THE INFLUENCE OF INFORMATION AND COMMUNICATION SYSTEMS (ICS) ON SUSTAINABLE LOGISTICS – *RFID* AND THE ‘AUTONOMY’ OF SUBJECTS

Heike FLÄMIG; *Institute for Transport Planning and Logistics, Hamburg University of Technology*

ABSTRACT

Modern information and communication systems (ICS) contribute to a steady and dynamic increase of the spatial division of labour among firms. In the context of economic and social transformations, modern ICS (e.g. internet-based technologies, GPS, RFID) are shaping the supply of goods in terms of quantities, of temporal and spatial organisation. The resulting increase in complexity of logistic networks complicates the coordination and control of transport chains. Up to now, physical and information logistics are often handled as separate fields of activity. However, more efficient communication and effective provision of the required information are essential for the management of value chains. And the overarching research question is whether a paradigm shift in the application of modern ICS allows for a sustainable organisation of the physical flow of goods.
This paper therefor discusses the influence of modern ICS on the spatio-temporal organisation of the physical flow of goods through the use of different control systems (e.g. push vs. pull). It reveals the changing prominence of distribution operations (storage, consolidation, cross docking, etc.), the types of logistical nodes (distribution centre, transshipment point, harbour, etc.) and the choice of logistic locations as well as the resulting traffic generation in time and space.
The analyses show an interrelation between the dominant control schemes of a supply chain, the effect of ICS and their impact on the spatial structure of production, the generation of traffic and the environment. A conceptual framework for this interrelation is developed on the basis of a new understanding of the role of communication and information elements within logistical systems.

RFID, production system, value chain, transport, sustainability

INTRODUCTION

The division of labour between different companies and across space has been expanded and accelerated recently, particularly due to the integration of value added activities. Cross-company supply chains were developed (Porter 1985, p. 33ff.) and transformed into global networks (Coughlan et al. 2006, p. 14ff.) as a result of the reduction of trade barriers and the establishment of global production networks. Thus value adding processes have become more efficient on the one hand, but also more vulnerable on the other hand. This also applies to the material flows of physical goods: The more likely bundling effects are becoming, and the more complex transport chains will be, the more difficult will be the related management and control of the chains. This is a consequence of rising transport volumes, longer distances and significantly more complex transport chains. The dynamic changes of (logistics) network structures – especially tendencies of geographical decentralisation – supported the increase of the complexity of processes while impeding efficient communication and sufficient supply of relevant information for central controlling authorities.

The realisation of global flows of goods was mainly driven by the invention of information and communication systems (ICS), which also influenced the development of spatial structures (Castells 1996, Dicken/Lloyd 1990, p. 383ff., Schamp 2000, p. 1). Interdependencies between ICS and spatial developments were recently discussed with respect to the breakthrough of the Internet and the emergence of Electronic Commerce (‘E-Commerce‘), which is defined as the trade between buyers and sellers using electronic media (Dohse et al. 2004, Flämig 2002a).

Current studies on E-Commerce deal with the traffic and/or environmental impacts of delivery services, sometimes under consideration of the spatial dimension. They include conceptual analyses and ideas about potential correlations between E-Commerce and traffic (Mokhtarian 2003, Mokhtarian/Salomon 2002, Janz 2001), surveys concentrating on tele-shoppers (Tacken 1990, Handy/Yantis 1997, Gould 1996, Gould/Golob 1997, Gould/Golob/Barwise 1998, Luley et al. 2002) and projections of the trips generated by E-Commerce in relation to the entire commercial traffic volume (TLN 2000). There are also studies concerning the home delivery of groceries. These studies mostly deal with more or less extensive simulations of real, precisely defined areas (Cairns 1998, 2003, Punakivi/Saranen 2001, Punakivi/Holmström 2001). Another study examines the emissions caused by the last mile in different distribution concepts (Orremo et al. 1999, 2000).

Regarding the evaluation of E-Commerce and its impact on traffic, some valuable work has been done by Cairns (1996). Her study identified a number of related factors and parameters of E-Commerce. Other studies concerning simulation were based on these calculations and obtained similar results. Depending on the variables chosen and their characteristics according to certain scenarios or service models, the simulations indicated that between 50 and 90 per cent of the mileage per unit could be saved by using a delivery service (Punakivi/Saranen 2001, Punakivi/Holmström 2001, Cairns 2003). Palmer’s (2001) calculations lead to the conclusion that, regarding the generation of traffic, a delivery out of shops was more efficient than delivery via fulfilment centres or distribution warehouses.

Most related studies have in common that the amount of kilometres per delivery vehicle is compared directly to the amount of private car kilometres saved. Regarding the impacts on traffic and the environment, this comparison is incomplete as, for example, an average private car needs less space and produces less noise and pollutants than the average van or truck. Therefore, each figure represents a maximum savings potential, as for the purpose of reducing complexity related assumptions made are not wholly realistic (e.g. a major substitution of shopping trips by home delivery), and a number of parameters have been neglected so far (such as alternative uses of the car, exhaust emissions and in some cases modal-split).

Orremo et al. (1999, 2000) and Punakivi et al. (Punakivi/Saranen 2001, Punakivi/Homström 2001) tried to overcome this deficit by evaluating emissions in rural and urban areas which are linked to shopping and delivery traffic. Depending on the delivery concept, the potential of reduction in the case of air pollution varied widely, ranging between 15 and 90 per cent. In general, both calculations revealed that delivery services are energetically more efficient than customers' shopping trips by car.

