# Logistics Management from a Complexity Perspective

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# Logistics Management from a Complexity Perspective

Abstract:

The aim of this paper is to discuss the implications a complexity perspective may have on the management of logistics. The CLM definition of logistics management is used as a base to address the implications a complexity perspective has on the logistics discipline. A framework is developed to assess the logistics complexity based on significant properties (structure, dynamics and adaptation) on three levels of resolution (individual/parts, the firm and the network). The identified emphasis of planning and controlling in logistics management are questioned and it is suggested that a change concerning the elements related to the property of adaptation is needed. This means that the process of planning and controlling has to be balanced by considerations to emergent phenomena and the processes of self-organization taking place in the flow of products and information. One conclusion is that a modified version of the definition of logistics management is called for.

**Keywords:** Complexity, Logistics, Management, Dynamics, Adaptation

# Introduction

This paper sets out to discuss complexity in the context of logistics management. The logistics discipline is considered as a complex system given that it involves interdependent actors with a high degree of interactions. The importance of logistics is predicted to increase since the ability to adjust procurement, production, and transportation to customer demands will, together with the management of fast and accurate information flows, become essential in future business environments (Shankar 2001). Logistics management covers the flow of products and information between firms, that is, logistics activities with the fundamental value-adding features of time and place utility (Ballou 1999, Lambert, Stock and Ellram 1998). Lambert, Stock and Ellram (2001, p. 454) refer to a study made of 100 US firms showing that logistics *"typically had responsibility for outbound transportation, intra company transportation, warehousing, inbound transport, materials handling, and inventory control."*

The difficulty in coordinating the logistics activities within and among firms is expected to increase since the dependence among interacting firms intensifies and thereby also the ability to deliver to and supply each other. Axelrod and Cohen (2000, p.26) expect *"systems to exhibit increasingly complex dynamics when changes occur that intensify interactions among the elements"*. Thus, handling the logistics system in the supply network will create new demands on logistics management, which means that new approaches and methods are needed for managers to understand and deal with logistics processes.

What logistics management is really about is how to handle the difficulties and complications that constitute logistical problems. Christopher (1998, p.54) observes that *"the complexity of the logistics task appears to be increasing exponentially."* However, the common approach to handling logistics complexity is based on mechanical assumptions, where the problems are broken down into separate parts that are easy to analyze and solve. With insights from the science of complexity the authors of this paper take another standpoint by questioning the prevailing thoughts about logistics management. The authors' aim in this paper is to discuss the implications a complexity perspective may have on the management of the socio-technical processes that constitute logistics.

## Logistics management

Logistics management is defined by the Council of Logistics Management (CLM) as:

> *"The process of planning, implementing and controlling the efficient, effective flow and storage of goods, services, and related information from point of origin to point of consumption for the purpose of conforming to customer requirements."* (*What's it all about?* CLM book - in Lambert, Stock & Ellram 1998, p.3)

Based on this definition one could say that logistics management covers several areas where managerial responsibility is addressed. Those are in this paper addressed as *the structure of and the flow within the logistics system*, *the scope of logistics activities*, and finally *the conformation to customer requirements*.

### The structure of and the flow within the logistics system

Logistics systems are often described as a network of nodes and links describing an interconnected web. Wandel and Ruijgrok (1995) establish the basic notion of networks and the correlation between the descriptions of the transport industry as a network. The correlation between the infrastructure, the resources that move on the infrastructure and constitute the transportation network are shown in Figure 1.

