory (cp. Scott 1998). It implies that organisations rely on a constant throughput of resources (flows of energy, material and information) to secure their reproduction. By particularly emphasising the issue of information and its processing within organisations, the open systems approach has itself laid the foundation for the notion of (informational) closure. This does not necessarily

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mean to give up the concept of openness. Remer (2002), for example, notes that organisations are able to sustain themselves only if they are materially open but closed with regard to 'ideal' matters like identity.

Considering it as the basic prerequisite for the organisation's self-reproduction, Luhmann (1984) offers the most consequent notion of informational closeness. He proposes to substitute the notion of self-referential closure for the distinction between open and closed systems. The meaning of self-referential closure in the organisational context can only be grasped if organisations are understood as systems based on sense (cp. Luhmann 2000). They emerge through sense-based selections referring to each other and thus stabilising as a condensed unity distinguishing itself from its environment through selectively reduced complexity. The boundary between an organisation and its environment thus marks a difference in complexity. On the inside of this boundary, the organisation can develop a specific identity, whereas the outside is perceived as environment. As the demarcation is the result of the organisation's internal activities, in a sense, the organisation constructs its own environment. As Seidl and Becker describe it, organisations "come into being by permanently constructing and reconstructing themselves by means of using distinctions, which mark what is part of their realm and what not" (2006: 9).

The sustainment of the organisation as a unity distinct from its environment is directly linked to the maintenance of its boundaries. Thus, the question of „boundaries is central, not peripheral to organizations" (Hernes 2004: 10). The same holds true for the issue of boundary maintenance which is not a function at the periphery of the organisation, but a core problem, which all operations refer to in one way or another.

In the context of sense systems, we can comprehend self-referential closure as simultaneity of closeness and openness. According to the New Systems Theory, openness is based on a double closure; double closure means that, first of all, systems are closed in regard to their basal self-reference (often termed 'autopoiesis'). We can speak of basal self-reference when systems reproduce their elements exclusively by means of already existing elements and their relations. Systems are considered doubly closed if they are able to refer to or reflect on themselves on the basis of this basal self-reference (cp. Luhmann 1984). As we are dealing with sense systems, this can only be achieved by means of distinctions; the system refers to itself by internally operating on the distinction between system (self-reference) and the environment (external reference). Double closure thus, in a sense, enables openness towards the environment (cp. Luhmann 1984). By openness, however, we mean a cognitive openness, which a self-referential social system uses to condition its own operations.

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In order to fully comprehend the simultaneity of openness and closeness of organisations, we have to take a closer look at Luhmann's notion of organisation. According to Luhmann, organizations (re-)produce themselves as social orders by means of decisions about their practices and procedures. Thus, organisations have to be understood as recursive unities of decisions. They are self-referentially closed systems as one decision has to connect to another decision to secure their continued existence. They are cognitively open systems, however, because their decisions permanently refer to their environment. Decisions represent organisations' specific form of operations, by which they conduct sense-based selections and thus distinguish what belongs to their 'realm' and what belongs to the environment. They are means to transform the uncertainty related to contingency ("What is the right choice?") into a temporary, self-produced relative certainty to which further decisions can refer.

We have already indicated that autonomous cooperation can be perceived as a process of boundary opening. Yet, if organisations are permanently characterised by simultaneity of openness and closeness, which meaning has the notion of boundary opening?

According to the above remarks, boundary opening refers to an organisation's cognitive openness and implies an expansion of the part of the world which has been made accessible by the organisation. On the basis of such an enhanced view of the world, the organisation is potentially able to modify its operations. This, however, can only be realised if external references are successfully connected to the own operations on the basis of reflexive closure. Therefore, we can argue that opening and closure condition themselves reciprocally. They are two different sides of the same process, namely the positioning of the system within its environment and thus the permanent operational confirmation or modification of the system's boundaries. Luhmann (2000) notes that systems oscillate between external references and self-reference. Organisational boundaries are the result of this oscillation process and as such in permanent motion. At every point in time they represent the organisation's only temporarily valid understanding of itself and its environment. As a result of previous operations they contain knowledge of successful or failed strategies of the past and thus offer hints for the future development; at the same time, however, they restrict the possibilities of organisations to change. Hernes (2003) correspondingly speaks of the "enabling and constraining properties of organisational boundaries".