Studies of tele-options primarily contain empirical data on how far individual and commercial traffic can be substituted by distance trade. At least regarding the purchasing of groceries it seems that people, who buy their food online, use their car less (Tacken 1990, Gould 1996, Handy/Yantis 1997).

Overall only few studies are currently available specifying the impacts of E-Commerce on traffic and the environment precisely. In particular, no further conclusions have been drawn so far regarding the impacts of new delivery concepts. In addition, the studies at hand are of limited comparability, as they differ in their assumptions, e.g. concerning unloading times or the loading capacity of the vehicles. Discussions focused on changing conditions of participation and spatial distribution of individuals, companies, cities and regions, not answering the question of spatial development and its environmental impact as subject to changing procurement and distribution practices.

More recent studies emphasised aspects such as traffic control and optimisation through the application of ICS or the increased transport impacts resulting from logistical concepts through temporal adjustment (e.g. just-in-time), rather than a reduction of transport. Issues such as mid- and long-term changes of transport- and traffic-networks caused by logistical modifications appear to be covered quite rarely. Only the role of newly established logistics nodes as a consequence of E-commerce (pick-up points, packing stations, automats, etc.) and the related impact on transport and the environment had been modeled (Taniguchi/Kakimoto 2004, Flämig 2002b).

The invention of 'Radio Frequency Identification' (RFID) has raised a renewed interest in gaining an insight into the related role of technological change with particular attention paid to a de-coupling of economic and transport growth. By providing technological options for making goods 'intelligent', RFID systems also enable the realisation of decentralised planning and controlling strategies. The term 'Internet of Things' (IOT) has been introduced, in order to describe the communication between objects and machinery (Fleisch, Mattern 2005).

In this context, the paper deals with the consideration of self-control of logistic processes through the decentralised co-ordination of autonomous logistics objects. For this, a set of scenarios is being developed. The guiding questions in this research are: Do intelligent logistics units lead to introducing a new approach in controlling logistics chains and thereby change the physical flow of goods and thus over-coming space? The overarching research question is whether a paradigm shift in technology allows for a sustainable organisation of the physical flows of goods.

In order to answer this question, a basic understanding of some principles for controlling supply chains is required, as they determine the demand for the transport of goods and potential alternatives (design, mode, utilisation). The fundamental principles will therefore be explained in more detail below, in order to discuss their influence on logistic and spatial systems. Also, a basic knowledge of the underlying architecture of the systems of goods flow is required in order to assess the impact of a changing logistical management on transport systems. Moreover, the paper touches on the development of information and communication systems, which are influencing the design and management of value chains and transport chains. Based on a particular knowledge of steering principles, freight transport systems-architecture and the related role of ICS, the potential impact of 'intelligent logistical units' on logistic chains, transport flows and spatial developments will be discussed using a differentiated scenario approach.

PRINCIPLES FOR CONTROLLING PHYSICAL SUPPLY CHAINS

In the 1980s the concept of 'Efficient Consumer Response (ECR)' was developed, which describes the idea of assigning every part of a product to the consumer at any time of the supply chain beginning at the store check-out. This information is to be forwarded in the opposite direction of the material flow directly to the producer and its suppliers. This idea basically follows the 'Kanban'-principle. Kanban was developed for efficiently organising production systems, particularly where subsequent units of production call for delivery of materials from the preceding unit, as part of autonomous circuits of steering. Here, 'Just-in-Time (JiT)' or 'Just-in-Sequence (JiS)' concepts ensure meeting the demands (quantity, time, order) of the customers. Further developments are based on the approach of 'Continuous- or Efficient Replenishment (CRP/ERP)' and the 'Vendor-Managed-Inventory (VMI)', in which the supplier is in charge of the delivery process (Cooke 1998). In the case of vertical co-operation along the consumer goods-supply chain, the approach of 'Collaborative Planning, Forecasting and Replenishment (CPFR)' in the context of the 'Voluntary Interindustry Commerce Standards Association (VICS)' is being applied (www.vics.org).

By integrating the concepts of JiT, ECR and ERP, a collaborative planning, forecasting and procurement procedure could be achieved, comprising the entire supply chain. CPFR extends the concept of ECR by triggering processes of joint and continuous improvement, also with respect to measuring the quality of data, in order to adjust production and storage to real-time demand.

According to Chopra/Meindl (2004, p. 54), two main goals were aimded for using the new steering principles of logistics and supply chain management: the reduction of stocks throughout the supply chain and thereby the reduction of the so-called 'Bullwhip-Effect' (physical efficiency), and also avoiding out-of-stock-situations and associated opportunity costs (market responsiveness). This is to be achieved by generating minimal costs, considering storage costs, capital commitment costs and mobilizing economies of scale (Bowersox 2007, pp.12).

The bullwhip effect (Forrester 1962) describes developing variations in the supply of a certain quantity of goods, starting with consumers via the retailers back to the producers and their suppliers. This also occurs when the demand of consumers at retail is constant. The activators are deviations of order quantities in relation to the demand, for example, to take advantage of economies of scale effects (volume discounts, price fluctuations, etc.). The higher the distance between the particular link in the chain and the final demand (in physical, organisational, legal) is, the lower is the correlation of the local production with the demand. The process of steering is determined by two basic principles: first by the temporal adjustment of the value adding processes (*time base)* via flow oriented or resource based (functional) approaches; second by the *nature of the order*, further distinguished by push and pull steering modes. The central idea behind these concepts is to reduce or even eliminate the total stock of product units within the supply chain at a certain time and to produce customer-oriented goods.

