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The transport geography of logistics and freight distribution

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Abstract

Goods movement and freight distribution are widely underrepresented in regional science and geographical research. This is surprising since a large body of traditional spatial theory has been developed with respect to transportation costs or to trade areas: those aspects that were originally closely connected with the exchange of goods. Growing attention is being paid in geography to related subjects, such as the emergence of global production networks, to structural changes in retail or to the commodification of modern consumption. To a certain extent, these processes depend upon the efficient transfer of information, finance and physical goods. Yet, with a few exceptions, the freight sector appears to be neglected in contemporary research. This paper provides an overview of the emerging transport geography of logistics and freight distribution. It challenges the traditional perspective where transportation is considered as a derived demand with the idea that logistical requirements underline transportation as a component of an integrated demand. The paper provides an analysis of the evolution of logistics as it pertains to the core dimensions of transport geography (flows, nodes/locations and networks). The concept of logistical friction is also introduced to illustrate the inclusion of the multidimensional notion of impedance in integrated freight transport demand.

Keywords: Logistics; Geography; Freight Transport; Physical distribution; Globalization

1. Logistics and freight transport: from derived to integrated demand

1.1. Introduction

The growing flows of freight have been a fundamental component of contemporary changes in economic systems at the global, regional and local scales. The consideration of these changes must be made within a perspective where they are not merely quantitative, but structural and operational. Structural changes mainly involve manufacturing systems with their geography of production, while operational changes mainly concern freight transportation with its geography of distribution. As such, the fundamental question does not necessarily reside in the nature, origins and destinations of freight movements, but *how* this freight is moving. New modes of production are concomitant with new modes of distribution, which brings forward the realm of logistics; the science of physical distribution. Although it represents an entire system of space/time interdependencies, we believe that physical distribution has been neglected in current geographical, urban or regional studies.

Up to recently, geography did not pay much attention to logistics and freight transportation, as the focus was mainly on passengers and individual mobility issues. Textbooks on urban or general transport geography, like those edited by Hanson (1995), Taaffe et al. (1996) or Hoyle and Knowles (1998), now raise more freight related questions than they did in earlier editions, particularly with regard to trade and ports. The latter is probably the only logistics subject that received major reference from academic geography. Other core spatial implications of distribution and logistics have been directly addressed in geography by few authors who developed an insight into wholesale activities and their geographical distribution (Glasmeier, 1992; McKinnon, 1983, 1988, 1998; Riemers, 1998; Vance, 1970). Following the nature of retailing as an originally distributive activity, geographic research on retail and consumption is of interest in the logistics context too. However, retail geography does not pay much attention to distribution changes (Marsden and Wrigley, 1996),

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although the physical movement of goods appears to be one of the costliest parts of retail activities (Christopherson, 2001). One exception to these observations is in Ralston (2003), who does address issues of inventory carrying costs and supply chain analysis.

Despite the upcoming notion of volatility and placelessness, and contrasting the enduring neglect of transportation by regional and geographical sciences, the material world of physical distribution and the respective locales is considered of geographical significance. The two traditional disciplines for investigating physical distribution are business administration (economics) and transportation sciences. Both cover, to varying degrees, aspects of space and location. However, it is legitimate to state that both disciplines did not pay much attention to the spatial character of their subject. In turn, economic and transport geography, did not develop too large a focus on logistics—keeping in mind the broad geographical relevance of distribution. A substantial amount of research covers different planning aspects of freight transport particularly in the urban context, either from a transport engineering and planning perspective or emphasizing related urban problems (Chinitz, 1960; Odgen, 1992; Woudsma, 2001). Logistics, as a geography, remains relatively unexplored.

Freight distribution is now considered with more attention as productivity gains in manufacturing are increasingly derived from efficiency at terminals instead of from the efficiency of transportation modes (Rodrigue, 1999). Because transport geography is traditionally more engaged in long distance trade issues, freight related work received significant attention. With emerging global trade, production networks and distribution systems, particular emphasis was given to ports and related research covering many of these issues (e.g. Hoyle, 1990, 1996; Hoyle and Pinder, 1992; Nuhn, 1999; Slack, 1998). In this context, an increasing amount of work on intermodal freight transport and terminal issues [1] appeared as well (van Klink and van den Berg, 1998; Drewe and Janssen, 1998). Generally, international trade increasingly contributes to the amount and the nature of physical distribution. Thus globalization is now discussed as having a major impact on goods exchange (Janelle and Beuthe, 1997; McCray, 1998; Pedersen, 2000; Woudsma, 1999).

Still, fallacies are noted in globalization discourses within economic geography, undermining the assessment of the role of transportation. Within the large body of work referring to the globalization discourse or the impacts of internationalization and free trade agreements, transport is not seen as a major issue or is de facto taken for granted (Holmes, 2000). Even classic trade theory neglects the role of transport and logistics (Dicken, 1998, p. 74), particularly the fact that transport costs have a fundamental impact on the amount of trade and goods exchange, as do traffic constraints and opportunities in general. We argue that this perspective is mainly the result of a misinterpretation of role of the transport sector, freight and passengers alike, as a derived demand. Under such circumstances, transportation is perceived as a residual consequence—derived—of other processes or a mere "space-shrinking" function (Dicken, 1998; Knox and Agnew, 1998). However, the same processes behind the focus of the globalization literature, such as international trade, multinational corporations and the division of labor/production, are also revealing a different perspective, which is the management of supply chains and their underlying logistics. Consequently, the role of distribution in globalization remains partially unanswered and a geographical analysis of logistics may provide substantial evidence in that respect.

1.2. Definition of the subject

Logistics consider the wide set of activities dedicated to the transformation and circulation of goods, such as the material supply of production, the core distribution and transport function, wholesale and retail and also the provision of households with consumer goods as well as the related information flows (Handfield and Nichols, 1999). These activities composing logistics are included into two major functions which are physical distribution; the derived transport segment, and materials management; the induced transport segment. More specifically:

- *Physical distribution* (PD) is the collective term for the range of activities involved in the movement of goods from points of production to final points of sale and consumption (McKinnon, 1988, 33). It must insure that the mobility requirements of supply chains are entirely met. PD comprises all the functions of movement and handling of goods, particularly transportation services (trucking, freight rail, air freight, inland waterways, marine shipping, and pipelines), transshipment and warehousing services (e.g. consignment, storage, inventory management), trade, wholesale and, in principle, retail. Conventionally, all these activities are assumed to be derived from materials management demands.
- *Materials management* (MM) considers all the activities related in the manufacturing of commodities in all their stages of production along a supply chain. MM includes production and marketing activities such as production planning, demand forecasting, purchasing and inventory management. It must insure that the requirements of supply chains are met

[1] The special issues on containerisation in GeoJournal 48, 1999 and on terminals in the Journal of Transport Geography 7, 1999.