Oscillation between opening and closure, i.e. the permanent operational confirmation or modification of organisational boundaries, enables the organisation to stabilize in its environment. When this process is interrupted, for example by rigidly clinging to given boundaries, the viability of the or-

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ganisation is endangered as its fit with the environment is at risk. Earlier, we have emphasised that boundary maintenance is an internal achievement of the organisation and that thereby the organisation in a sense constructs its own environment. Yet, this does not imply that the world does not provide surprises. Organisational boundaries do not cut through causal relations and – when neglected – these causal relations transform the world to a source of permanent, potential threats to the organisation (cp. Schreyögg and Steinmann 2005). Especially in dynamic and systemically differentiated environments, strong and complex interdependencies require a constant adaptation of boundaries and thus a permanent reconfiguration of the relation between opening and closure.

We emphasise again that this process of reconfiguration is not a peripheral function. Rather, all operations of the organisation in some way refer to the duality of opening and closure. The same holds true for common criteria of differentiation applied to organisations. Table 3.1 gives some examples and relates them to openness and closeness respectively.

Table 3.1 Organisational criteria of differentiation related to openness and closeness

Openness	Closeness
Increase in complexity	Reduction of complexity
Variety	Redundancy
Flexibility	Inflexibility
Viability	Optimisation
Loose coupling	Tight coupling
Resource slack	Leanness

The notions in the same columns can be considered correlative concepts. The properties they refer to occur together, yet cannot be arranged in a strict causal hierarchy. They point to the same problem in regard to the self-reproduction of the organisation but from different perspectives. These different perspectives can be used to strengthen the understanding of the notions of openness and closeness. Increasing complexity, variety, flexibility, viability, loose coupling and resource slack stand for organisational openness, whereas reduced complexity, redundancy, inflexibility, optimisation, tight coupling and leanness refer to its closeness. We stress again that the mentioned concepts do not represent antipodes but condition each other reciprocally. Correspondingly, each organisation is characterised by a specific relation between openness and closeness. Otherwise its reproduction would be impossible.

Finally, we propose to relate the duality of autonomous cooperation and external control to the duality of openness and closeness. In order to sub-

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stantiate this suggestion, we have to develop an understanding of autonomous cooperation which fits the theoretical context outlined in this section. For this purpose, we comprehend autonomous cooperation as a problem of the internal structuration of the organisation as decision system. We have already argued that autonomous cooperation can be understood as a form of decentral, heterarchical decision making in contrast to external control as central, hierarchical decision making. Thus, we can clarify the meaning of autonomous cooperation on the basis of this difference.

According to Baecker (2005), the function of hierarchy with regard to the structuration of the organisation is to ensure the connectivity of decisions in two ways; firstly, hierarchy supports organisations in referring to decisions as their own operations. Everything that is confirmed by means of hierarchy can be expected to be valid and thus binding in an organisation. On the one hand, autonomous cooperation reduces this effect and thus the probability of successful connections. Yet, this negative influence on the organisation's self-reproduction is compensated by an increase in the variety of decisions on the other hand; while hierarchical control strongly predetermines decision making processes, thereby excluding many options and serving as a cognitive constraint, autonomous cooperation allows to process a high number of external references. It literally helps organisations to broaden their horizons and to find "proper reductions" (Baecker 2005) instead of reducing complexity at any price. Yet, while autonomous cooperation increases the variety of options the organisation is potentially able to realise, it complicates the realisation of each particular option as the organisation gives up the reference points for decision making provided by a hierarchical decision making structure. In the language of New Systems Theory, we can say that it becomes more difficult to ensure the connectivity of decisions.

The second function of hierarchy is related to this problem and refers to the solution of possible conflicts between different decisions. Autonomous cooperation makes it more difficult to deal with this problem and organisations have to find functional alternatives to hierarchy (cp. Ehnert et al. in press; Dembski and Timm 2005).

On the basis of the outlined systems theoretical understanding of organisations, it is possible to appropriately frame the strategic meaning of autonomous cooperation. Here, it should be explicitly emphasised that our notion of strategy refers to the long-term viability of an organisation in relation to its environment. Despite the current dominance of the resource-based view, the idea that strategy is related to an organisation's performance in its environment is still widely prevalent in the strategic management literature (cp. Sydow and Windeler 2001). As Mintzberg and Lampel note, strategic management is generally "concerned with how organisa-

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tions use degrees of freedom to manoeuvre through their environments" (1999: 25). Our notion of strategy, however, is distinct from conventional concepts as it directs the attention to the organisation's viability in its environment and thus to Luhmann's concept of systems rationality (Luhmann 1970, 1984) instead of simple means/ends-relations and purposive reasoning (cp. Schreyögg 1984).