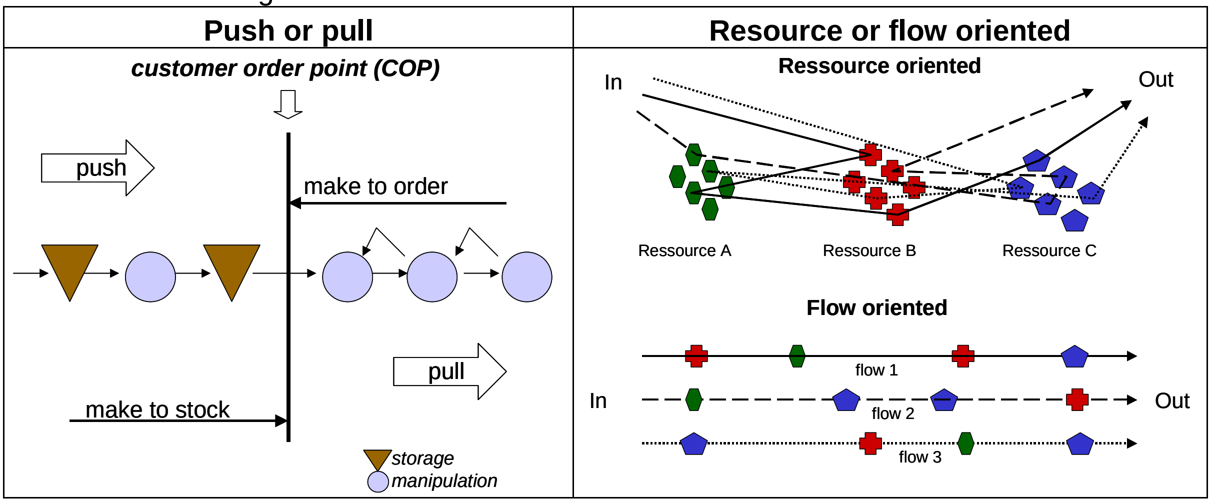

Figure 1: Principles of controlling physical supply chains

In the flow-oriented approach the steering is organised via the time that is required for certain tasks to be done. The central steering parameter is the lead time which has to be kept at a minimum. In the resource-oriented approach the steering is organised via the available capacities of resources and the time that is required for getting certain tasks done; these capacities can comprise e.g., machinery or staff capacity. In logistic transport systems, this approach plays an important role for big logistics nodes, such as harbours, freight traffic centres, goods distribution centres with major warehouses and consolidation outlets. They tend to be crucial for the functionality of these nodes. However, some specialised interfaces may only be suitable for meeting very specific demands. A standardised production system, which is found in the case of hubs of courier, express and postal service providers, is adjusted to a consistent use of capacity with standardised shipment (dimensions, weight) and covers only forwarding (no storage or commissioning) and the function of consolidation for bundled transport.
Steering the supply chain by means of the type of order is closely connected to the point of time of the individual customer's order, the so-called 'Order Penetration Point' (Sharman 1984, p. 73). At this point the final product is individualised and in most cases its destination is known. In the case of mass products, the order penetration point is not used for controlling purposes. In the case of customer-independent production, goods are being delivered out of the warehouse. The production follows the push-principle, is forecast-based and will be

steered by a plan outside the production system (Hopp/Spearman 2001, p. 340). In the case of customer specific products, i.e. in the ship building-industry, the customer is supplied directly, avoiding storage (contract manufacturing). In such pull-systems, the steering occurs via the status of the system itself (Hopp/Spearman 2001, p. 340). The programme manufacturing can be seen as a combination of both approaches. This mostly occurs in correlation with customer-neutral pre-fabrication. Once the customer order is received, the product will be finished as in the pull-principle, which is also the basis for the JiT-philosophy and the ECR-concept. For this order-oriented way of controlling, the flow of information is directed in the opposite way compared to the flow of goods. For example in the automobile industry this is daily practice, where the pre-fabrication is customer-neutral while the completion of the car occurs individually for customers (customizing). Thus for the programme-manufacturing the push-principle is applied ahead of the incoming customer order. After the 'Order Penetration Point', an individual differentiation of standard products is performed for the customer following the pull-principle. The aim is to postpone the final point of the production process in the customer's direction ('product-related' postponement, manufacturing or assembly form postponement). On the other side there is the logistic or geographical postponement (Bowersox et al. 2007, p. 14). Here, differentiated products are stored in warehouses until the customer order is being received. This approach requires a fast and safe transport to meet the customer needs.
The selection of the type of controlling highly depends on the value and the quantity of the product, on possible benefits of economies of scale in the production process, on manufacturing technologies, on alternatives of competition and on customer wishes regarding speed and reliability. In practice, combined systems are increasingly being applied. However, time and costs for overcoming space (transport) are only considered with respect to modal comparisons, often without questioning the related framework conditions (e.g. volumes, distances).