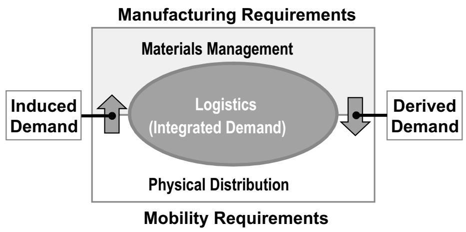

Fig. 1. Logistics and integrated transport demand.

by dealing with a wide array of parts for assembly and raw materials, including packaging (for transport and retailing) and, ultimately, recycling discarded commodities. [2] All these activities are assumed to be inducing physical distribution demands.

The close integration of PD and MM through logistics is blurring the induced/derived demand distinction. The reciprocal relationship between the induced transport demand function of physical distribution and the derived demand function of materials management is thus considered as the *integrated transport demand* of logistics (Fig. 1). This implies that distribution, as always, is derived from materials management activities (namely production), but also, that these activities are coordinated within distribution capabilities. Production, distribution and consumption are thus difficult to separate.

The more connected the different actors along a supply chain are, the harder it is to make a clear distinction between PD and MM as distribution channels extend from suppliers to consumers and as responsibility for transport and warehousing is shared between manufacturers, wholesalers and retailers (McKinnon, 1988). Logistics must be consistent with the products it supports as customers tend to not place any difference between a product and the distribution system that supplies it. Consequently, it is becoming increasingly difficult to consider transportation solely as a derived demand, or industrial production, manufacturing and consumption solely as factors inducing transport demand. We thus argue that the classic transport geography concept of derived freight demand has been blurred by the diffusion and adaptation of logistics. Manufacturing and mobility requirements are both embedded as what is being produced, a part, or a finished product, has to be moved at a similar rate along the supply chain. This paradigm shift leaning on supply chain management, materials flow management and freight transportation thus requires the elaboration of its own transport geography.

[2] This is often labeled as reverse distribution, or integrated repair and return (Rodrigue et al., 2001).

The purpose of the paper consequently is to assess how geography is related to logistics and how logistics enforces a specific geography of production/distribution by exploring the integrated transport demand function. It will first investigate the processes that have led to the integration of different functions into what has become known as supply chain management. Second, its underlying geographical dimensions are introduced, namely the core concepts of flows, nodes and networks, which supply chain management has substantially modified. Last, spatial impedance (friction) factors linked to logistics are discussed.

2. The evolution of logistics

Although logistics were initially applied to military operations, its most significant impact is being felt through the functions of production, distribution and consumption (Rodrigue and Slack, 2002). The exchange of goods is a constant feature of human economic activity. It was once essential for the rise of the mercantile economy in medieval Europe (Braudel, 1982) and became a large scale activity during the industrial revolution. The location of industrial activity and thus the geography of manufacturing in general evolved with respect to accessibility improvements that were particularly offered by railroads (which were then predominantly freight related). Vice versa, every "long wave" in the process of industrialization embodies distinct transportation orientations and appropriate infrastructure requirements (Hayter, 1997, 27). This was true for the railroad in the fordist economy, as it is for trucking and air freight more recently. The origins of the modern distribution sector go back to the emergence of the capitalist economy, the development of specific modes of industrial production and the unfolding of a particular division of labor. This created a distinct "sphere of circulation", situated between production and consumption (Marx, 1939/1953). To a certain extent, circulation allowed for the transition from use-value to exchange-value, and thus made possible the large-scale capitalization of commodities. Mass distribution and marketing became incorporated in the practice of modern management (Chandler, 1977) and have been significant factors of wealth generation.

The organization and technology of modern distribution are embedded in a changing macro- and microeconomic framework. It can be roughly characterized by the terms of flexibilization and globalization. Flexibilization represents, far beyond the narrow interpretation of "flexible specialization", a highly differentiated, strongly market- and customer-driven mode of creating added-value. Contemporary production and distribution is no longer subject to single-firm activity, but increasingly practiced in networks of suppliers and subcontractors (Dicken and Thrift, 1992; Gertler, 1992; Hudson, 2001). The supply chain bundles together all this by information, communication, cooperation, and, last but not least, by physical distribution (Bowersox et al., 2000). Globalization means that the spatial frame for the entire economy has been expanded, implying the spatial expansion of the economy, more complex global economic integration, and an intricate network of global flows and hubs (cf. Dicken, 1998; Held et al., 1999; Knox and Agnew, 1998). Logistics thus developed against the background of long-term structural change in economy, technology and society affecting all major industrialized countries (IMF, 2001). These interrelated changes comprise sectoral and structural changes, mainly the rise of service economies, the increasing share of goods with high value and low weight, consumerism, the upcoming high tech and knowledge based sectors (Castells, 1996); they also include a new political framework, namely the policies of deregulation and liberalization that were effective for the US in the late 1970s and early 1980s, and for Europe since the introduction of the Single European Market in 1992 (Knowles and Hall, 1998). These policies are now also being adopted by many developing countries, with varied success.

The principles of modern logistics can be traced back to Taylor (1947), the conceptual creator of fordism. Although his ideas were related to improving efficiency within the factory by organizing the worker's tasks along an assembly line, the temporal dimensions introduced, such as sequence, duration, schedule, rhythm, synchronization and time perspective are of high significance to logistical management. What Taylor's principles of management were able to achieve within the factory in terms of productivity improvements, logistics are able to achieve between elements of the supply chain: a system of integrated factories. A milestone that marked rapid changes in the entire distribution system was the invention of the concept of lean management, primarily in manufacturing (Womack et al., 1990; Harrison, 1997). One of the main premises of lean management is eliminating inventories and organizing materials supply strictly on demand, replacing the former storage and stock keeping of inventory.