If we substantiate the notion of strategy with Luhmann's understanding of systems rationality (cp. Schreyögg 1984) we can easily grasp its strategic meaning. Autonomous cooperation provides the organisation with more options to operate and thus potentially enhances its problem solving capability. The rising number of external references that can be processed increases the organisation's sensibility towards the environment, thereby raising the probability to find ways to evolve in accordance with it. Hence, opening on the level of decision making structures increases the probability that the organisation finds viable solutions. Yet, this opening comes at a price. With the growing number of options, it becomes more difficult to realise particular ones and an excess of external references endangers the connectivity of decisions. From the perspective of the organisation, this dilemma appears as an increase in contingency and uncertainty.

Recalling that organisations are permanently striving to reduce contingency and uncertainty, the difficulties with regard to the decision about autonomous cooperation become obvious and it is comprehensible why the delegation of decision making to a technical system with non-technical properties might face resistance from within the organisation.

1.1.4 Boundary management as an enabling tool for the implementation of autonomous cooperation

Understanding autonomous cooperation as a process of boundary opening, we finally have to address ways to regulate this process and thus to provide a context in which managers can decide in favour of the implementation of autonomous cooperation. In the following, we outline a concept of boundary management for these purposes.

Reflecting our understanding of boundaries, boundary management is not conceptualised as a particular management function at the periphery of the organisation, but rather a necessary, managerial process of reflection focusing on the viability of the organisation in its environment. Thus, in

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contrast to other concepts of boundary management[3], we understand it as a kind of meta-management with a strategic, reflexive character.

What are the issues that have to be addressed by this process of reflection? Following the previous considerations it seems appropriate to direct the attention to Luhmann's notion of decision premises. Decision premises – Luhmann explicitly refers to decision programmes, communication channels, persons and organisational culture (Luhmann 2000) – condition and structure the organisation as a recursive unity of decisions able to reproduce itself; to put it in Luhmann's words, decision premises "articulate" the interior of organisational boundaries (Luhmann 2000: 239) and thus regulate the internal processes of their maintenance.

While management is generally concerned with deciding about decision premises, the particular contribution of boundary management is to reflect on and modify these decision premises with reference to the viability of the organisation in its environment. Hence, boundary management influences the decision about autonomous cooperation in two different ways. First of all, it can directly address the decision premise communication channels, i.e. the way the organisation structures its decision making processes. Facing increasing internal and environmental complexity the organisation might indeed consider reconfiguring its communication channels, e.g. by granting more autonomy to local decision makers. Existing approaches of decentralisation in practice confirm this. Yet, arguing that reflecting on the need for autonomous cooperation is sufficient to solve the related decision problem seems unsatisfactory if we recall the argument laid out in this article. Thus, we should direct the attention to the second

[3] There are two main perspectives on boundaries and their management in management theory. The first perspective constitutes what has been termed the boundary school of strategic management (cp. Foss 2001). It deals with the strategic importance of the boundaries of the firm and is strongly influenced by the transaction cost approach. The boundary school reflects the growing tendency for hybrid, interorganisational arrangements. Thereby, it is related to the second, more design-oriented perspective, which perceives boundary management as part of the management of interorganisational relations (cp. Windeler 2001). In some cases, this concept of boundary management is also applied to intergroup relations. In our view, both perspectives rely on an insufficient understanding of organisational boundaries; boundaries are neither condensed results of efficiency deliberations nor well-defined design problems at the periphery of the organisation. Referring to their central meaning for the organisation's self-reproduction, our understanding of boundary management connects to the problem of systems rationality (cp. Tacke 1999). Yet, we do not suggest that other concepts are meaningless. Especially the design-orientied perspective offers important contributions to be integrated with our perspective.

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way boundary management influences the decision about autonomous cooperation. For this purpose, it is important to note that the mentioned decision premises are not independent from each other but condition each other reciprocally. Hence, it is possible to influence the decision about autonomous cooperation, i.e. opening with regard to the decision premise communication channels, by modifications on the level of decision programmes, persons and organisational culture. Table 4.1 shows some aspects which should be addressed in the context of these decision premises. These aspects represent exemplary design problems that can be derived from our concept of boundary management.

Table 4.1 Selected aspects to be addressed by boundary management

Decision programmes	Persons	Organisational culture
Collective strategies	Boundary roles	Reflection of contingency of culture
Resource and cost allocation	Qualification of boundary spanners	Culture development
Profit sharing	Personal identification	Management of cultural artefacts

Decision programmes are "what would usually be called procedures or plans – they specify how decisions should be made, (…) or what goals should be pursued" (Mingers 2002: 110). They are adopted "to provide guidelines for evaluating the correctness of decisions" (Luhmann 2002: 45). The reflection and modification of decision programmes in regard to viability is an important aspect of boundary management. Issues especially relevant in regard to fostering autonomous cooperation in logistics are collective strategies, agreements about resource and cost allocation as well as profit sharing.