NETWORKS FOR OVERCOMING SPACE AND TIME

The increase in cross-company supply chains and networks leads to a growing importance of the three main logistic functions. Transport serves to overcome space and defines the connection of space and time between sender and recipient of goods, handling serves to balance quantities, breaking up large quantities (function of disaggregation) or bundle small quantities (function of aggregation) in logistic nodes (harbours, distribution centres, railway yards, etc.). These also provide storage capacity and overcoming time between the completion or the procurement of a product and the point of its distribution.
The movement of goods itself is carried out within transport networks (edges). Their spatial integration is depending on geographical conditions and existing infrastructure. Transport systems (road, rail, water, air and pipelines) have different qualities in terms of space and time, different capacities, infrastructures and accessibilities for demand, according to the so-called 'values of transport' ('Verkehrswertigkeiten', VOIGT 1973):

Time: speed, punctuality, frequency of transport service, seasonal, regular,
Quantity: mass performance,
Distance: ability to establish networks,
Quality/degree of service: safety, comfort, reliability, computability.

Beside the infrastructure of transport and the utilisation of edges, the number, form and spatial distribution of logistic networks plays an important role for efficiency of logistic flows. Logistic nodes are interfaces, which often appear at company boundaries, when changing the transport medium, rearranging, distributing or storing goods. Logistic nodes can be harbour locations in worldwide supply chain networks, central or regional warehouses, distribution centres, business locations of commercial or industrial enterprises as well as interfaces between suppliers and end customers or in the transport system itself, like handling points.

In general it is distinguished between direct and indirect flow systems of goods. Direct flow systems are characterized by two existing interfaces: one at the origin and one at the destination of a transport chain. There is no interruption within the supply chain. Instead goods are transported directly from the sender to the recipient. In direct flow systems the flow of goods is interrupted by various trade levels, changing loading units, transport routes or transport mediums in order to bundle shipments (consolidation) and thereby increasing the efficiency of the system. Thus vehicles can be used to their full capacity or bigger and more efficient means of transportation can be used.

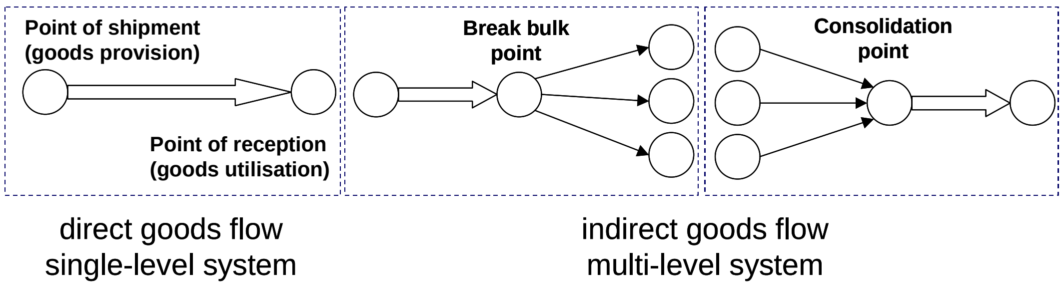

Figure 2: Systems of good flows (according to Pfohl 2004, p. 6)

Concerning the transport management, this means that transport is either realized through direct transport or through grid patterns or so-called ‘Hub-and-Spoke’ (HuB)-Systems. In grid patterns, handling points are exclusively connected by direct transport. Co-operations in the case of general cargo are often organized this way. The bundled main transport flows between two hubs are indicated by the thick arrows in Figure 2, while the thin arrows symbolize consolidating or distributing transport on the so-called last mile. Courier, express and parcel services were the first user of HuB-structures. Today a lot of forwarding agencies or cooperations have two-leveled systems. Only once covering the last mile major differences can be detected. Depending on controlling via push- or pull-principle, goods on the last mile are either brought to the recipient or collected by the recipient. In practice many of these systems are used and sometimes even realised simultaneously. However, some basic types of systems can be distinguished (according to Holderied 2005, p. 234ff.):

- shuttle transport (two opposed routes on the same relation);
- triangular- or occasionally quadrangular transports (shuttle transport between three or four logistic junctions) and
- exchange transport (two vehicles on one relation or more vehicles on a junction, which can only be one highway parking where an exchange of handling units takes place).

In the 1990s the flow oriented ‘Cross Docking (x-docking)’ was developed for customers in the retail business. Today it is an important part of ECR. It is characterised by a direct transfer from the reception area to the outbound area without existing storage in between. For one leveled cross docking the loading unit (i.e. the pallet) remains the same, while for two leveled cross docking (transshipment) the shipment is broken up and commissioned for example according to branches. Hence the sender does not commission goods according to branches but according to the cross docking-point. This can however lead to the bullwhip-effect, which can be avoided by integrating article-based real time information of CPFR. In order to do so, information and communication systems have to be considered as important factors.

DEVELOPMENT OF ICS AND THEIR INTERACTION WITH THE PHYSICAL FLOW OF GOODS

In order to assess and to determine the effects of information and communication systems (ICS) on the organization of physical flows of goods, the framework model of Krcmar can be applied (2005). It distinguishes between *information management* (supply and demand of information), *IC-technologies* for communication purposes (transmission, processing and storage) and *information systems* (data, processes and application systems).
Information management, which can be understood as information logistics, deals with the same issues as logistics for organizing material flows: providing the supply of the right goods (information) in the right quantity and quality at the right time to the right place (customer). The flows of goods and of information are closely connected. The flow of information can be organised either in advance of the material flow, simultaneously or afterwards (Pfohl 2004, p. 81):

- *information flows situated in advance* of the material flow inform about the type, the quantity and quality of the good, from where to where it is transported, at what costs, by which kind of transport medium and at what time it is ordered;
- *the information flow* which happens *simultaneously* to the material flow enables the identification of the good as well as its origin and destination;
- *information flows after delivery* are required to give and receive feedback about the order status, the quality of delivery service and to identify the right time for invoicing.