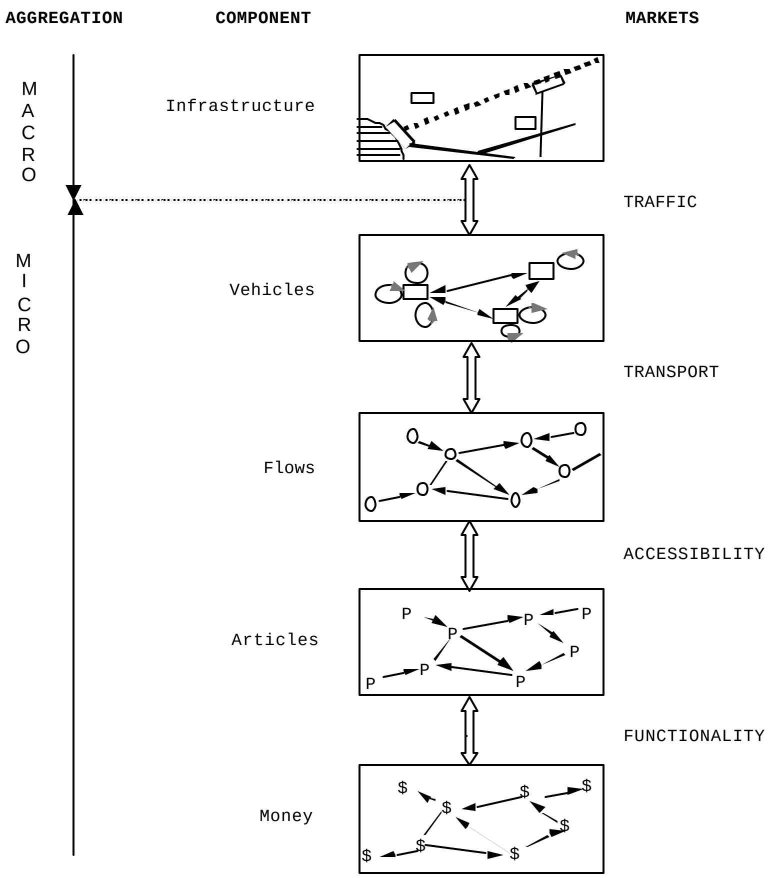


**Figure 1**

**The transport network, resources and infrastructure (Wandel & Ruijgrok, 1995), (derived from Waidringer 1999)**

The figure describes the correlation between the aggregation level, from macro to micro, the components of the system and the markets. Traffic is regarded as a market for infrastructure services, e.g. the trade of space and time. Transport is the market for the movement of vehicles on the infrastructure. The accessibility market is the market for flows (or slots) made available by the service providers operating on the transport market. Finally there is a market for functionality that is derived from producer and consumer relations. The consumers buy (using money or an equivalent) articles that give the users a functionality. The model could possibly be expanded to include the financial market including the macro economic scale but it was not regarded as useful to expand the model that far in this context.

## The scope of logistics activities

The scope, in CLM's definition on page 2, *from point of origin to point of consumption* indicates that logistics management covers several firms. This is supported by Bowersox, Closs and Stank (2000) who claim in their conclusion that it has been estimated that only 20 percent of the scope of logistics activities are within the direct control of a firm's logistics function. One reason for this is the evolutionary change of information and physical flows that have reshaped the logistics context from being a question of a number of detailed but not related material flows to complex supply networks. Of major influence are innovations in information technology, which both have fostered a distinct quickening in information processing as well as reduced, for example, the tonnage handled in physical flow. The value-to-weight ratio of a pound of GDP in the US has gone from $3.64 in 1977 to $6.52 in 1997, a 79 per cent increase (Meyer, 1999). Consequently, products are easier and hence less costly to move, which has forced industry to reconsider its logistics flows and usage of performance indicators.

Logistics activities and the term supply chain, introduced by Oliver and Webber (1982), have been discussed at different systems levels, as indicated in figure 2. The three stages also describe the basic evolution into more and more integrative solutions that has been noted over the years. For example, the notion of supply chains have been modified, which Rice and Hoppe (2001) explain by masking the point that supply network is a better term than supply chain when addressing the networks of companies engaged in the supply relationships of today. In the stages below we also incorporate the transformation of logistics from a cost saver inside a specific organization to logistics as a set of activities that supports the strategic intentions of coordinated organizations, as noted by Bowersox and Closs (1996).

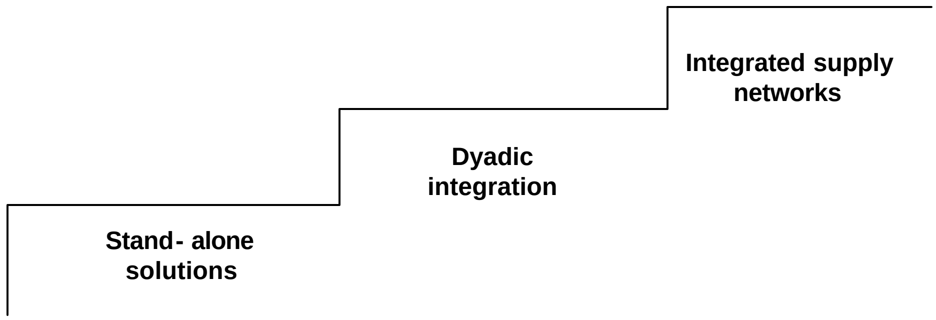


**Figure 2**

**The evolution of logistics solutions (Sjöstedt et al 2001, modified)**

In the first stage with stand-alone solutions no actual supply chain can be distinguished and the focus for logistics management is on optimization within the individual firm in order to reach cost savings.

