

## **Robustness in the Context of Autonomous Cooperating Logistic Processes: A Sustainability Perspective**

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**Abstract.** Autonomous cooperating logistic processes seem to be a promising approach to increase the robustness of logistics systems. Searching for the necessary organizational prerequisites for the successful implementation and sustainment of autonomous cooperating logistic processes we pick up the concept of robustness and use the New Systems Theory to outline a notion of organizational robustness, which can be regarded as an important factor enabling businesses to adopt innovations in spite of related uncertainties.

### **1. Introduction**

In recent times, researchers in the field of logistics and supply chain management have increasingly directed their attention to concepts like robustness, resilience or risk management (cf. e.g. Christopher/Peck 2000; Norman/Lindroth 2004). All these concepts refer to the question how logistics systems or supply chains can function effectively while being confronted with complex and dynamic environmental conditions and demands.

A particular approach to deal with this challenge is addressed by the German Collaborative Research Center (CRC) 637 „Autonomous Cooperating Logistic Processes”. The CRC focuses on a paradigm shift in logistics based upon fundamental changes in decision-making processes within logistics systems due to the fact that the dynamic and structural complexity of logistics networks makes it more and more impossible to provide a central planning and control unit with all decision-relevant information and thus requires adaptive logistic processes. The notion of autonomous cooperating logistic processes refers to the decentralised

coordination of autonomous logistic objects in a heterarchical organizational structure. Precondition as well as driving force of autonomous logistic processes are developments in information and communication technologies, like RFID (Radio Frequency Identification) technology or wireless communication networks.

Against the background of increasing dynamic and structural complexity within logistics networks – caused by changing conditions in the markets like the shift from seller to buyer markets and the increasing importance of customer orientation and individualisation – autonomous cooperating logistic processes are intended to provide an improved capability to react to unanticipated events maintaining a high level of efficiency and effectiveness and thereby increasing the robustness of the logistics system.

While this effect seems to be favorable from the perspective of businesses, autonomous cooperating logistic processes also confront them with new challenges. An increase in the level of autonomous control of intra-organizational and inter-organizational logistic processes has considerable consequences on the management level. These consequences can be inferred from the fundamental dilemma in regard to autonomous control: Decentral information processing and decision-making increases flexibility but at the same time makes it more difficult to ensure that the local decisions are in the best interest of the business. Correspondingly, the gain in robustness on the level of a single logistic process may not be a sufficient incentive for businesses to invest in the infrastructure necessary for autonomous cooperating logistic processes.

Against this background we suggest to distinguish between the notion of robustness on the process level and a concept of organizational robustness which refers to the organizational structures in which autonomous logistics systems are embedded. The purpose of this paper is to outline this concept of organizational robustness and to examine how organizational robustness can help businesses to deal with the fundamental dilemma of autonomous control.

## 2. The Concept of Robustness

While the concept of robustness is popular within natural and engineering sciences, its application in the context of social systems stands only at its beginning. Therefore we cannot offer a general, widely accepted definition of robustness. Referring to Jen (2003), we define robustness as a measure of feature persistence of a system under changing environmental conditions, which provide the system with unforeseen perturbations. This very general definition, however, requires further specification. At first, it is necessary to specify the features, whose persistence is to be investigated. Here, we want to draw upon the New Systems Theory, which sets aside any ontological notion of systems and replaces it by an observer-relative understanding. Organizations as social systems are then considered as self-referential, operationally closed unities. This means that by establishing a boundary between themselves and the environment organizations continually create themselves and the whole bandwidth of features, which can be attributed to them.

Corresponding to the notion of self-referential closure an organization arranges all its operations such that they contribute to the reproduction of the system/environment-distinction and thus to the self-reproduction of the organization.

If, as suggested above, we connect the idea of feature persistence with the system/environment-distinction and therefore with the self-reproduction of the organization, the link between robustness and the way the organization creates its own boundaries becomes obvious. By sustaining the system/environment-distinction the system creates a difference between internal and external complexity that marks the boundary between system and environment. It should be emphasized that the New Systems Theory considers social systems, including organizations, as sense-systems. Accordingly, the system/environment-distinction does not refer to some kind of spatial boundaries but to a difference based on sense. Correspondingly, organizational boundaries have to be considered as based on sense as well (cf. Ortmann/Sydow 1999). Luhmann (1997; 2000) specifies the New Systems Theory's notion of organization by characterizing it as a recursive unity of decisions. Decisions are perceived as a specific form of communications which constitute the emergence of organizations as social systems. If an organization succeeds in continuing this self-referential circle of decisions, which marks the inside of the system, its self-reproduction is successful. The notion that organizations act to some purpose or have to achieve specified functions plays an important role in sustaining the organization as a recursive unity of decisions.

In the following we will address the question under which circumstances an organization's specific way of establishing and maintaining its boundaries contributes to its robustness. In order to find an answer to this question we have to direct our attention to the system/environment-distinction again. Referring to the inside of this distinction, an organization is able to develop a certain identity, which is largely based upon specific functions the organization strives to achieve. This organizational identity can be considered as a self-description that serves as a basis for the future operations of the system. It is exactly this self-description and its capacity to provide the organization with a simplified notion of the relation between system and environment that enables an organization to act under complex environmental conditions without possessing the variety to confront the whole environmental complexity within the system. Recalling that an organization can be considered as a recursive unity of decisions, it is obvious that past decisions play an important role in the creation of an organization's identity and thus enable and restrain future decisions at the same time.