In the context of the so-called ‘digital revolution’ several generations of IC-technology have been created and applied. Only through the invention of information technologies, various forms of division of labour in space and time became possible (cf. Flämig/Sjöstedt 2003, p. 116ff): At first, independent mainframe computers were used to solve complex problems for the optimization of processes at a location as well as to store data (Kretschmer 1963, p 137). The storage of data was performed by exchangeable storage devices, which had to be read in again when needed. The exchange of data and information was carried out on paper documents, later on accelerated by the invention of the fax machine, which is still used today in context of transport logistics, especially for the avis of delivery.

The personal computer can be seen as the second generation of IT. With its development it became possible to realize intra-organizational planning and transactions digitally. Production, exchange relations, and delivery sequences between different locations could now be planned and controlled at the same time. Thinking in processes could thus be supported by the required information logistics. As a consequence, the concept of work flow-management was created. Based on this idea, new logistic concepts such as the JiT-principle could emerge. Another important step was the development of information networks, which enabled real time actualization and synchronization of databases between computers without human interaction. The so-called 'Electronic Data Exchange (EDI)' plays an important role in this area today. It describes the transfer of structured data by agreed message standards from one computer system to another by electronic means (Schüppler 1998, p. 25). Besides the internal cross-linking, EDI allows the cross-linking to and between external companies. Today, agreed message standards provide unified and transparent structures for all market participants.

Hence EDI represents an opportunity for the automation of information flows between companies without facing the risk of media interruption. EDI replaces the manual input and the printout of paper documents (such as orders, invoices, delivery receipts), which in contrast to conventional media like letters, telefax or telex, leads to a higher speed of transmission. Preventing double entries, reaction times and thereby processing times are reduced. A lower susceptibility to errors and lower costs can be realised. This development was further supported by the introduction of barcodes and scanning methods. An important step towards a greater customer orientation could be made by realizing the ECR concept and thereby by the supply chain-wide co-ordination of good flows and information flows, leading to a reduction of transport errors.

Further reputation for logistic processes via EDI was gained after the development of the internet. Browsers reduced the barriers of usability significantly. E-Commerce and E-Business have emerged. Today, computers are able to illustrate various complex business processes and resulting physical operations online at the same time. Today's generation of information technology allows for the collaborative handling of abstract orders even at greater distance. At the same time access barriers to information on supply and sale sources are reduced, which leads to the simplification of establishing remote business relations with corresponding good flows.

SMART GENERATION

The currently evolving 'smart generation'-technologies had mainly been made possible by RFID-applications. Instead of connecting companies, the informatisation and cross-linking of physical items took centre stage, also known as the 'Internet of Things' (Fleisch, Mattern 2005). After EDI helped to reduce media interruption in the information chain, RFID now enables sending information from the physical good into the abstract world of information systems. The Internet of Things links real and virtual space (Fleisch, Mattern 2005, p. 64) by uniting informational and physical parts of the supply chain. A new standard, the Electronic Product Code (EPC), allows for the clear labeling and thus the identification of objects.

Table 1: RFID-Technology

Radio-Frequency-Identification (RFID) is a method of communication between a tag, which is able to transmit as well as to respond, and a writing and/or reading unit with an associated evaluation unit. The performance of RFID-units is based on its type, its power supply and its frequency. The type of power supply of the transponder (activ, passiv, semi activ) influences the possibilities of locating and the 'intelligence' of the tags. The frequency influences range and behaviour in different media. Today, existing systems feature ranges between 1 cm and 300 m. This range can be enlarged, by using space-based global navigation satellite systems, like e.g. the Global Positioning System (GPS).

RFID systems thus expand the options of logistics chains, particularly regarding identification, tracking and tracing, quality assurance, billing and modes of control (cf. Table 2).

Table 2: Performance of RFID in the supply chain (following Gronau 2005)

Function	**Value**
Identification	Establishing an automated link between environment and object
Track & Trace	Adding information about the location
Quality assurance	Linking objects with quality requirements and rules
Billing	Usage-based billing and assessment, pay-per-damage
Control	Decentralized control of the logistical channels

By satellite-based positioning, e.g. GPS, it has been possible in retail and commerce for some time now to locate the flow of goods geographically on edges. Today many vehicles or transport containers are equipped with GPS. However, the current data, which are submitted from GPS systems are primarily used by logistics service providers to optimise their fleet, and only afterwards the information will be made available to shippers and receivers of consignments. Data on tracking the goods at any time are currently not transmitted instantly. The exact contents of the cargo unit depend on the reliability of the loading place. RFID would be able to ensure a 100-per cent certainty about the loaded article.

The coupling of satellite-systems and RFID-systems allows for not only to render those flows of goods virtually visible, which are resulting from distributed processes, but also to actually locate the materials at any time; and with an appropriate sensor technology it is furthermore possible to determine the quality condition and submit it. The flow of information accompanying the flow of material gains a new quality. By using RFID-systems, products and goods can be monitored and possibly readjusted throughout the entire flow. Thus, the self-controlled logistical units are able to provide information on their current location, their condition or their environment (e.g. temperature) or about singular events (such as strokes due to an accident) at any time. Intelligent logistical units could navigated through the logistical channels. They are able to control the vehicle choice locally, because they own the (real-time updated) information about the place of use. In addition, they could perform the route planning by themselves. In combination with information about the means of transport they can optimise tour planning and load factors. Depending on the configuration of the system, it will be possible to change this information at short notice (cf. anticipatory information).