In the second stage with integrated firms in pairs it is possible to talk about an interaction between at least two of the participants in the chain. Cost saving is still an important issue but is supplemented by activities that increase the participants' market shares.

In the last stage, integrated supply networks have been predicted by several researchers to become the dominant organizational form for future competition (Christopher 1998, Cox 1999, Lambert, Cooper, & Pagh 1998, Durtsche *et al*, 2000, Lee, Padmanabhan, & Whang 1997). A major reason is greater demands from customers and competitors, which compel firms to focus on delivering greater value to the customers, in less time. In order to satisfy these demands, the ability of suppliers to speed up the innovation process increase. This means that firms are encouraged to cooperate with several other firms and sometimes even transfer several in-house capabilities to suppliers (Rice & Hoppe 2001, Bowersox & Closs 1996). Consequently, the strategic capabilities for a specific firm will then lie in the relationships it has with other firms in its business context. In other words, the network in which firms are involved will be the source of competitive advantage (Gulati, Nohria, & Zaheer 2000, Kogut 2000).

## The conformation of customer requirements

Satisfying the end-customer's requirements is increasingly becoming the key element for success. Traditionally, the value logistics contributed with was lowering the transportation costs for the firms in the supply chain when they pushed products toward the market. Today, the value is created through adding a service dimension that besides the product features required, gives the customer accessibility to the product based on the customer's demand.

The core function of any logistical system is, in figure 3, simply referred to as management of flows. The figure illustrates how the consumption functions, as part of marketing or other business activities, generate a specification that is transferred through the logistical function to the producer.

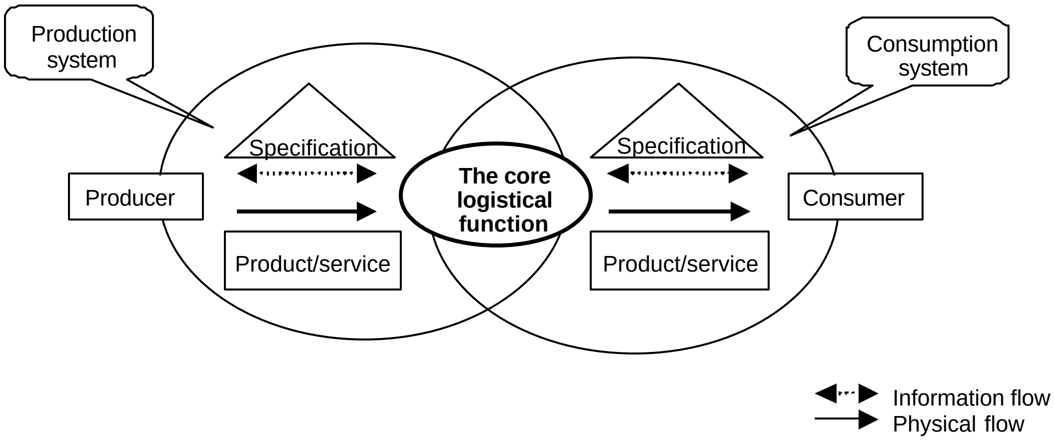


**Figure 3**

**The role of the core logistical function in a Value-Added Industrial System (Sjöstedt et al 2001, modified)**

Through the production function the producer materializes the specification into a tangible product or service, which is brought forward to the consumer through the logistical function. The producer has to judge how many resources have to be used in order to meet the specification in a satisfactory way; that is basically a judgment of the market opportunity. The consumer in his or her turn judges how well the product or service correlates with his or her expectations, a process which in this case basically is a utility evaluation.

## Complexity in logistics systems

The notion of logistics systems as being complex is not new, which the following citation, given by Manheim as early as in 1979, shows:

> *"Transportation involves the movement of people or goods from one location to another. This requires the expenditure of energy by man, animal or machine., …, In many cases, especially in industrialized countries, transportation is achieved by quite* ***complex processes*** *in which men and machines interact, within institutions that are often large and complex, to deliver transportation services to customers."* (Manheim 1979, p.13)

Although Manheim does not define the concept of complexity or discuss how this complexity arises or can be handled, he observes that the logistics system consists of complex processes. However, describing and understand logistics systems as a class of complex systems is quite recent occurrence.