The organization's environment, which is at the outside of the system/environment-distinction, functions as a negative correlative of the organization's unity. System and environment thus simply mark different sides of the same form. Against this background it seems only reasonable that all organizations exhibit a certain tendency to protect their identity from changes and to maintain rigid boundaries. This form of closure is a constitutive characteristic of self-referential systems and intended to ensure the self-reproduction of the organization.

What can we infer from these considerations regarding the robustness of an organization? Is rigidity of an organization's identity and its boundaries sufficient to

qualify an organization as robust? In order to negate this question we only have to take into account that the establishment of sense-based boundaries does not cut through causal relationships between system and environment. Even if – as the New Systems Theory suggests – the system/environment-distinction is the result of an internal activity of the system, this distinction cannot be maintained against causal relations. In other words, there must be a fit between the system and the environment, which does not only depend on factors internal to the system. Especially against the background of changing environmental conditions an organization tends to compromise its fit with the environment by rigorously clinging to a given identity and boundaries.

Referring to the notion of an organization as a recursive unity of decisions, we can use the terms redundancy and variety to address the problem mentioned above. According to Luhmann (1988) redundancy is a measure of the structural rigidity of an organization as a unity of decisions. If the scope of decisions possible in the future is narrowed to a relevant extent by previous decisions and resulting organizational structures, we can speak of redundancy. The bias of organizations towards redundancy can be considered as another expression for the aforementioned tendency of organizations to protect their identity from changes and to maintain rigid boundaries in order to ensure their self-reproduction. What we stated above about the perils of rigidity of identity and boundaries holds true for redundancy as well. Thus, redundancy can compromise the fit between the organization and its environment, especially if the system operates in a rapidly changing environment. Redundancy alone does not make organizations robust. Instead we have to turn our attention to variety, which, according to Luhmann, describes the dissimilitude of decisions within an organization. Variety enables organizations to continue their decision-making on the basis of a wide range of options. Variety gives organizations the opportunity to decide about previous decisions, a property which Baecker (2003) characterizes as re-entry of uncertainty into the organization, which is originally intended to absorb uncertainty. At the same time this property is an important prerequisite for reflexivity, which increases the likelihood of the fit between organization and environment.

Referring to the terms redundancy and variety, it can be argued that the robustness of an organization marks the optimal level of redundancy and variety. This optimal level ensures the maintenance of the system/environment-distinction and thus the continuation of the self-referential closure of the organization. At the same time it enables the organization to process perturbations which result from changes in the environmental conditions and to which the system must react in order to ensure its fit with the environment. A robust organization neither clings rigidly to its given identity by imposing non-fitting boundaries on its environment nor opens its boundaries to an extent that endangers its self-reproduction.

It has to be emphasized that there are no blueprints for organizational robustness. The optimal level of redundancy and variety varies from organization to organization. The question which conditions lead to the emergence of robustness and how the creation of robustness can be addressed within the management process must be the subject of further research.

### **3. Organizational Robustness and Autonomous Cooperating Logistic Processes**

Finally we want to discuss the meaning of the outlined concept of organizational robustness in the context of autonomous cooperating logistic processes and the fundamental dilemma of autonomous control. Robustness plays an important role in regard to the management and organization level of autonomous logistics systems. It is likely that already the decision to participate and to invest in an autonomous logistics system is affected by an organization's robustness, as a robust organization will not consider the uncertainties associated with autonomous control of logistic processes as perils to the organization's identity and thus to the sustainment of the organization itself. A robust organization is able to deal with these uncertainties without compromising the basis of its future operations. In addition, robustness increases the sensitivity of the organization towards changes in its environment which require the system to act in order to maintain the fit between organization and environment. This increases the probability that the organization will be able to deal with the fundamental dilemma of autonomous control in a constructive manner. A robust organization is likely to welcome innovations like autonomous logistic processes. Instead of perceiving them as impediments to achieving certain functions, they will be considered as necessary preconditions in order to be able to achieve functions at all. Robustness thus implies the ability to restrain an organization's effort to achieve its function in the short run in the interest of the sustainment of the organization's ability to continue its existence and to achieve its function in the long run. Thus, it becomes obvious that the outlined concept of organizational robustness is strongly linked to the concept of sustainability. An organization is sustainable if it succeeds to secure its continued existence in the long run. As can be inferred from the considerations above, a robust organization is more likely to be sustainable than a less robust one.

### **4. Summary**

In this paper we argued that in the context of autonomous cooperating logistic processes it makes sense to distinguish an original technical notion of robustness, referring to the logistic processes itself, from a concept of organizational robustness which has a positive influence on the successful implementation of autonomous logistic processes. The concept of organizational robustness was outlined on the basis of the New Systems Theory and focussing on the relation between redundancy and variety. Furthermore, it was shown that organizational robustness is strongly linked to a systemic notion of sustainability.

Considering the importance of organizational robustness in the context of autonomous logistic processes, it seems indicated to undertake further research effort in order to examine the emergence of organizational robustness.

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