Table 3 gives an overview of the range of additional information that can be provided by ICS regarding the physical transport - in advance, accompanying and following the material flow. Besides new information, e.g. concerning the reporting on the permanent local and condition of the item, the innovation includes that all data can be provided real-time directly at the logistical unit. Temporal frictions in the transport chain can be avoided, material flow and storage processes (e.g. at the terminal) can be optimised.

Table *3*: Time and type of information through intelligent items in transport chains

Information flow related to physical flow	**In advance**	**Accompanying**	**Following**
Document	Order Avis	Consignment note	Invoice
Current information	Subject Quantity Origin Destination Quality	Subject Quantity Origin Destination	Subject Quantity Quality
New information	Article Availability	Location of shipment Conditions / state of the shipment	Performance
		> Real time	

As part of the next section, the question will be investigated further to what extent the physical flow of goods as a result of new data handling (such as the use of RFID systems) can be reorganised and which spatial impacts are to be expected.

A SCENARIO OF IMPACTS OF ICS IN LOGISTICS CHAINS ON TRANSPORT IN SPATIAL CONTEXTS

Once considering the transport impact and the associated changes in spatial contexts, the issue discussed is particularly about the ‘intelligence’ of goods between different stages of added value. Although the (total) order size and production volume can no longer be determined, the geographic postponement may be refined and cross-docking approaches continue to gain importance. If RFID-systems are installed thoroughly, it would be possible to produce full accounting capabilities. Theoretically, it is possible to move the order penetration point as far as possible into the transport chain, being much closer to the area of distribution than to the area of production. Prerequisites for this opton are rapid turnover frequencies and large order-volumes, in order to ensure the most efficient delivery bundling against direct deliveries. Thus it is conceivable that logistical units, which are still in a cross-docking point, could be adjusted according to order volumes or locations of delivery.
Concomitantly, such self-controlled logistic units would be able to adjust and control their ‘own’ material flow, on short term and demand-oriented, through the logistics system at shorter relations or other transport, for example, from the lorry onto the train. By applying the basic principles of the systems of goods flow (see Figure 2) to the issues outlined here, the

‘intelligent’ logistical unit needs to decide again whether it makes more sense to form smaller logistical units (break bulk) or to combine itself with other logistical units to a larger logistical unit (consolidation). In the latter case, a significant ’pooling potential’ can be mobilized for increasing the load factor of vehicles, for using larger and thus more efficient vehicles, or for shifting transport modes in favour of the rail or inland waterway modes.

Due to the increased load factor of road transport vehicles and the more frequent use of mass transport modes such as rail or barge, respectively, the ecological efficiency along the supply chain can be improved.

Table 4 provides an overview of possible interdependencies. Starting with newly derived principles of management and control, exemplary cases of applications and products are listed. In such cases, the use of new ICS is expected to change the logistical organisation and the associated spatial and transport impacts can be estimated.

Table *4*: Scenarios of the influence of ICS on sustainable logistics

Scenario	**A**	**B**	**C**	**D**
Product attributes	• Low value • Functional • High suitability for forecasting • Mass product • High product demand	• Middle value • Functional • Trendy • Susceptible to failure • High product demand	• Trendy • Mass product	• High value • Customized • Low product demand (order quantity1) • Spezialized
Examples	Canned vegetables Toilet paper	Cell phone Camera	Fashion	Ship modules Airplane modules Medicine technology
Main aim of control	Shorten inventory	Lead time reduction	Lead time reduction	Lead time reduction
RFID-System	Passive tag	Passive tag [with GPS]	Active tag	Active tag with gps
Postponement	Geographic	Geographic	Geographic	Manufacturing
Logistics advantages	Lower number of default trips	Lower number of lost products; reverse logistics as pull-system	Lower number of default trips	Lower number of default trips
Logistics organisation	Consolidation Cross docking	Consolidation Cross docking	Break bulk Cross docking	-
Routing	Routing via notes	[Free routing]	Routing via notes	Free routing
Transport corridors	Modal shift	Modal shift	No changes	Less congestion
Spatial balance	No changes besides quantity	Agglomeration	Fragmentation	No changes
Transport balance	Lower number of trips	Lower number of trips	Increase in shipments	Smaller shipments with trucks
Emission balance	Emission reduction	Emission reduction	Emission increase	Emission increase

Scenario A: Replenishment in the retail business: functional products

During the manufacturing of functional or low value products such as toilet paper or canned vegetables, the production itself is based on the concept of economies of scale. According to that the actual manufacturing is mainly based on the forecast data. The order penetration point (see Chapter 2) is situated behind the completion of the product. Therefore the storage of finished products is initially located near the production centre. With the help of RFID-systems, differences of quantities which occure at the point of sale (e.g. shrinkage, spoilage) can now already be detected at the shelf. Related pilot projects are already being implemented in Germany, for example the *Metro Future Store*-project pursued by the *Metro AG*. In the mid-1990s, *Metro* took over the management of their logistics chains and has since then ordered from the factory. Specifically for that reason the *Metro Group Logistics Warehousing GmbH & Co*. *KG (MGL)* was set up. In order to increase the visibility of the logistics network, *Metro* uses RFID-technology for realising 'Smart Shelf'. In addition it uses the technology for controlling the flow of goods between the distribution centre and the showroom, at case or pallet level. The smart shelf is a shelf that can identify what item and what amount is stored. For that reason the shelf is provided with an RFID-reader and each sales unit has been tagged with an RFID-label. Thus the demand control can be improved and the availability of goods can be increased.