During the 1980s, the application of this "principle of flow" permitted the reduction of inventories in time-sensitive manufacturing activities from several days' worth to several hours. Much of these efforts initially took place within the factory, while supply and output flowed as batches from suppliers and to distributors. High rack storages, which later became automatically driven, or the internal movement of packages by flat robots were early expressions of logistical engineering. Initially, logistics was an activity divided around the supplying, warehousing, production and distribution functions, most of them being fairly independent from the other. With the new organization and management principles, firms were following a more integrated approach, thus responding to the upcoming demand for flexibility without raising costs. At the same time, many firms took advantage of new manufacturing opportunities in developing countries. As production became increasingly fragmented, activities related to its management were consolidated. Spatial fragmentation became a by-product of economies of scale in distribution. In the 1990s, with the convergence of logistics and information technologies, this principle was increasingly applied to the whole supply chain, particularly to the function of distribution. In some highly efficient facilities, the warehousing function went down as far as 15 min worth of parts in inventory. It is now being introduced in service functions such as wholesale and retail where inventory in stores are kept at a minimum and resupplied on a daily basis.

Whereas contemporary logistics was originally dedicated to the automation of production processes, in order to organize industrial manufacturing as efficiently as possible, the subsequent modernization of logistics can been characterized by an increasing degree of integration. This trend was already on the way in the 1960s, as a key area for future productivity improvements (Bowersox et al., 1968). However, only with the implementation of modern information and communication technologies did this assumption become possible. They allow for the integrated management and control of information, finance and goods flows and made possible a new range of production and distribution systems (Abernathy et al., 2000). Step by step, and according to improvements in information and communication technologies, the two ends of the assembly line became integrated into the logistics of the supply chain: the timely supply of raw materials and components from outside, and the effective organization of distribution and marketing (Fig. 2).

Flexible order and supply behavior is actually made possible by new technologies, primarily through the real-time exchange of information. Because of information and communication technologies, firms are able to order from point-of-sale, to adjust inventories to meeting demand (if not to eliminate them entirely) and to reduce redundancy almost totally. Features such as electronic data interchange (EDI), automated product flow in distribution centers (DCs) and warehouses, or the recent computer based tracing-and-tracking systems—which offer on-line control of shipped parcels via the web—are primary sources of enormous productivity gains over last two decades (Fig. 3). They still seem to be more important than innovations associated with the upcoming electronic commerce (Hesse, 2002a; OECD/ECMT, 2001).

While cycle time requirements substantially decreased from the 1960s to 1980s, this came at the expense of growing logistics costs, notably inventory. From that point on, the major achievements were related to pro-

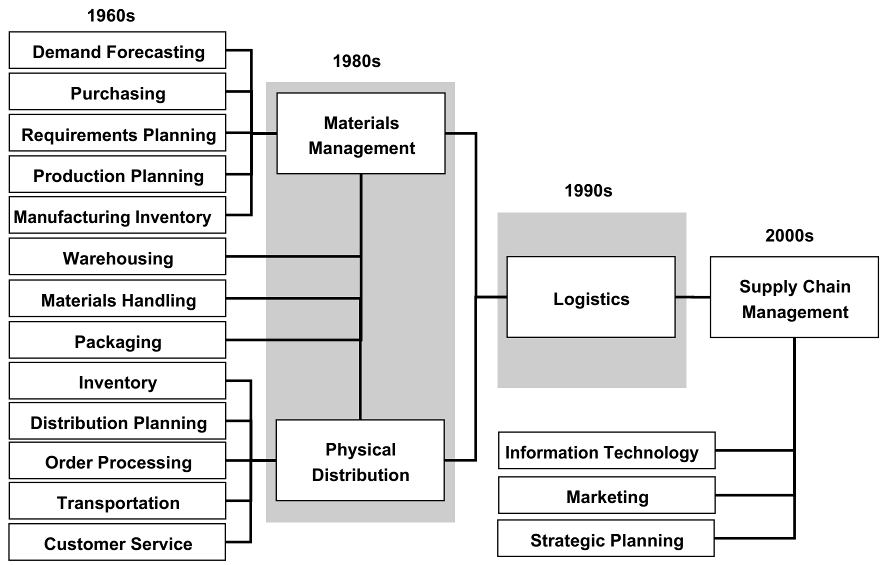

Fig. 2. Evolution of logistical integration, 1960–2000.

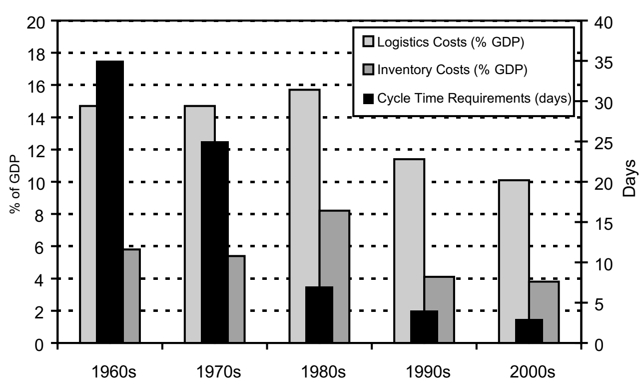

Fig. 3. Logistical improvements, manufacturing sector, 1960–2000.

ductivity gains in distribution, accompanied by a reduction of cycle time requirements, but as importantly, of inventory costs. Another important requirement was containerization, which conferred substantial flexibility to production systems in addition to the container being its own storage unit. The expansion of classical infrastructure such as highways, terminals and airports was also essential for the development of modern logistics. The remarkable growth of freight transport could not have happened without extensive networks of freeways for regional and long-distance traffic, just as the railway system had provided the basis for industrialization decades earlier.

