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DIRECTNESS AS A KEY PERFORMANCE INDICATOR FOR FREIGHT TRANSPORT CHAINS

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Abstract

From the perspective of a transport service buyer and at the abstraction level of material flows, all transports travel directly from product supplier to product customer. In reality, however, the directness of transport services depends on factors such as geography, available infrastructure, temporary conditions, shippers' qualitative preferences, the economy of and practical possibilities for consolidation and access to return flows. This work examines directness by structuring and elaborating upon the causes of freight transport detours and briefly analysing their effect. The article also includes a discussion about the prospects of capturing directness in a KPI, and how such a measure can be designed, measured, monitored and used, as well as a brief analysis of the consequences of using it for monitoring and controlling supply chain performance. Detours are divided into supply chain, logistics and freight transport detours respectively and most attention is paid to the last kind of detour. Freight transport detours are divided into physical, political, commercial, operational and non-planned causes for detours. The first two stipulate the system environment in which the focused actors, transport service providers, decide upon detours. Operational causes are subject to internal decision making whereas commercial and non-planned causes are both external and internal to transport service providers.

Keywords: Detour, directness, distance, efficiency, freight transport, key performance indicator.

1 Introduction

Very few, if any, freight transport services are performed as the crow flies between the consignor and the consignee. Passability due to geography, infrastructure, traffic and weather conditions are reasons for not choosing the shortest path. Operational and cost-minimising measures to consolidate goods in terminals and through routeing, to chase balanced flows, to utilise different traffic modes and to route for cheaper fuel supply, infrastructure and transport services also imply detours. Furthermore, regulation adds distance with cabotage rules, subsidies to certain services, variations in infrastructure quality and charging, restrictions to few border crossings, zones or paths with forbidden transit and limited driving hours.

It is acknowledged that travelling the theoretically shortest distance is not an aim *per se* and there is often a perfectly rational reason behind a detouring decision. It is also simple to manipulate the key

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performance indicator (KPI) of directness by, for instance, using badly filled or smaller vehicles. Another obvious option to increase directness would be to disregard the market forces by actions like collective optimisation of all freight flows, restricting delivery frequencies or duration in specific zones, or legislating against low filling grades in vehicles and specific detours.

It is still regarded as worthwhile to analyse the causes of detours and to elaborate on a categorisation of the different causes of this theoretical inefficiency of freight transport services. Such an analysis has been done for passenger transport (see, e.g. Héran, 2009; Witlox, 2007) but seemingly not to a great extent for freight transport, although it is a common component of articles addressing network configurations (see, e.g., Kreutzberger, 1999 and 2004; Liu *et al.*, 2003; Woxenius, 2007) and sustainability (see, e.g., Browne and Allen, 1998; Leonardi and Baumgartner, 2004; van Wee *et al.*, 2005). It has also been highlighted by Hjelle and Fridell (2010) and Vanherle and Delhaye (2010) that road transport and RoRo shipping are so similar in CO_2 performance that the traffic mode with a detour comes out badly in comparisons.

With a slightly different focus, however, Samuelsson and Tilanus used two articles (1997a and 1997b) to develop a framework model and to investigate inefficiencies in regional less-than-truckload/break-bulk distribution. They compared a highly theoretical situation where full-sized lorries were fully loaded, travelled at maximum allowed speed in a straight line around the clock; with a real-world situation revealed by interviews with representatives from the road haulage industry. The utilisation factor was assessed to a mere 0.00043. The maximum efficiency is obviously strictly hypothetical; at least the lorries must stay to load and unload occasionally to be able to offer service to the shippers. Stopping at traffic lights, changing drivers and refuelling would also be inevitable sources of inefficiencies. It is still an interesting exercise and Samuelsson and Tilanus were careful to point out that the purpose was not to prove that regional road-based distribution is inefficient but to structure the issue and deliver a tool for identifying areas of improvements. This study is similar in its approach.

A plausible user of further knowledge of the nature and causes of detours is an infrastructure administration analysing where to invest in improvements or new infrastructure. An origin-destination matrix would be helpful to capture the demand, but if much of the freight is directed via an area with many terminals, other links in the network than the direct one should attract their attention (Andersson *et al.*, 2005). Transport operators and transport co-ordinators would also be helped by further insight into detours in their aspirations of improving their operations, and shippers need the data for estimating and decreasing their ecological footprint (Ülkü, In press) and for informing consumers of the actual distances their products have covered.

The purpose of this conceptual article is to identify, categorise and briefly analyse the causes of detours in freight transport services and to qualitatively analyse these effects. The article also includes a discussion about the prospects of capturing directness in a KPI, and how such a measure can be designed, measured, monitored and used, as well as a brief analysis of the consequences of using it for monitoring and controlling supply chain performance.