Even though logistics has been mentioned in articles about complexity before, there are only two articles to the authors' knowledge, that specifically address this issue based on the science of complexity. The first article addresses the complexity as uncertainty involved in supply chains and discusses this from, according to Wilding (1998, p.599), *"three interacting yet independent effects."* These are deterministic chaos, parallel interactions and demand amplification. These effects cause complexity in the logistical processes based on uncertainty in the supply chain. In the second article, Lumsdén, Hultén and Waidringer (1998) also address the uncertainty of causing complexity, the uncertainty of customer demands and time needed for sub-processes are especially noted. Further, three other aspects are addressed regarding the complexity of logistics systems namely; a large number of system states, heterogeneous system, and distributed decision-making. They conclude that there is a need for *"better models of logistical systems… [that] lead to better predictions of the behavior of real systems"*(p.171). In both articles the complexity, which has arisen in the logistics systems, is derived from mainly universal and external aspects that can be objectively viewed, and are global phenomena for these systems. However, the impact the parts within these interconnected and interdependent systems have on each other in creating the global phenomena, are not emphasized to a great extent.

Our paper takes the standpoint that complexity in logistics systems appears when technical systems are put in a social context. The technical systems can in themselves be more or less complex, but when the relationships and interaction between technology and man for a certain class of systems is subject to analysis, each system description is too extensive, since in practice it will be impossible for human actors to handle. The most important factors in such a statement are:

- that there exists a infrastructure or network dimension that is characterized by having properties that change slowly. For example the infrastructure is relatively constant since changes take time i.e. when a new road connection is built or a process-machine is placed within a paper mill. This is a technical dimension once structure elements such as the road network or the placement of machines are set.

- the processes in supply networks are changed faster than the network or infrastructure since the processes use this structure. The use of roads or railways can be changed due to many factors such as cost benefits, regulatory changes or new customers on new locations. The processes can both be technical as well as social at the same time.
- that the infrastructure and the processes are influenced by a large number of decision-makers (actors) that are often spread geographically, with different goal functions and different time horizons for their decisions. This is a social dimension.

## A logistics complexity framework

In order to discuss logistics complexity a definition proposed by Waidringer (2001) is used:

> *Transportation and logistics systems' complexity resides in the nature of the structure, dynamics and adaptation. It is a measure of the possibility of modeling these properties and their interaction in a way that allows of implementation of control mechanisms, forcing the system under study to meet required service, cost and environmental demands.* (Waidringer 2001, p.115)

To address the complexity of logistics activities three properties have been identified within the logistics area that have significant impact for the management of logistics activities. These are *the structure property, the dynamics property*, and *the property of adaptation.* The structure property is related to the infrastructure in the context of logistics, and covers physical as well as information and communicational structures. The dynamic property is related to the processes performed on the network i.e. the flow of goods, money and information within the structure and hence the dynamics in these processes. The property of adaptation is related to the organization and the decision-making i.e. the management and control of the structure and the dynamics, in order to realize the processes on the network.

These properties are in this paper put into three different levels of resolution in the context of logistics and the emergent behaviors or patterns in the transition between the levels are then discussed. It is to be noted that these levels are arbitrary and it is regarded as beneficial to adapt these levels to the problem being studied. The levels chosen are: *the individual/parts, the firm* and*, the network*.

The individual/parts level is where the smallest relevant elements for a logistics systems description are positioned. These elements are the individuals performing different activities but also artifacts that are being used by the individuals. Together, these elements represent the structure. The actual actions by the individuals are addressed as the dynamics. Finally the adaptation is related to how each individual perceives the effects of his/her own actions as well as actions performed by others which affect both the structure and the dynamics.

On the level of the firm the structure is referred to as the infrastructure within each firm in terms of physical structure and intranet, to informal networks emerging from connections among the individuals and/or the parts. The structure of the firm and the perceived boundaries provide the cognitive representation for the individuals of what *"constitutes the object of membership, that is, of identity"* (Kogut 2000, p.408). This makes it the internal perspective where the dynamics constitute of the movement of individuals and the flow of objects, information etc. between the structure elements. The distinction between the individual and the firm level is something Lissack (1999, p.111) addresses by firms *"often experience change as an emergent process."* Still it is the people in the process of sense making that individually and collectively give meaning to the actions (i.e. the adaptation property) that are performed by firms (Lissack 1999).