The flow-oriented mode of corporate management and organization currently affects almost every single activity within the entire process of value creation. The core component of materials management is the supply chain, the time- and space-related arrangement of the whole goods flow between supply, manufacturing, distribution and consumption. Its major parts are the supplier, the producer, the distributor (e.g. a wholesaler, a freight forwarder, a carrier), the retailer, the end consumer, all of whom represent important players and particular interests (Bovet et al., 2000; Bowersox et al., 2000). Compared with the former, more traditional shape of the freight transport system, the evolution of supply chain management and the related emergence of the logistics industry is mainly characterized by four features:

- First, a fundamental restructuring of goods merchandising by establishing *integrated supply chains with integrated freight transport demand*.
- Second, whereas transport was traditionally regarded as a tool for overcoming space, *logistics is critical in terms of time*. This was achieved by shifts towards vertical integration, namely subcontracting and outsourcing, including the logistical function itself (Harvey, 1989).
- Third, according to macro-economic structural changes, demand-side oriented activities are becoming predominant. While traditional delivery was primarily managed by the supply side, current *supply chains are increasingly managed by demand*.
- Fourth, the logistics services are becoming complex and time-sensitive to the point that many firms are now sub-contracting parts of their supply chain management to *third-party logistics providers*. These providers benefit from economies of scale and scope by offering integrated solutions to many freight distribution problems.

3. The core geographical dimensions of logistics

The structural change in distribution and logistics has distinct geographical dimensions, investigated by transport geography, and which are expressed in terms of flows (information, freight, transportation, vehicles), nodes and networks within the supply chain. Recent commentators also noted a rising interest in hubs, flows and networks in the broader sense (Crang, 2002; Creswell, 2001). In the context of this paper, the system of physical distribution can be regarded as a material foundation for such mobility of people, goods, and information. These elements interact in space, but also in time (Fig. 4).

Space/time convergence is a well-known concept in transport geography, where time was simply considered as the amount of space that could be traded with a specific amount of time, which included travel and transshipment. Logistics has expended this concept to include activities that were not previously considered fully in space/time relationships. They now imply an organization and synchronization of flows through nodes and network strategies. For instance, the conventional expansion of a distribution system (Fig. 4) involves a trade-off between marginal improvements of spatial coverage (ΔS) and the associated marginal time change (ΔT). Supply chain management enables a more efficient space/time convergence since the marginal differences are larger for space (ΔS) than for time ($\Delta T1$). The emerging paradigm also includes in the space/time convergence the notion of *time as a management constraint of transportation*. In addition of being a factor of distance/friction/impedance, time is a component of flows, synchronized at nodes and the expression of a network structure. Consequently, the expansion and improvement of a distribution system from DS1 to DS3 (Fig. 4) could either imply an extended spatial coverage with a similar amount of time or a similar spatial coverage with a reduction of time, or ideally, a combination of both. The distribution system is not only providing for the constant flow of commodities, but ensuring their availability and accessibility in a synchronized–timely-fashion.

3.1. Flows

The growth of geographical areas of interaction and the temporal flexibilization of freight flows result in a rising amount of freight transport. The traditional arrangement of goods flow included the processing of raw materials to manufacturers, with a storage function usually acting as a buffer. The flow continued via wholesaler and/or shipper to retailer, ending at the final customer. Delays were very common on all segments of this chain and accumulated as inventories in warehouses. There was a limited flow of information from the consumer to the supply chain. This procedure is now going a different way, mainly by eliminating one or more of the costly operations in the supply chain organization. An important physical outcome of supply chain management is the concentration of storage or warehousing in one facility, instead of several. This facility is increasingly being designed as a flow- and throughput-oriented distribution center (DC), instead of a warehouse holding cost intensive large inventories (Fig. 5).

Recent freight flows tend to be of lower volumes, of higher frequency, often taking place over longer distances. These flows have been associated with modal adaptation. The magnitude of change can be characterized by the growth of geographical areas of interaction, and by the temporal flexibilization of freight flows, both resulting in a rising amount of freight transport. The distribution center thus becomes the core component of such a distribution system (Fig. 5).

Truck vehicle miles have almost kept pace with GDP and have more than tripled between 1970 and 1999 in the US and in Europe (USDOT, 2000). At the same time, freight by ton-miles developed more dynamically than by freight tons, which indicates both a dematerialization of the economy and rising average transport distances. Structural change is associated with modal shift away from rail and waterway transport, supporting road and air modes. Whereas intercity truck ton-miles

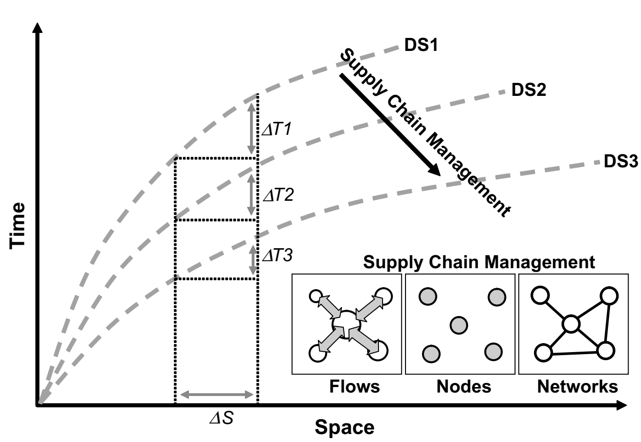

Fig. 4. Geographical dimensions of logistics.

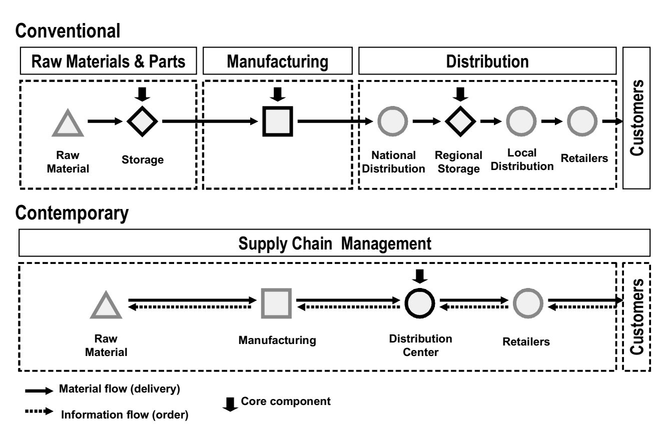

Fig. 5. Conventional and contemporary arrangement of freight flows.

grew by 124% in the US 1970–1995, air carrier ton-miles grew by 468% (Lakshmanan and Anderson, 2002, p. 9). Containerization has permitted lower volume flows while offering economies of scale by the consolidation of numerous shipments in batch flow units (e.g., cellular containerships and doublestack trains).