The study is wider than Samuelsson and Tilanus (1997a and 1997b) in its general scope of transport services, but narrower in the scope of efficiencies investigated due to the focus on directness, or ‘distance efficiency’ in their terminology. The wide scope of transport services implies that quantitative findings are lacking at this stage of the research. The work is primarily based on logical deduction of the causes for detours and a qualitative discussion about their effects, but it includes a literature review and frequent real-world examples. Conclusions are drawn regarding the usefulness of using directness as a KPI for different stakeholder groups.

The foundation for the analysis is first laid with an elaboration upon the scope of supply, logistics and transport chains, the actors typically involved and examples of typical transport chains. It continues with a brief discussion on supply and logistics chain detours before being more particular about the transport chain detours in coming sections. The consequences of detours are then briefly and qualitatively discussed and some conclusions are drawn.

2 Supply, logistics and freight transport chains

Detours are universally present in transport chains but are obviously also present in supply chains and logistics chains. There are strong dependencies between the different types of detours since shipper preferences regarding traffic mode, transport time, size of consignments, etc. affect the transport service providers’ and transport operators’ chances of finding short paths. The focus in this article is on freight transport detours; but further analysis requires a clear—however contextual—view of the scope of supply chains, logistics chains and transport chains.

The logistics and marketing literature is full of more or less distinct definitions of the terms supply chain management, logistics and transport. Conceptual models are also abundant. The terms have evolved over the years (see, e.g., Hesse and Rodrigue, 2004; Klaus, 2009) and the often non-stringent use has made them rather blunt conceptions. Consequently, many scientific authors find reasons for at least making operational or contextual definitions. In a physical product setting, the different kinds of chains can be explained in the following way:

- *A supply chain* focuses upon a **product** and extends back over the different actors, activities and resources required for making it available at the place of consumption.

- *A logistics chain* focuses upon an **item** or article and extends from when the item number is created until it is dissolved (item consumed, becoming a part of another item or being split into several items).

- *A transport chain* focuses upon a **consignment** and extends over movement, physical handling and activities directly related to transport such as dispatch, reception, transport planning and control.

In Figure 1, which depicts an example of a supply chain and its parts, it can be noted that the transport chains partly overlap the consignors and the consignees, thus including dispatching and reception activities, often referred to as floor-to-floor rather than door-to-door. Note also that transhipment and consolidation terminals are parts of transport chains while warehouses and distribution centres are not. The reason for this is that the consignee of the shipment is known in the former case and the goods are cross-docked, not stored, or just stored temporarily for capacity bridging or co-ordination reasons (Hultén, 1997). For distribution centres, the transport chain ends when the article is received at the warehouse and another transport chain starts when it is dispatched from the warehouse when the consignee of the next transport chain is known. Hence, transhipment and consolidation terminals belong to the transport service provider (TSP) domain while warehouses belong to the transport service buyer (TSB) domain. Warehouses and distribution centres are embedded in a logistics chain as long as the item number is not changed.