Real-time data submission from the shelf utilises geographic postponement in the supply management. Ultimately, this contributes to cutting the distances travelled by the commodities, since these can be allotted more short-term, consumption oriented, which is also more in-line with the real demand. It is thus also achieved that unnecessary items are not transported, hence the traffic volume is being reduced.

Scenario B*: Replenishment in the retail business: products of higher value*

Passive tags are already used for high-quality products on the item level; for example there is the showcase of the *Otto Group*, who already applies this technology. Cell phone, cameras, etc. are equipped with a bar code combined with a passive tag, added to each good at the distribution centre. The goods are stored in a separate, locked picking location. After the activation of the picking and distribution process by the customer's order, it is now possible to trace the path and the exact localization of the goods. Therefore loss rates can be reduced and in the case of eventual recalls by manufacturers, customers can directly be contacted.

The use of RFID systems significantly improves providing information related to the flow of material. This makes it possible to completely reconstruct the life-cycle of an item and its components; thus more detailed information can be provided, for example in the case of claims, liability issues, call-backs, etc. Reverse logistics operations, which are closely related to call-backs, can now be more efficiently organised as a pull-system. By using GPS, the exact position of a good can be localized. Flows of goods thus can be better concentrated in time and space; the conditions for a shift to other transport systems like rail or waterway are being improved.

Thereby the spatial performance of the logistics system can be improved as well, e.g. once many separate lorry trips can be combined or bundled, following the hub-and-spoke approach, and the long haulage is shifted to mass transport modes. This standardisation and the associated further automation of transport and handling can allow for a higher concentration of traffic on a few highways and a few logistical nodes, such as large sea ports. Due to the bundling of transports close to the customers, transport efficiency will be increased.

Scenario C: Replenishment in the retail business: 'trendy' products

In the case of 'trendy' products any data based on concrete business experiences is missing, and thus the forecasting options appear limited (e.g. in the case of textiles) and the production begins according to the pull-system, after receipt of the order. Starting with the first re-order, RFID-systems may allow for placing these textiles at the precise point of sale or consumption according to demand. The tags will deliver the required information concerning the future time of demand in the subsequent stage of adding value.
If the logistic unit also possesses the information on which transport modes (truck, ship, train, airplane) it can be transported in the available time frame (and offer the required capacity), then it would be possible to use alternative means or routes for transport, identified by the logistical unit. A sufficient time window may allow for significant modal shifts. Transport related environmental impacts might be reduced.

Scenario D: Customized products

A different development is expected in the case of the batch size one. Here, the production begins according to the pull-system after receipt of the order. This means that for all parts, assemblies and modules that are required according to the order penetration point, both, the precise quantity and geographic location within the following steps are already determined.
RFID-systems can contribute to increasing the quality and the reliability of the manufacturing-process. This is also associated with lower transport costs, since only those goods will be transported that are actually needed. Due to the increased value of such goods, it is likely that (even more) smaller consignments with smaller (road) vehicles will be transported. Consequently, this will raise the related transport and environmental costs.

Scenario E: Management of means of transport, GPS

Currently the identification of the goods flow is taking place in nodes, usually in a warehouse of a shipper or a recipient, and also in a terminal (distribution centre, port, etc.). In the long term it will be possible to install the appropriate reading units not only in the logistical nodes, but also to integrate them into the modes of transport. Regarding the road transport system, toll bridges could be used; in the railway system, the reading units could be installed at the rail tracks; for the inland waterway the installation on bridges would be conceivable. Data exchange is ensured by global positioning systems (GPS) mentioned above, in order to detect road vehicles beyond the highway as well as ocean ships and airplanes.

Through the use of isolated, passive tags, the physical flow and thus transport activity can be recorded at a reading station or a gate. The monitoring of the tag commences in the distribution centre where it is recognized at the dispatching point and 'married' with the vehicle. In the central computer system this information can be linked with the information on the content of transport. The further assessment and monitoring will take place as usual by detecting the bar code. Hence, it is limited to the track-and-tracing process. However, it will be possible to recognize at the reading gates whether the planned routing is still useful or not. For instance, in this case traffic jams caused by clogged transport axes can be avoided.

DISCUSSION AND OUTLOOK

The aim of logistic management approaches is the system-wide increase in efficiency and effectiveness of the processes along the logistical channel, in order to improve customer benefits and contentment. The approaches pursue the reduction of stocks in general and of the bullwhip effect in particular, and the reduction of processing times at minimal cost. The related performance is strongly influenced by the use of the three logistics functions - transportation, handling, storage - and the manipulation time (editing, commissioning).

The new ICS improve communication across the entire logistics chain, thus fluctuations and variations in the supply and demand will be reduced, as well as the sales order can be fulfilled in a shorter time. ICS now allow for (real-time) transmissions, the (mass) storage and the (automated) processing of information flows, which are situated upstream, associated and downstream with regards to the material flows.