The network level represents the new organizational form where the structure is referred to the constellation of firms and the infrastructure for both information and physical flow that is being used. The link between the firm structure and the network structure lies in the jointly emergent phenomena embedded in spatially defined networks of labor (Kogut 2000). The dynamics derive from all logistics activities between the firms. Ballou (1997, p.623) states, with relevance to the property of dynamics, that the activities involved on an inter-organizational level are little understood and *"if organizational processes can be developed to deal with logistics matters external to the firm, the firm stands to gain in a way not otherwise possible"*. Concerning the adaptation property of the network, it is considered that both the firm and the supply network are emergent outcomes from interactions of the individuals at the same time as the notion of the firm and the supply network influences the behaviors of the individuals' actions and perpetual constructions. That is to say that they exist at the same time forming each other.

In order to address the implications a complexity perspective may have on logistics management, the three properties (structure, dynamics and adaptation), and the different levels of resolution are used as a framework.

## Implications for logistics management

The identified implications a complexity perspective may have for logistics management will here be discussed based on the framework described above. Since logistics management is connected to other kinds of management there are of course similarities in the type of problems that are being treated. However, logistics is by nature a discipline where a mechanistic approach has been successful since the benefits firms exhibit from logistics are time and place utility of products. Time can easily be divided into time intervals and measured quite easily. The spatial dimension is also rather easy to divide into parts because there is a measurable distance from for example Boston to Chicago. Both these measurements are of a technical character and fit well in the property of structure as well as the property of dynamics since distance is related to structure and time is related do dynamics. With a perspective of reality as being objective it is then quite easy to deal with these properties with a mechanical and summative approach. However, as stated in the framework above, the dynamics, taking place in the structure, is being interpreted by logistics managers that by their actions influence the properties of structure and dynamics. The actions are based on the perpetual construction of reality each individual makes. This, being directly related to the property of adaptation has not been greatly emphasized in logistics management.

### Planning and Control

As stated in the CLM definition of logistics management, the focus in logistics is on planning and controlling the activities performed. The easiest way to plan and control is in trying to eliminate the complexity involved. Lambert, Stock and Ellram (2001, p. 453) observe that *"an effective organization must exhibit stability and continuity; it must find a unique offering that it can deliver to the market and stick with it to provide customer value."* The emphasis on stability and continuity is expressed in the models used which address transportation and logistics, since these are based on equilibrium assumptions (Allen 2000). In other words, the desirable strategy for logistics managers is to reach equilibrium states that are simple enough to handle by eliminating redundancy and focusing on efficiency and cost reductions. *"Disorder is the price of progress in a dynamic world"* as stated by Quinn (in Coleman 1999, p.38) and this view is also the price for logistics activities.

However, since logistics management covers management of socio-technical processes the dominant approach of planning and control of activities and processes by managers is questioned by the authors. Stacey (2001) describes the view of planning and control as fruitless since the predictability within firms is limited if not impossible and Lissack (1999) argues against this traditional management assumption of control and prediction by stating that with human activity follow emergent outcomes.

The emphasis on planning, and thereby prediction, and control implies a formative and rationalist teleology based on the teleological view Stacey, Griffin and Shaw (2000) describe in their book *Complexity and Management*. A central assumption in logistics management is that the manager has a position outside the system being controlled, which puts him/her in the position of an observer. The manager or the management team has the freedom of choosing the future goals for the logistics system and the capability to design its structure and how and when the flows are determined to take place. This description places logistics management as rationalist teleology since *"the observer has the freedom to choose goals for a system"* and *"even the ability to design it"* (Stacey, Griffin and Shaw 2000, p.72). Added to this is the formative teleology since the manager, in the position of an observer, is able to stand outside the system. Stacey, Griffin and Shaw (2000) especially point out that a formative teleology excludes the interlinked matters of human freedom, the unknown and ethics.

Further, added to the planning and control emphasis, the common approach to handling logistics activities is based on a top-down approach. This means that the actions are planned and decided by the logistics management, which has the ability of viewing the logistics system from "above" i.e. the plan will be based on global logistics phenomena. The planned actions are then properly being distributed to the right places where each action is performed. However, since *"the complex whole may exhibit properties that are not readily explained by understanding the parts"* (Kauffman 1995, p.2), the result is that emergent phenomena formed from the bottom-up by local interactions of autonomous individuals and parts, are not being captured. Bonabeau (2002) especially address that emergent phenomena may in several cases be counter intuitive, which make these emergent phenomena impossible for managers to neither plan nor control.

Based on the levels of the resolution described earlier, the individual level is of major importance for logistics management since it is on this level that actions are performed or affected by autonomous individuals. As a result of their actions and the perpetual interpretations of the outcome of other individuals' actions, global phenomenon emerges. Allen (2000, p.83) points out that as a process of sense making: *"there is a complex and changing relationship between latent and revealed preferences, as individuals experience the system and question their own assumptions and goals"*. Bonabeau (2002) address that it is the individuals within firms (and not processes) that make mistakes and causing errors and he goes as far to point to a paradigm shift from spreadsheet and process-oriented approaches to focus on the individuals.