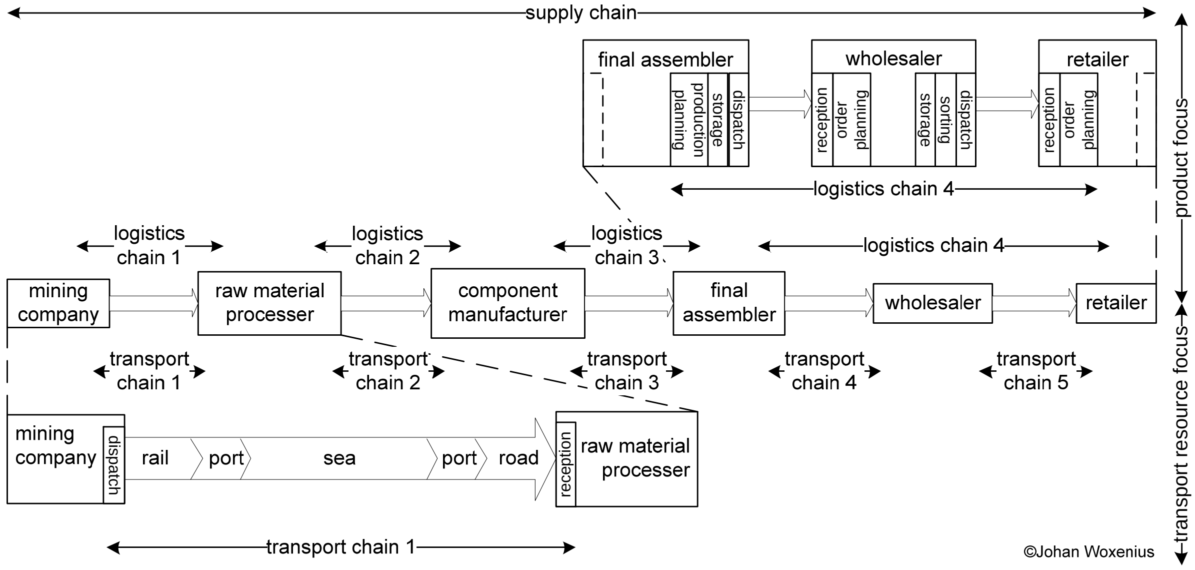

Figure 1. – Examples of the scope of a supply chain, logistics chains and transport chains.
Source: Adapted from Ramstedt and Woxenius, 2006.

The design of supply, logistics and freight transport chains develop over the years, as does the division of labour. This implies that the provision of a product to a consumer might be stable regarding the source of raw material and components, but the configuration determines how the supply chain is divided into logistics and transport chains. One example is the role of Hong Kong in international trade that, according to Wang and Cheng (2010) has developed from being limited to a transhipment port—hence a part of a transport chain—to a knowledge-based supply chain management centre adding much more value to supply chains than a mere transhipment between ships. Previous freight transport chains are thus divided into several transport chains by the addition of transforming or stocking activities in Hong Kong reshaping the pattern of supply chains and logistics chains.

Analysing the causes of detours also requires rather strict definitions of *actor roles*, but for all three types of chains these are complicated to define. This is particularly true for transport chains since the industrial organisation differs significantly between different types of transport services depending on the character of the demand, traffic modes involved, regulations, levels of vertical and horizontal integration, etc. As long as the level of analysis allows it, the generic actor names presented in Table 1 are used and if the practically used actor names are needed, the Northern European context is used.

Table 1. Categories of transport chain actors.

Abstract terms	Generic actor names	Roles	Actor group names used in European practice
Origin/source	Consignor	Send goods	(Product) Supplier
Destination/sink	Consignee	Receive goods	(Product) Customer
Management	Transport co-ordinator	Co-ordinate transport services	Forwarder, Third party logistics provider, Agent
Link operator	Transport operator	Move goods	Road haulier, Rail operator, Ship owner/Shipping line, Airline
Node operator	Terminal operator	Tranship, consolidate goods	Port, Airport, Intermodal terminal operator, Consolidation terminal operator

The generic terms TSB and TSP are used here for denoting the *roles* at the demand and supply sides of the market for transport services; however, Table 1 does not define the business relationships between the actors, i.e., who acts as TSB and who acts as TSP. The consignor, the consignee or someone appointed by them can take on the TSB role and the TSP role can be played by a transport co-ordinator or a transport operator directly. The amount of transport on one's own account is diminishing, but large parts of the transport market involve only two parties, for instance a road haulier transporting clothes from a retailer's distribution centre to its stores or a rail operator moving iron ore from a mine to a port owned by the mining company. Still, there are often hierarchies of companies on either side of the TSB-TSP interface (see, e.g., Andersson and Norrman, 2002; Stefansson, 2004, however, these authors apply a different terminology).

3 Detours in supply chains

Much of the public debate on long transport distances relates to globalisation and distant sourcing. It is easily confused, also among logistics scholars, with detours in logistics chains and transport chains. The rendering here is short due to the focus on transport chain detours. Following the definitions of the chain types above, the focus is on products and production systems including several manufacturing stages. Detours in supply chains stem from strategic decisions regarding supply chain configuration.

Discussing directness in relation to distant sourcing makes sense only if the real supply chains are contrasted against a world where supply chains are centrally designed aiming at minimising transport work. Measuring the directness opens questions of which options to compare. The actual supply chain could be matched against one using the closest potential supplier of equivalent material or components, one using the closest suitable production unit or even one based on shortest route of the raw material used in the final product.

Acknowledging the benefits of applying market forces rather than centrally managed optimisation, much of the debate is less relevant in a directness context and relates more to a general discussion on sourcing practices and transport distances. This debate would benefit from more knowledge about the relationship between distance and environmental strain shedding light on the paradoxes involved.

Nevertheless, the design of supply chains obviously affects the levels of logistics chains and transport chains and is the root cause of many transport detours. The supply of efficient and cheap transport services has, on the other hand, facilitated the design of the currently geographically-long supply chains (see, e.g., Hesse and Rodrigue, 2004; Rodrigue, 2006) and information systems have assisted with the possibilities to control them (Lasserre, 2004). Long-distance trade in raw materials and finished products has an ancient history, but the substantial increase in total transport distance is caused by off-shoring of the intermediary manufacturing stages (e.g., Woxenius 2006).