Persons within an organisation function as decision premises as well. As such, they potentially play an important role in mediating processes of boundary opening. The comprehensive amount of literature on 'boundary spanners' (cp. Adams 1976; Aldrich and Herker 1977; Kiessling et al. 2004) indicates that management theory is aware of the relevance of persons with regards to managing boundaries. Boundary spanners are defined as "persons who operate as exchange or linking agents at the periphery or boundary of the organisation with elements outside it and who link two or more systems whose goals and expectations are likely partially conflicting" (Halley, 1997: 153). Important aspects of boundary management with regard to persons are reflecting and establishing boundary roles as well as qualifying boundary spanners for their task. Measures supporting personal

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identification can contribute to the closure of the organisation on the level of persons.

Here, we put a special emphasis on organisational culture as one aspect of boundary management. Organisational culture is usually defined as "pattern of basic assumptions that a given group has invented, discovered, or developed in learning to cope with its problems of external adaptation and internal integration" (Schein, 1984: 3). As such, it is implicit in all actions of the organisation's members. Luhmann (2000) argues that organisational culture is largely based on values, i.e. existing preferences which function as reference points for decisions without being explicitly referred to. The history of an organisation manifests in these values. Rather than a "knowledge repository" (Lemon and Sahota 2004) organisational culture thus functions as a pool of preferences, which – of course – are strongly related to the knowledge the organisation has acquired throughout its history. Processes of boundary opening can only be successful if the corresponding changes can be communicated as important innovations rather than unwished deviations from organisational culture. Utilizing organisational culture for managing boundaries presupposes the development of a corresponding managerial sensitiveness in this respect.

While it is readily comprehended that organisational culture has an important influence on the configuration of organisational boundaries, it is less obvious how organisational culture can be developed to support the management of boundaries. As Czarniawska-Joerges notes, "in order to control through culture, one had to be able to control culture first." (1992: 174). Yet, as Luhmann argues, organisational culture is the only decision premise which cannot be decided upon (Luhmann 2000).

How can this dilemma be solved, i.e. how can organisational culture be regulated in order to mediate the process of boundary opening? The first and maybe the most important aspect is once more reflection; even if we assume that changes in organisational culture have to be understood as evolutionary processes, a fundamental condition to influence these processes is a proper reflection of culture and its impact on the organisation's operations. This reflection, optimally taking place at all levels of the organisation, induces processes of boundary opening by revealing the contingency of traditional patterns within the organisation. Understanding this contingency implies the insight that things could be handled in a different way; it is a first step towards organisational change. Fundamental convictions like the refusal to cooperate with competitors can suddenly be questioned. Revealing the contingency of culture can be considered a prerequisite of a directed process of culture development. Probst and Büchel (1994) bring forward a concept of culture development that strongly emphasises the development of corporate visions. These, however, represent

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only a single aspect of organisational culture. A more comprehensive notion of influencing the development of organisational culture is provided by authors focusing on cultural artefacts. Shrivastava (1985) identifies several "cultural products" being the result of organisational culture (like myths and sagas, language systems and metaphors, symbolism, ceremony and rituals as well as value systems and behaviour norms) and relates them to strategic change. Higgins and McAllaster (2004) underscore this proposition by bringing forward a case study to emphasise the possibility of managing the aforementioned "cultural artefacts" to support strategic change.

1.1.5 Conclusions

Having to decide about the implementation of autonomous cooperation in logistics, managers are confronted with a difficult task. In this article, we have argued that the strategic meaning of this decision and the related difficulties do not stem from the implementation of autonomous cooperation as a new technology as such, but from its particular 'non-technical' character. From an organisational perspective, autonomous cooperation can be perceived as delegation of decision making confronting organisations with the necessity to open their boundaries. Drawing on Luhmann's theory of social systems, we analysed the strategic nature of this process of boundary opening. Finally, we proposed a concept of boundary management that supports building the context for decisions in favour of autonomous cooperation and thus functions as an enabling tool.

We have argued that due to the importance and the central character of boundary maintenance in organisations, it is not indicated to conceptualise boundary management as a set of predefined managerial measures. Successful management of boundaries rather starts with a process of reflection of decision premises as a basis for subsequent changes. This process of reflexion is the first step in building a context for decisions in favour of autonomous cooperation.

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