International trade increasingly contributes to the amount and the nature of physical distribution, since world exports have grown much faster than world production. Whereas the average annual growth rate of world production during the 1990s accounts for 2.7%, global imports and exports grew by 6.7% annually (Wienert, 2002, based on IMF data). In this respect, globalization is now considered a major framework condition of goods exchange, along the "rivers of trade" (McCray, 1998). The internationalization of corporate activity, e.g. by the activity of transnational corporations (TNC), through foreign direct investments or in particular as a consequence of free trade agreements such as NAFTA or the European Single Market, has substantially contributed to the emergence of global flows (Janelle and Beuthe, 1997; Pedersen, 2000; Woudsma, 1999) (see Fig. 6).

Regarding the nature of goods flows as originally derived from economic exchange, a considerable amount of research has been conducted on the production or commodity chain approach. This concept was originally developed by Wallerstein and Hopkins in the context of world-system analysis and received a broader distribution by Gereffi and Korzeniewicz (1994). The commodity chain represents a conceptual structure that allows for the analysis and assessment of interlinked processes, with particular regard to interdependencies between production, distribution and consumption. In terms of economic (geography) research, this concept marked a substantial progress in linking the micro- and macro-dimensions of production and consumption (e.g. Hartwick, 1998; Leslie and Reimer, 1999). Yet, it is still missing appropriate coverage of its freight and logistics dimension.

3.2. Nodes and locations

Due to new corporate strategies, a concentration of logistics functions in certain facilities at strategic locations is prevalent. Many improvements in freight flows are achieved at terminals (Trip and Bontekoning, 2002; Rodrigue, 1999). Facilities are much larger than before, the locations being characterized by a particular connection of regional and long-distance relations. Traditionally, freight distribution has been located at major places of production, for instance in the manufacturing belt at the North American east coast and in the Midwest, or in the old industrialized regions of England and continental Europe. Today, particularly large-scale goods flows are directed through major gateways and hubs, mainly large ports and major airports, and at highway intersections with access to a market area. The changing geography of manufacturing and industrial production has been accompanied by a changing geography of freight distribution. This is notably the case in Pacific Asia, where industrialization and integration to global trade have been accompanied by the emergence of large scale high throughput nodes such as Hong Kong, Singapore, Shanghai, Busan and Kaohsiung (Comtois and Rimmer, 1997). Not surprisingly, these hubs are the largest container ports in the world.

Distribution is increasingly planned and operated on the basis of nationally designed networks, due to the premise of cost reduction by economics of scale. According to this particular pattern of re-structuring, favorite locations are either those gateways or transportation corridors with access both to traditional gateways of trade (interfaces) and to large consumer

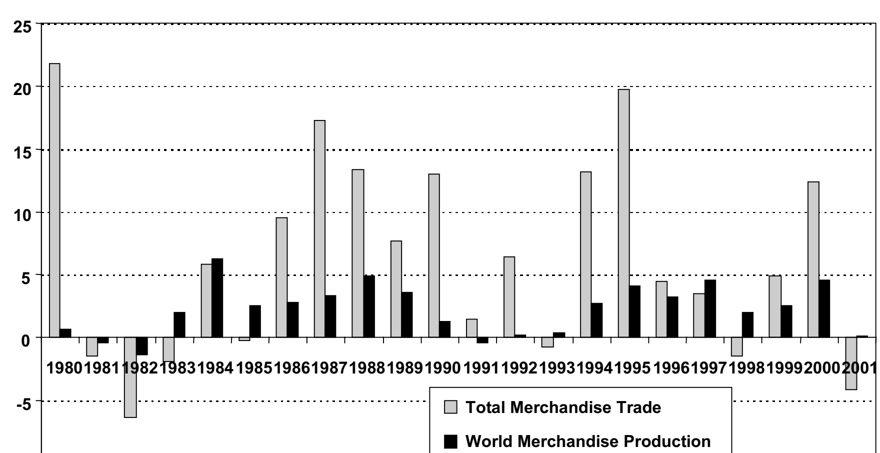

Fig. 6. Growth in the volume of world merchandise exports and world production, 1980–2001 (*Source*: WTO, 2002).

markets (destinations). Distribution firms respond to structural change and competition by expanding the infrastructure and rationalizing flows in order to meet the demand for quick and precise delivery. Owing to the increased competition between distribution locations, all major freight hubs (large ports, freight airports, inland hubs) are currently committed to expanding their infrastructure. In the case of North America, those particular hubs are the strategic gateways at East and West Coasts, e.g. the Ports of the San Pedro Bay in Los Angeles, the Port of Seattle/Tacoma, the Port of New York/New Jersey. The expansion of such places is primarily due to the growth of trade and transport in general, supported by economic growth and the enlargement of market areas, both favoring scale economies. Yet the strategy of concentrating freight at hub locations is increasingly becoming restricted, due to density, land constraints, and congested traffic arterials. Such limits to expansion and the scarce hinterland connections of major hubs are considered the most important obstacle for further developing major hub locations.

As a consequence, so called "Inland Hubs" are becoming more and more important, where primarily road and air freight is consolidated. These new DC areas are mainly affiliated with the interstate network and air cargo facilities. Consequently, warehousing, trucking, freight forwarding and air cargo activities are major indicators and drivers of this new distribution economy. One of such new inland hubs is emerging along the Ohio River Valley, particularly following a corridor from Ohio and Indiana to Tennessee. "The 'first generation' e-fulfillment providers are gravitating towards the preferred location for a single, centralized distribution facility, the greater Ohio River Valley, namely the states of Ohio, Indiana, Kentucky, and Tennessee. Industrial markets such as Columbus/OH, Indianapolis/IN, Hebron/KY (Cincinnati/OH) and Louisville/KY have seen substantial demand from these users." (Abbey et al., 2001, 15). In 1997, more than 150 distribution centers larger than 50,000 square feet were located only in the City of Columbus/OH. Both inventory and recent absorption in the Columbus industrial real estate submarket belongs to 80% to warehousing (SIOR database, 2001).