The utilisation of cheap labour is the traditional motive used to stretch supply chains, but economies of scale in manufacturing, patents and competition between supply chains with mutually exclusive partners add to transport distances. The issue is truly complex, particularly for supply chain managers trying to combine strategies of being green, lean and global (Mollenkopf *et al.*, 2010). On a political scale, customs tariffs, tax incentives, compensatory purchasing as parts of arms deals or foreign aid and distant sourcing due to embargoes or, to a diminishing extent, lack of trade agreements with closer trading partners add to detours for raw material, components and finished products. In the case of raw material, an increased element of geopolitical considerations can be observed.

Examples like the well-travelled yogurt pot (Böge, 1995) are often striking but often also taken out of a proper economic, supply chain and transport efficiency context. Ülkü (In press) shows the benefits of consolidation when optimising on both costs and CO_2 emissions. A paradox is also that the ecological footprint actually often decreases by distance at some distance intervals when consolidation or traffic mode shift becomes economically viable.

4 Detours in logistics chains

The rendering here focuses movement and storage of items or articles between manufacturing stages and the distribution of finished products to consumers, the latter however overlapping the scope of supply chains. The directness in logistics chains are affected by decisions by TSBs rather than by TSPs.

The public debate can be regarded as most intense in the field of transport of food. The successive reduction of distribution centres and the resulting logistics detours are of particular interest. McKinnon (2007) identifies a diminishing rate of centralisation in the U.K. industry, but in contrast, Sweden is currently experiencing a dramatic phase of centralisation in the grocery sector. The Swedish retail chains argue that the concentrated flows allow them to utilise the generous Swedish maximum vehicle sizes and transfer flows to rail as well as increasing directness in the capillary distribution (see, e.g. Coop, 2008; ICA, 2009) but it is delicate to communicate the overall sustainability to consumers who tend to view the path of a single product. Carbon auditing and labelling at an individual product level weighing in the travelled distance might be a solution. McKinnon (2010), however, claims that it is currently not worth the great data collection and calculation effort but also methodologically doubtful since similar products can take quite different paths to the store shelf and the allocation of CO_2 emissions would differ between individual deliveries.

The inter-organisational design of distribution chains obviously has a huge impact on item detours. Decisions on who and how many layers that keep stock, sometimes referred to as the handling factor (Piecyk and McKinnon, 2008; Sanchez-Rodrigues *et al.*, 2010), is one example affecting the directness of items but the decisions can also reduce the number of transport chains involved in a logistics chain. One example is Adlibris, a Swedish online retailer of books that does not keep its own stock but operates a distribution centre for cross-docking deliveries by order lines from publishing firms into consolidated customer orders (Adlibris, 2010). Following the definitions in section 2, if Adlibris kept stock, its facility would have been denoted a warehouse embedded in a logistics chain, but without stock-keeping it is a terminal embedded in a transport chain since the final customer is known to Adlibris when ordering the books from the publishers. To transport operators, however, the design would still be interpreted as two separate transport chains. One of those is from the publisher to Adlibris' terminal and one further to the consumers or their pick-up points. The services are of quite a different nature and are typically performed by different TSPs.

Another example of the fine line between logistics and transport chains regards postponement. Long transport distances and slow traffic modes imply long lead times but their effect can be decreased by sending a consignment in roughly the right direction and then fine-tune the final destination when the final consignee becomes known. Crude oil shipments from the Middle East can shift owners several times in transit but the principle only results in detours when the final destination is decided after the potential routes diverge. Following the operational definitions used here, a logistics chain is thus transformed into a transport chain when the consignee is known.

Another inter-organisational example is the use of vendor-managed inventory as investigated by, e.g., Disney *et al.* (2003). The principle can be used for delivering batches equalling the full capacity of a vehicle or vessel but also as delivery of stand-by goods filling up unused capacity when delivering other consignments. The former case leaves a back-haul problem and the latter case a slight detour but the aim is often to decrease the total traffic work.

The factors contributing to detours on a logistics chain level also include insufficient planning and unforeseen events (Sanchez-Rodrigues *et al.*, 2010), the use of exclusive agents at large markets and preferred ports of entry for imports.