What is required for logistics management in order to move towards robust network constellations is a shift in mind-set. Park (2000, p.61) address this clearly by stating that *"executives must realize that the old top-down, command-and-control structure is ineffective, and in many cases counterproductive."* This approach is in line with the new kind of management Tasaka (1999) describes in his article "Twenty-first-century Management and the Complexity Paradigm." He states that managers should not plan or manage but instead stimulate self-organization. It is through self-organization that the behavior emerges from interactions individuals make with each other (Bonabeau and Meyer 2001).

Consequently, a paradigmatic change from a planning and control approach (top-down) to an emergent and self-organizing approach (bottom-up) would result in changes in the way logistics activities are being managed. Dent (1999, p.12) describes this as *"how we see things determines much of what we see"*. Therefore is it today impossible to describe what we are expected to see when a complexity perspective has influenced how we see for example the activities related to logistics. However, the transformation of mind-set, from a planning, control, to an emergent and self-organization approach, may have consequences for the definitions used in logistics.

The implications a complexity perspective has on logistics management are here illustrated by a discussion of the CLM definition used in this paper. The first part, *"the process of planning, implementing and controlling"* is what logistics management are doing *"for the purpose of conforming to customer requirements."* This is by definition related to the property of adaptation since it demands interpretation by people concerning the customer requirements, and especially for logistics management concerning planning and controlling activities needed for customer fulfillment. Since we are living in an increasingly interconnected world there are several factors that might influence the customer requirements, but certainly also the actual flow and storage of products and information. This leaves logistics management with great interpretation consequences since emergent phenomena are unpredictable and the managers are not in the position of an observer or designer standing outside the logistics system. Still, they are supposed to plan and control the flows of products and information in increasingly interconnected supply networks. What is needed to handle this paradox is a more balanced view of planning and control with considerations to emergence and self-organization.

For logistics management to realize the paradox of control and self-organization, a bottom-up perspective on the logistics activities could give novel insights and act as the balanced view. This could act as a complement to the dominant focus on global phenomena and the associated top-down approach related to this. Possible insights might be that logistics managers will learn that the possibility of breaking network level problems down to actions for individuals is difficult. The effects would be interesting and challenging since global patterns identified in complex systems are not possible to be broken down into the behavior of the individuals/parts (Stacey 1996)

## Conclusions and future research

This paper has discussed and analyzed the implications of a complexity perspective on logistics and one conclusion is that a modified version of the definition of logistics management is called for. Based on the discussion earlier in this paper would suggest a change concerning the elements related to the property of adaptation. This means that *"the process of planning, implementing and, controlling"* has to be balanced by considerations to emergent phenomena and the processes of self-organization taking place in the flow and storage of products and information. This will have to be studied further in order to find a better definition, that is more in line with the environment and conditions that logistics management faces in everything from strategic thinking to everyday work.

In this paper only a short assessment of some of the components that give rise to complexity in logistics systems has been made, although these components are considered some of the main factors. In order to assess the full complexity it is necessary to go deeper in the analysis, but the purpose of this paper was mainly to analyze the concept of complexity in the context of logistics management and to show that it is possible and useful to describe and analyze logistics systems in this context. The underlying purpose of this research is that if the complexity of logistics systems complexity can be modeled and assessed it will give researchers as well as logistics managers a better understanding of these systems and in the future facilitate a more efficient and effective handling of logistics systems.

This paper provides another conceptual model to the research area of logistics that hopefully will give an increased understanding of the problems and systems analyzed and that it in this way will be a part of a further development and enhancement of the research into complex logistics systems. Basically the paper has explored if complexity as a concept and metaphor is useful for describing the shortcomings of logistics systems and it has been proved valid in at least one case.

The future research envisaged is twofold, to analyze complexity in logistics systems *per se* and to study different concepts, models and methods that will help us in understanding and adhering to the requirements of a sustainable society. It is the firm conviction of the authors that there will be an increased demand for more sophisticated solutions to the transport of goods and people which will require more sophisticated approaches, methods and models both to assess these systems properties and to be able to manage and control them in the most efficient way. The concept of complexity is one tool that is possible to use to assess and model logistics systems in order to create a basis for more efficient and effective sustainable logistics solutions.

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