Recent European developments seem to be comparable. European Distribution Centers (EDC) are becoming larger, as the pressure to consolidate distribution centers into pan-European centers continues. With access to a significant part of the European marketplace required, core Europe is the preferred location—most notably Benelux and eastern France. National and regional centers are under pressure in all these countries, as distributors attempt to offload this layer of warehousing. The Netherlands is emerging as the most favored location for European logistics, due to excellent accessibility, advanced terminal and transport infrastructure, critical mass of logistics functions and attractive operating conditions (vis-à-vis its neighbours). Schiphol Airport and the Port of Rotterdam are among the most important hubs for international freight flows in Europe. Major population concentrations are well represented—Paris, London, the Ruhr area and Frankfurt (Europe's largest air cargo hub). Flanders in northern Belgium and the Nord-Pas de Calais region in northern France also score highly. UK distributors tend to prefer north-west Europe, due to improved access to the continent via the Channel Tunnel (cf. JonesLang-LaSalle, 2001).

The contemporary location of distribution centers is an outcome of high pressure on supply chains, caused by accelerated information transfers, changing consumer preferences and rising competition. Since many parts of the supply chain are now globally integrated, distribution centers tend to be the link between global sourcing and regional distribution. The DC has become an interface between the geographies of manufacturing and retailing, consequently handling the distribution scale and scope. Innovations such as containerization and particularly IT developments have integrated all components of the chain. In response, major players in the distribution business (e.g. container shipping lines, freight forwarders, warehousing firms, terminal operators) are trying to control as many parts of the logistics chain as possible. Not coincidentally, these firms are challenged by vertical and horizontal linkages, by mergers, takeovers and strategic alliances (Slack et al., 2002). For them, staying competitive means increasing the throughput and providing the demanded services at low rates. As a result, the activity space of main ports is increasingly becoming relocated to low cost locations reaching far beyond traditional terminal sites and connecting more distant places of their hinterlands.

Regarding the location issue, corporate decision makers are used to carefully assessing advantages and disadvantages of different locations. Compared with core urban areas, suburban sites offer larger and cheaper land resources, unrestricted transport access, a 'robust' environment for round-the-clock operations, and the locational advantage of intersections, connecting local and long-distance flows (Hesse, 2002b). Existing facilities often do not fit into the customers' profile, particularly with old buildings, or if they are surrounded by sensitive neighborhoods. Trade-offs between inventory and transport costs are also highly supportive for suburban locations, since mobilities (freight transport) and immobilities (land use) are closely intertwined. In order to find the optimal ratio between low land prices and short distances to the point of final distribution, firms move their DC location as far away from expensive land markets as necessary. For logistical and cost reasons, they also need to stay as close to their customers as possible. Not coincidentally, most recent construction of DCs and warehouses takes place in metropolitan regions, at the urban fringe or beyond. Further, the function of nodes has become more complex with several distribution centers performing light manufacturing tasks such as assembly and especially packaging. The functions of production and distribution thus became blurred with logistical integration.

3.3. Networks

The spatial structure of contemporary transportation networks is the expression of the spatial structure of distribution. Network building leads to a shift towards larger distribution centers, often serving significant transnational catchments. However, this does not mean the demise of national or regional distribution centers, with some goods still requiring a three-tier distribution system, with regional, national and international DCs. The structure of networks has also adapted to fulfill the requirements of an integrated freight transport demand, which can take many forms and operate at different scales (Fig. 7).

Point-to-point distribution is common when specialized and specific one-time orders have to be satisfied, which often creates less-than-full-load as well as empty return problems. The logistical requirements of such a structure are minimal, but at the expense of efficiency. Corridor structures of distribution often link high density agglomerations with services such as the landbridge where container trains link seaboards. Traffic along the corridor can be loaded or unloaded at local/regional distribution centers. Hub-and-spoke networks have mainly emerged with air freight distribution and with high throughput distribution centers favored by parcel services (O'Kelly, 1998; SRI International, 2002). Such a structure is made possible only if the hub has the capacity to handle large amounts of time-sensitive consignments. The logistical requirements of a hub-and-spoke structure are consequently extensive as efficiency is dominantly derived at the hub's terminal. Routing networks tend to use circular configurations where freight can be transshipped form one route to the other at specific hubs. Pendulum networks characterizing many container shipping services are relevant examples of relatively fixed routing distribution networks. Achieving flexible routing is a complex network strategy requiring a high level of logistical integration as routes and hubs are shifting depending on anticipated variations of the integrated freight transport demand.

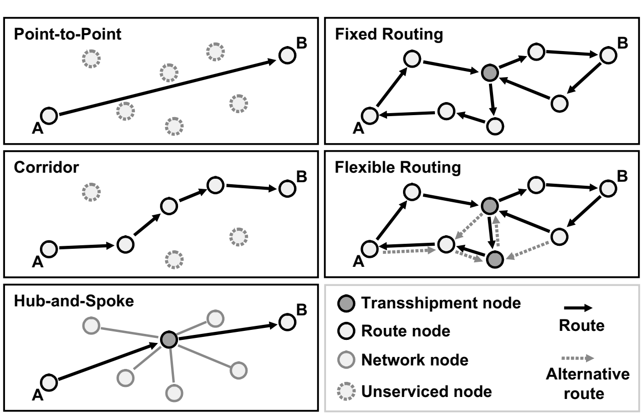

Fig. 7. Freight distribution and network strategies. *Source*: Adapted from Woxenius (2002) "Conceptual Modelling of an Intermodal Express Transport System", International Congress on Freight Transport Automation and Multimodality, Delft, The Netherlands.

4. The concept of friction in the transport geography of logistics

The concept of impedance, or the friction of space, is central to many geographical considerations of economic and social processes. Conventionally, this concept was subjugated to issues concerning distance and how to quantify it. Substantial economic research has focused on assessing impedance, the impacts of distance, time and elasticities on freight flows (Button, 1993). As discussed so far, significant changes have incurred in freight transport nodes, flows and networks, which impacted on the concept of impedance. Logistics and freight distribution, as a transport paradigm, require a review of this multidimensional concept to include four core elements, namely the traditional *transport costs*, but also the *organization of the supply chain*, and the *transactional and physical environments* in which freight distribution evolves. These four elements, which are difficult to consider independently, jointly define the concept of *logistical friction* and its possible improvements.