5 Detours in freight transport chains

Landing at the core focus of the article, this section contains the further elaboration of freight transport detours. The detours in this domain can be structured along the motivations or objectives lying behind TSPs' detouring decisions. Examples would be to use specific traffic modes, improve vehicle filling grades by consolidation or routeing, or save time by using better but less direct infrastructure or circle temporal traffic congestion. Another option is to divide along whether the detours are classified as rational or irrational, but that would obviously lead to difficulties regarding definition. It would also give an impression of putting blame on transport operators or individual employees; however, on the positive side it would likely identify an agenda for improvement in applying lean thinking. Yet another plausible way of structuring the issue would be to depart from the root causes for the detour decisions with a rough division between causes internal and external to TSPs. Examples of the former would be consolidation network operation and of the latter to circle a closed road section.

The structure chosen tries to combine the advantages of the different categorisation options. A start with causes for detours external to TSPs sorted in physical, regulatory and partly commercial reasons is followed by causes due to TSP-internal, operational decisions. The section is concluded with non-planned or *ad hoc* detours.

The rendering takes the perspective of TSPs in terms of transport co-ordinators and transport operators and the focus is on consignments; however, detours of vehicles and vessels are also considered. In particular, this regards empty runs and route distribution, which imply detours tricky to allocate to a single consignment but done to minimise the total mileage.

5.1 Physical causes

The first set of reasons for detours is the most obvious as it reflects the possibilities and restrictions for transport operations Mother Nature and infrastructure administrations have contributed with. This stipulates the range of available traffic modes and the route options for each mode.

Geography and topography could be argued to affect air the least among the traffic modes; ideally implying detours only in the z dimension (from reaching cruising altitude and to follow the earth's radius of curvature) and few limitations in the path between take-off and landing although air-traffic control might order detours. Availability of airports is, however, a strong restriction so the combination of air and surface traffic modes implies certain detours and often substantial ones for shorter transport services. Surface modes are interesting since geography and topography can imply both short-cuts and detours for sea, inland waterways, rail and road traffic, respectively.

Geography and topography are generally static, but seasonal and long-time *climate conditions* imply changing conditions for transportation. One example is that global warming seems to foster the use of the Northern Sea Route saving, for instance, 40% of the distance between Yokohama and Rotterdam (Liu and Kronbak, 2010) during parts of the year. Another example is ice in archipelagos that prevents shipping, forces detours around thicker ice or restriction to ice-broken fairways. For road transport, on the other hand, ice can open up for shortcuts. Passability in mountainous areas is often also subject to seasonal changes.

Detouring to avoid *temporary and local weather conditions* is common for air and sea transport but particularly wind and snow affect also road and rail. Routeing around bad weather in shipping is often caused by concerns for ship and cargo safety, but increasingly also for saving fuel and prolonging the structural lifetime of ships (Wengang *et al.*, 2010).

Geography and topography could be regarded as the most decisive; these factors also give the conditions for the *directness and quality of infrastructure*. On a larger scale, the quality of land transport infrastructure implies detours when consignments are routed to follow main arteries. On a minor scale, all roads, railway tracks and inland waterways wind through the landscape. Modern highways are even purposely equipped with curves to prevent drivers from falling asleep. The division of the rail network into a passenger network and a freight network (Reynaud and Jiang, 2001) implies detours since paths assigned to the other application are not open. For air and sea, transport chain detours attributed to infrastructure are defined by node location, accessibility and equipment rather than link configuration and quality. Examples of restrictions were abundant in the early days of containerisation and more recently when ship sizes grew rapidly and few ports were properly equipped for handling post-panamax vessels. Regarding node location, Medda and Carbonaro (2007) identified the deviation from the Suez-Gibraltar route as a decisive factor for the competitiveness of Mediterranean transhipment ports and Rodrigue and Notteboom (2010) visualise the detours arguing that the shipping lines are willing to include ports rather far from the shortest route as long as there is a concentration of demand in the port vicinity. Port selection in bulk shipping is also subject to sufficient draught in ports. Also, infrastructure passability is subject to temporal restrictions, for instance diversions around links closed for maintenance or for clearing up after accidents besides the aforementioned weather restrictions.

The rendering under this heading considers detours due to restrictions in the supply of suitable infrastructure referring to the infrastructure factor as defined by Samuelsson and Tilanus (1997a). Limited access is dealt with in the next section and the choices of which particular infrastructure to use made by transport co-ordinators and operators are discussed under the sections on commercial and operational causes of detours.

5.2 Political causes

The second category of detours is caused by political decisions and is therefore external to the TSPs. On a large scale, the division of the world into economic regions and national states contributes to transport chain detours. Trade agreements and custom tariffs contribute primarily to supply chain and logistics chain detours but the *channelling of international consignments* through certain border crossings, ports and airports imply transport chain detours. Cabotage rules, security and customs inspection restrictions are examples of common reasons for extra distance. A particular example is the U.S. Department of Homeland Security's Container Security Initiative imposing restrictions on which ports containers are allowed to be loaded before the final sea leg to the United States. With less than 50 ports cleared for shipping directly to the United States, detours are inevitable.