However, the dynamic changes of the logistics network architectures that are currently being observed – particularly the tendency of spatial decentralisation – may increasingly hinder efficient communication and the allocation of the required informations to the so far installed *central* units of management, planning and decision making. This may contribute further to an increased complexity of the logistics processes. Though the rising demand for communication – in the light of the likewise increasing complexity – requires a high level of flexibility and adaptability of the logistics processes. This can hardly be achieved by centrally organised systems of information and communication.

One solution is usually seen in the decentralised self-controlling of logistics processes. Here, with the help of new information and communication technologies, such as RFID tags, positioning systems and wireless communication networks, the planning and control processes can be transferred to the physical flow of goods, which in particular can show their advantage in pull systems. This decentralised control combined with the demanded flexibility requires active transponders. The price today, however, is significantly higher than of other embodiments. Because of the high costs which are associated with the introduction of RFID-technology, the current fields of application of this technology are conceivably fields, which need to provide evidence for the high process reliability and consistent documentation of health or safety features (food, drugs, requiring documentation components, etc.). Other fields of application include a closed loop system, which ensures the reuse of the more expensive chips. Regarding passive tags, there is a certain reservation – mainly within retail trade – with respect to a widespread use on all products.

Advantages offered by RFID-systems will be significantly useful at the level of replenishment, which currently takes place at the retail outlets (the *point-of-sales)*, by scanning the barcode according to the pull-principle. The central warehouse-management system triggers orders based on sales data, supplemented by additional forecasting informations (e.g. on leakages, scrap or possible changes in demand, caused by weather or other singular events, e.g. holidays, sports events). In ideal cases, these data may also trigger manufacturing activites in upstream stages of the value chain.

Basically it must be assumed that functional or low-value goods tend to be equipped with simple, passive systems, and that high-quality, innovative products will be equipped with more complex and active systems. When, however, loss rates are taken into account, more items will be subject to a continuous tracing. The same issue applies to the cases of sold out products, high cost of manual price displays (without RFID) and physical inventories as well as cost savings through fully automated cashier operations.

Nevertheless, a truly *100 per cent*-service level cannot be realised concerning the category of every day consumer goods, apparently promising the delivery of the right product in the right quantity at the right time, at the right place, in the right quality and at the right price. The order lead time, if not the production time, includes even for ‘batch size one’ consignments the delivery by the producer to the point-of-sale. This depends - among other variables - mainly on the geographic distance between two places, which can not be nullified even by RFID systems. All in all, the geographic postponement is gaining momentum, since ICS tends to adjourn the routing of single commodities into the transport chain.

The scenarios as discussed in this paper have made obvious that by developing and applying ‘intelligent logistic units’, certain improvements can be achieved, namely a reduction in the number of mislead transports, a higher load factor of delivery vehicles and a short-term, individual choice of transportation and choice of route. In a nutshell: With the help of intelligent logistic units, the transport costs and the associated environmental impacts can be reduced significantly. For this purpose, transponders are not necessarily required. Rather, the different value chains need to be connected in terms of information; the same applies to the logistic service providers. The related information management should provide for real-time data and allow for flexibility in response to changes that may occur at short notice. It has become clear that nowadays the physical flows of goods are as diverse as the world of commodities appears to be. In this respect it is no surprise that, concerning transport and environmental impacts, the particular way of orchestrating the value chain seems to be essential, rather than the degree of application of new technologies.

Depending on which ‘intelligence’, which objectives, requirements and rules are being assigned to the logistic unit, the spatial and environmental effects can be negative. This is particularly the case once certain logistical volumes are being centralised, storage levels will be reduced and, at the same time, more small consignments will be transported. Thus it would become necessary to create even more major logistical nodes and mega-hubs, located at just a few places nationwide, respectively in Europe and possibly blocking much of motorway capacity. Other logistical edges (transport infrastructure) and hubs (e.g. ports) may become more important when there are capacity constraints on those goods flow relations which will be commonly used for transport.

In the near future the flows of goods and the use of space through the new ICS will not change, as initially the improved refresh period and locating of logistic units will be of great benefit for the actors. In the long term it is conceivable that flows of goods will be spatially redistributed, once capacity constraints occur on certain routes, such as traffic jams or other congestions, e.g. due to a lack of handling capacity at ports. Then it is possible that not only alternative relations will be chosen, but that in general a switching toward faster modes of transport will be a more viable option.

Equally, a slow-down or deceleration-effect can occur, if the purchasers of products no longer specify a certain delivery date, but define a broader time window which is in line with their demand but more relaxed in terms of transport management. As a consequence, the units could make ‘independent’ decisions according to the now broadened time frame, adjusting transport mode, route choice and delivery date. Overall, such adaptations could provide for a more environmentally friendly pattern of transport.

These first qualitative considerations reveal that by developing and applying new information and communication systems, both possibilites - traffic reduction and traffic generation - may be associated as possible side effects of the application of ICS. Hence, based on these findings further research will be required, first in order to test the conceptual model presented here empirically, second for deriving thorough conclusions that may result from the practice of ICS for policy and planning. Because of the missing large scale implementation of ‘intelligent’ items or units it will take some time to further observe and evaluate the scenario developed above in the reality. To overcome this lack of implementation, as well as to be prepared for the future and to avoid possible negative burdens on the spatial development or on the environment, the quantification of the developed scenario in a systems dynamic model will be essential.

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