4.1. Transport/logistics cost

Traditionally transports costs were considered as a distance decay function. The most significant considerations of logistics on transport costs are related to the functions of composition, transshipment and decomposition, which have been transformed by logistics. More specifically, composition and decomposition costs, which involve activities such as packaging, warehousing, and assembly of goods into batches, can account to 10% of production costs. A higher level of inventory management (e.g. lean management) can lead to significant reduction in the logistical friction as well as terminal improvements decreasing transshipment times and costs (Fig. 8). Time is becoming as important as distance in the assessment of transportation costs and impedance. As transport costs went down through space/time convergence, the value of time went up proportionally. For

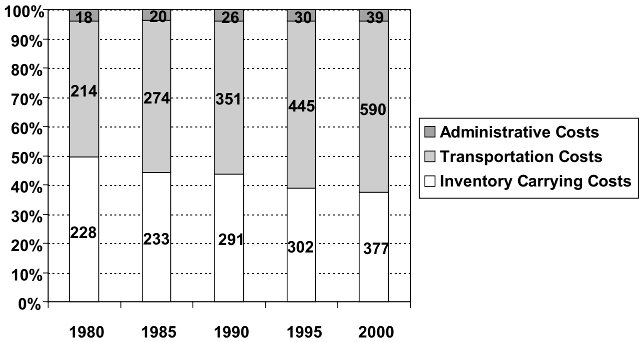

Fig. 8. Logistics costs, US, 1980–2000 (in billions of $). *Source*: Cass and ProLogic (2002).

instance, between 1950 and 1998, the average time in transit for imported goods fell from 40 days to about 10 days. Each transit day adds about 0.8% to the final cost of goods. As such, 20 days at sea adds the equivalent to a 16% tariff on international trade (Hummel, 2001). Concomitantly, the costs of logistics in the American economy went from about 16% of the GDP in 1980 to 10% in 2000 (Fig. 8).

However, within the components of logistics costs, the transportation segment has experienced absolute as well as relative growth. While it accounted for 46.5% of total logistics costs in 1980, this share climbed to 58.6% in 2000 (Fig. 8). Inventories are thus increasingly in circulation and inventory costs were reduced proportionally. The issue of *mobile inventories*, as opposed to the traditional concept of *fixed inventories* has blurred the assessment of logistics costs. Trade-offs between fixed costs (inventories, warehouses, etc.) and variable costs (transportation) play a major role in corporate strategies, since the advancement of new technologies allows for the mobilization of inventories and, subsequently, the elimination of facilities—whereas the deregulation of transport markets attracted firms to expand their shipping and transportation activities, by significantly lowering the freight rates. Thus companies were able to reduce a considerable amount of total distribution costs.

4.2. Complexity of the supply chain

An integrated freight transport system requires a high level of coordination. The more complex the supply chain, the higher the friction since it involves both organizational and geographical complexity (see below). Under such circumstances, the logistical friction takes the form of an exponential growth function of the complexity of the supply chain (Fig. 9). A core dimension of this geographical complexity is linked with the level of spatial fragmentation of production and consumption. Globalization has thus been concomitant with a complexification of the supply chain and logistical integration permitted to support it. Many industrial location concepts indirectly address this perspective by investigating how firms grow in space and how production is organized to take advantage of comparative advantages (Dicken, 1998). The extended range of suppliers and the globalization of markets have put increasing pressures on the supply chain, a problem partially solved by using high-throughput distribution centers.

The geographical scale of the supply chain is linked with a level of logistical friction as nationally oriented supply chains tend to be less complex than multinational supply chains, mainly because they are less spatially fragmented. From an operational perspective, it considers a balance between the benefits derived from the increased fragmentation of the supply chain with the organizational costs that come along. At some point, it becomes excessively difficult to maintain the coherence of the supply chain. The marginal costs of this function have substantially been reduced by information technologies and corporate strategies such as mergers and joint ventures, implying that increasingly complex supply chains can be supported with the resulting improvements in productivity, efficiency and reliability. Consequently, it is possible to maintain or improve key time-dependent logistical requirements over an extended geography of distribution, namely the availability of parts and products, their order cycle time, and the frequency, on-time and reliability of deliveries. The consolidation of logistical activities in *high-throughput*

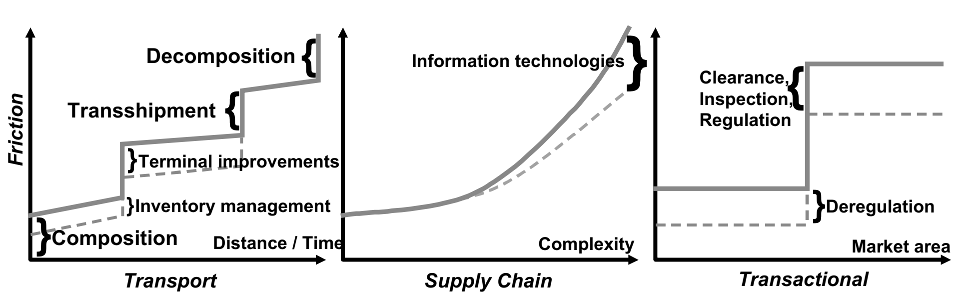

Fig. 9. Logistical friction.

distribution centers or the reliance on third-party logistics providers (which are using their own terminals or distribution centers), are strategies to reduce the friction of the supply chain (Fig. 9).

4.3. Transactional environment

According to the increasing degree of logistics integration, a rising number of firms and locations are bound together in material flows and value chains. In order to operate their businesses efficiently and competitively, these firms establish complex relationships that are performed by contracting (vertically or horizontally), by competition (horizontally), or, in rare cases, by co-operation. Since different players pursue different interests and have distinct authority to realize their vital interests, their transactional environment is characterized by structural tensions. They unfold distinct power issues along the chain, which is regarded as a major source of logistical friction. This issue has extensively been discussed with regard to producer-supplier relationships in the automotive industry, where the costs of time, of uncertainty and risk (notably expressed in transaction costs) were passed on to suppliers and subcontractors. Regarding the widely practiced outsourcing in distribution and logistics, such behavior is becoming more and more common in this business as well.