In addition, the absence of political control can lead to detours through *banned links*. Navigation around piracy prone waters such as Gulf of Aden might be the currently most debated example (see, e.g., Hong and Ng, 2010), but doubling war zones or conflict areas also contributes as do lack of transit rights in national air space, waters or on land infrastructure.

Nationally different rules for size and weight of vehicles and vessels, night-time driving and emission standards also make certain routes unattractive for transport operators. The tradition of limiting the size of trucks allowed in Switzerland has in practice meant banned routes for road hauliers, which often has been solved by detouring through France or Austria on routes between Germany and Italy.

However caused by nature, the decisions on *temporarily closed links* due to volcanic ash clouds in Europe in 2010 were based on air safety regulation but the necessity was partly debated. It resulted mostly in delays, but also to aeroplanes taking detours around the ash cloud or by using longer routes by other traffic modes.

On the national or local level, *selective road and street restrictions* prevent the use of the shortest paths for certain vehicles regarding size and weight but also emission standards. It is also common to restrict when specific vehicle types can access city streets. Furthermore, there is regulation giving detours for specific types of consignments. Hazardous cargo is particularly subject to restrictions regarding time to use sensitive links such as ferries, tunnels and city streets. Transport planning taking timing into account can often prevent detours.

5.3 Commercial causes

Some would argue that TSBs' preferences only regard the attributes of the services, not the content. With such a view, detouring decisions would be subject to physical and political causes but otherwise left to TSPs' discretion as long as the agreed quality performance is met. There are, however, numerous examples of *TSBs specifying the route*. Preferences for customs clearance at certain ports specialising in the particular commodity is one and preventing TSPs from mixing with competitors' consignments is another that might cause detours. Commercial reasons for detouring are consequently regarded as partly external and partly internal to TSPs.

Competition between firms is an obvious reason for supply chains being designed with longer transport distances than if a central planning agency uses an operations research tool to generate a solution minimising the total distance needed to satisfy the total transport demand. Transport chains are accordingly affected by *competition* between transport co-ordinators, transport operators and terminal operators. Road hauliers are, for instance, evidently tempted to change the most direct ferry service for a cheaper or otherwise attractive ferry service if their total cost or inconvenience of the detour is below the gains. Another example is that routeing detours increase with the number of competitors serving a less-than-truckload market.

Differences in factor prices, such as for fuel and infrastructure use, also cause detours, although international harmonisation attempts are in place to decrease such inefficiencies. One example is that Luxembourg has been forced to raise fuel taxes by the European Commission, reducing the incentives for road hauliers to route through Luxembourg for cheap fuel. Another example is that the introduction of the selective German highway charge, the MAUT, included close monitoring of the extent to which road hauliers circumvented the fees by detouring on minor roads.

5.4 Operational causes

From the perspective of a TSB and often also of policy makers and at the abstraction level of material flows, all transports are directly from product supplier to customer. In reality, however, the directness of transport services obviously depends on the economy, the demand for transport quality as well as practical possibilities for consolidation and finding return flows at an operational level. A number of parameters and their effects can be distinguished:

- consignment size – the closer to the full capacity of a vehicle or vessel, the more direct
- transport distance – the shorter, the more direct
- transport time demand – the more particular, the more direct
- product characteristics – the more particular, the more direct
- availability of other goods along the route – the lesser availability, the more direct

Detouring at the discretion of TSPs is the focus of this section. Detouring decisions at the operational level could be argued as internal to the TSPs, but of course subject to a range of decisions taken by policy makers and TSBs. The focus is on principal and systematic ways of using detours to fulfil other objectives than shortest consignment paths. Cost induced detours for using cheaper infrastructure or transport services are among the causes mentioned above and individual and non-planned decisions are treated under the next heading.

Of the factors mentioned in the list above, consignment size is particularly conclusive for the number of transport chains, i.e., sets of consignors and consignees, which are combined by a vehicle or vessel schedule. Detours are inevitable when consignments are smaller than economically feasible for direct traffic. A main divider between transport chain designs is whether the cargo stays on the vehicle or vessel along the whole route, referred to as, e.g., part load services in road transport and direct calls or strings in container shipping, or if it is consolidated with other goods at terminals in consolidated cargo or parcel services. Hall (1987) adds inventory consolidation to vehicle and terminal consolidation, but that refers to logistics chains rather than transport chains and is not considered here.

The number of consignors and consignees included in a route has, in turn, great influence on who takes on the TSB and TSP roles and the degree of influence the TSB has on the routeing as is indicated in Table 2. In some cases it is also realistic that transport is performed on own account, and thus the TSB and TSP are not relevant. Nevertheless, detours are then likely to be longer due to less consolidation and routeing options.

Table 2. Characteristics of transport chains based on number of consignors and consignees. The service terminology is taken from the European road transport sector. Adapted from Ramstedt and Woxenius, 2006.

From-to	Type of transport	Transport on own account realistic?	TSB	TSP	Typical amount of operational detours
one-one	FL	Yes	C-r/C-e	TO	Very low
one-few	PL	Yes	C-r	TO	Low
one-many	PL/CC	Hardly	C-r	TO/TC	Medium
few-one	PL	Yes	C-e	TO	Low
few-few	PL	No	C-r/C-e	TO/TC	Medium
few-many	CC	No	C-r	TC	High
many-one	PL/CC	Hardly	C-e	TO/TC	Medium
many-few	CC	No	C-r/C-e	TC	High
many-many	CC/Parcel	No	C-r	TC	Very high

Abbr.: FL=Full load; PL=Part load; CC=Consolidated cargo; C-e=Consignee; C-r=Consignor; TSB=Transport service buyer; TSP=Transport service provider; TO=Transport operator; TC=Transport co-ordinator.

When terminals such as consolidation terminals, intermodal terminals, airports, and transhipment ports are used, different vehicles and vessels are used for different links in the network. *Consolidation network operation* is an evident reason for consignment detours. The objective of such networks is simply not to minimise consignment distance but rather to minimise costs by reducing traffic work within the restrictions set by TSBs' qualitative demand and physical, political and commercial issues. The directness differs widely between different network configurations, which is well captured in literature (see, e.g., Kreutzberger, 1999 and 2004; Liu *et al.*, 2003; Woxenius, 2007) and particularly hub-and-spoke networks show a large amount of detours for consignments and passengers (see, e.g., Alderighi *et al.*, 2007).

The subject of when the consignments stay at vehicles and vessels during *route collection and distribution* has also attracted much scientific attention, primarily in the field of operations research. The principles are the same for services connecting one-many or many-one, such as collection to or distribution from one fixed location or the first and final legs of consolidation networks where smaller vehicles are used for local pick-ups and deliveries. Detours are generally longer than for a part load service or container shipping string where a few locations in each end of a long link are connected. Particularly the first consignment in a pick-up route and the last in a distribution route experience long detours. The trans-ocean container shipping strings between Asia and Europe typically connecting about ten ports actually do not add much to the detours caused by geography since ports are selected more or less along the route.

The issue of online shopping *vs.* conventional shopping is an example where routeing involves transport chain detours. It is a delicate analysis with assumptions and subject of the context but Edwards *et al.* (2010) show that online shopping decreases CO_2 emissions under a set of assumptions. One example they mention is that the drop density of delivery vans is a vital factor and Boyer *et al.* (2009) analyse the effect of customer density for e-commerce in the United States. Co-location of freight terminals and warehouses in suburban areas (Cidell, 2010) might increase the drop-off density and thus increases directness.

Boyer *et al.* (2009) also investigated the effect of delivery *time windows*, a well known contributor of routeing inefficiencies. Sommar and Woxenius (2007) first failed to identify the logics behind many

Swedish part load trucking routes and further investigation revealed a common problem. Routes were initially carefully planned based on the demands of the largest TSB and additional consignors and consignees were then offered time windows. When the transport co-ordinator lost the large TSB, inertia in changing the time windows for the others prevented them from adjusting the route to an efficient one. Time windows correspond to the agreements with TSBs, but regularly appearing congestion on individual links has a similar effect for routeing.

Another cause of detours is *intermodal transport*. Intermodal routeing can of course be treated as just a subset of consolidation network operations, but it is here discussed separately since the objective is rather to use more efficient traffic modes than minimising traffic work. Terminals for shifting traffic modes are rarely located along the most direct route (Train and Wilson, 2007) and diversions can be significant. The modes also work in combinations as intermodal relays but are also overlapping when lorries and rail wagons travel with ferries or lorries with rolling highway services by rail. An important factor when analysing the competitiveness of intermodal transport is the total intermodal distance compared to unimodal transport as investigated by Sommar and Woxenius (2007).

Repositioning of empty resources to access the next scheduled transport assignment implies detours that are difficult to allocate to individual consignments but the phenomenon still adds to the difference between the straight and actually travelled route for consignments if the repositioning is part of the route optimisation. Vehicles and vessels are not the only resources in which repositioning causes diversions. An effect of stricter European legislation of driving hours is that routes have to include more margins for delays and sometimes employment of more transport equipment than before.