Supply chain power is particularly performed by firms who are acting as purchase and order agents, e.g. large retail chains who are buying transport services from 3PL logistics firms, freight forwarders who are trading and brokering orders, large ocean shipping companies who are responsible for moving a considerable amount of cargo worldwide, or large conglomerates having multiple production and distribution units (e.g. Japanese keiretsus). These units are able to command the conditions of delivery that have to be fulfilled by service providers. In order to cope with this pressure, transport and distribution firms are impelled to provide high service quality at low cost, in an increasingly competitive environment. The uneven distribution of power is primarily due to specific supplier–customer relationships, it depends on the firms' position within the chain, related to market demand (Taylor and Hallsworth, 2000), to its organizational or technological know how, or to factors such as the mere size of the firm. In comparison to traditional approaches mainly based on transport costs, the concept of logistical friction mirrors a more comprehensive understanding of the constraints and capabilities of firms.

The transactional environment also includes regulation issues, since public policy appears as another major factor of influence. Even in the age of transport market deregulation, government issues and the public sector remain influential on the distribution framework and thus on the freight traffic performance. This is due to legal issues, particularly the enforcement of load and vehicle inspections, to the continuous check of drivers' working hours, or to the definition of vehicle noise and air emission standards, in order to improve the environmental performance of truck fleets. At the local and regional level, zoning policies and building permits regulate the locational constraints and opportunities of the firms. To some extent, firms depend upon the establishment of a co-operative transactional and regulation environment—even if capital nowadays seems to be more powerful than the state or the local communities appear.

4.4. Physical environment

The physical environment of logistics and distribution comprises the "material space" where any social and economic activity is embedded in, and also the 'hard' transport infrastructure that is necessary for the efficient operation of the system, like roads, railways, warehouses, terminals or ports. Such physical environment appears as a major *external* determinant of the movement of vessels and vehicles. It thus can become decisive for the success or the shortcoming of the distribution system. Normally it is regarded as a component of transport costs, since infrastructure bottlenecks or road congestion do harm the firms' productivity in terms of delays and malfunctions. This follows the more 'negative' consideration of space as a barrier for the notion and the physics of flow.

In the concept of logistical friction, the physical environment plays a more sophisticated role, since it represents the entire pressure that is exerted by space on the supply chain, positively and critically. This happens particularly in those areas that are characterized by scarcity of access: e.g. congested places such as port areas and port hinterlands, or core urban areas that are problematic for delivery. They are not only bottlenecks for exact channel distribution, but also traditional locales where logistics is committed to adjust to its built environment. This is the simple reason why urban delivery vehicles are lighter and smaller than the long-distance trucks. Port areas embody the contradiction between scale economies and the limitations of infrastructure and facilities in a very typical way: in cases where simple expansion of a port system is out of question, due to space, money or policy constraints, the agents of distribution have to arrange themselves with their environment. Such ability to balance different interests, originally caused by constraints for the usual path of development, can also be considered positively, as a source of creativity and innovation.

Fig. 9 represents an attempt at operationalization of the logistical friction concept discussed so far with the possible impedance measures displayed on Table 1.

Table 1
Logistical friction

Impedance factor	Assessment measures
Transport/logistics costs	Distance, time, composition, transshipment, decomposition
Supply chain complexity	Number of suppliers, number of distribution centers, number of parts/variety of components
Transactional environment	Competition, (sub-) contracting, inter-firm relationships, power issues, (de-) regulation
Physical environment	Infrastructure supply, road bottlenecks and congestion, urban density, urban adjustments

5. Conclusion and outlook

This paper has argued that because of logistical integration, transport cannot be solely considered as a derived demand, but as an integrated demand where physical distribution and materials management are interdependent. Since logistics emerged as a key organizational system for materials flow and goods delivery, and due to the outstanding growth of freight traffic in the 1990s, contemporary analysis of logistics has to acknowledge the character of distribution as a complex, interdependent system. In this respect, a deeper geographical investigation is favored, since geographical approaches seem to be useful for covering the broader interactions of firms and flows with their spatial environments. Traditional transportation science tends to be devoted primarily to transport capacities, to economic issues or trade aspects. Compared to that, "looking through spatial lenses" promises a more comprehensive insight into the nature of distribution and its geographical dimensions, particularly in those areas that are intensively shaped by freight traffic and logistics facilities.

Due to the current lack of comprehensive understanding freight and distribution, future research should address this issue. First and foremost, there is a need for empirical investigation: Since distribution is closely related with the entire value chain, logistics interdependencies with production systems and networks, with wholesale and retail markets are relevant subjects of research. This means to study the degree to which logistics principles and requirements are becoming decisive for organizational or locational decisions of such firms. How do certain actors within the chain interact with locations? How is the physical space interwoven with informational structures? How far is distribution linked to the "social systems of production" (Hollingsworth and Boyer, 1997), e.g. regarding the labor issue? Answering these questions remains a challenge as most of the empirical evidence is proprietary and therefore can only be reported indirectly.

Second, freight transport is likely to consume an increasing amount of energy and land, and it contributes to a wide range of problems such as air and noise emissions, congestion, traffic fatalities, etc. Social costs associated with road and air freight transport are reportedly much higher than those of rail and waterway freight modes (INFRAS/IWW, 2000), both in terms of absolute and specific numbers. Both dimensions emphasize the need for policy and planning. With respect to these issues, a major requirement is improving the knowledge on the volume, composition and dynamics of physical distribution at different geographical levels. Empirical evidence on the interactions of geographical systems of production (firms) and systems of consumption (urban regions) is thus required.

Finally, theoretical considerations are also welcome in order to understand the degree of contemporary change more comprehensively. As this paper pointed out, common investigations of logistics and freight distribution refer to the fragmentation of corporate activity in different segments of the value chain and respective commodity transfers. Since it represents more than just a metaphor, fragmentation often functions as a explanatory keyword in the context of post-fordism and flexible specialization (see above); at least the general hypothesis of flexibility as an overarching paradigm of re-structuring seems to be convincing. Once freight transport and logistics are analyzed as a derived demand, they appear accordingly: segmented and flexible, highly adjusted to the specialized demand of shippers and receivers, representing functional and organizational compartments rather than an all-embracing structure.

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