Shifts in the production factor costs occur over time. If the time-dependent labour cost becomes cheaper in relation to the distance cost there will be more occasions when it is profitable to let a driver wait for a back-haul and thus reduce total travelled distance. The opposite, that is, more detours, is also plausible and perhaps more likely. The traffic work savings from consolidation might more often off set the extra terminal labour costs.

5.5 Non-planned causes

The performance of all transport systems are subject to the level of execution robustness, that is, how well the plans capture the risks during transit and the systems' ability to adjust to actual conditions. Some temporal conditions causing detours such as local weather, ash clouds, unsecure areas, infrastructure maintenance and accidents are mentioned above. In addition, there are numerous examples of other non-systematic internally and externally induced diversions from the most direct or planned routeing option. Common examples are *excessively rigid planning* (Naim *et al.*, 2006), a lack of information about the passability of individual links, strikes, as well as individuals' false awareness or failure to adhere to the given route orders. Drivers might, for instance, *disobey routeing orders* and travel extra mileage to combine business and a pleasure like good food, pleasant scenery or a meeting with an acquaintance. The extent of the resulting detours relies heavily on the pre-warning time, the urgency of the transport and the length of the detouring options at hand.

Methods of counteracting irrational detours taken by individuals include strict orders for which route to follow, compulsory use of global positioning systems (GPS) and geofencing systems issuing warnings if vehicles deviate from planned routes. However, monitoring employees is a difficult objective; increasing general efficiency, employee safety and preventing theft are the prime reasons. Following route suggestions from the GPS device potentially saves a great deal of distance, but GPS devices also add to detours when set to minimise travel time, for instance, by suggesting longer but faster diversions around congested links. Table 3 is an attempt to classify the different transport chain detours.

Table 3. Nature and actor groups' influence on causes of transport chain detours.

Cause of detour	Nature	Society	TSB	TC	TO	Individuals
Physical causes						
Geography and topography	x					
Climate conditions	x					
Local weather conditions	x					
Directness and quality of infrastructure	x	x				
Political causes						
Channelling international consignments		x	x			
Banned links		x				
Temporarily closed links		x				
Selective road and street restrictions		x				
Commercial causes						
TSBs specifying the route			x			
Competition				x	x	
Differences in factor prices		x	x	x	x	
Operational causes						
Consolidation network operation				x		
Route collection and distribution				x	x	
Time windows			x			
Intermodal transport				x	x	
Repositioning of empty resources				x	x	
Non-planned						
Excessively rigid planning			x	x	x	
Disobeying routeing orders						x

Abbreviations: TSB=Transport service buyer; TC=Transport co-ordinator, TO=Transport operator.

6 The potential usefulness of directness as a key performance indicator

It should be clear from the above sections that there is a wide array of causes of detours. This section contains a discussion about the prospects of capturing detours or directness in a KPI, and how such a measure can be designed, measured, monitored and used, as well as a brief analysis of the consequences of using it for monitoring and controlling the performance of supply, logistics and transport chains. This section focuses on transport chain directness in a supply chain and logistics context.

6.1 Who needs a directness KPI and for what purposes?

KPIs are used for improving processes. Forslund (2007) defines the steps of performance management as follows: set objectives and strategies; define metrics; set targets; measure; analyse; evaluate; and then act to improve the process. KPIs in logistics range from high-level measures monitoring wide logistics processes to specific activity-level KPIs (Griffis *et al.*, 2007). The directness metrics discussed here are clearly on the activity level.

The usual objectives of performance management are to decrease cost and to improve efficiency and effectiveness. An issue that arises is whether an item, a consignment, a unit load, a vehicle or vessel, a full transport system or even a logistics or supply chain is the best level of analysis. This is of course subject to context, the actor category using the KPI and its individual targets. Swedish Transport Administration (2010), for instance, suggests KPIs for both transport services and transport corridors including the nodes and links involved as a tool to accomplish economic development through efficient transport. Shipment distance is promoted as a part of the energy use KPI (*ibid.* p. 25), that together with organisational KPIs and more technical KPIs measuring emission performance make up criteria for achieving a green corridor label.

Nevertheless, more detailed knowledge about the nature of detours would be useful for authorities planning infrastructure investments. Such decisions are currently often based on analyses of rough origin-destination matrices aligned to a future situation by macro-economic KPIs. Such methods rarely capture the design of logistics chains or real routeing of long-distance freight and neither is very good at predicting real routes if new links are added or old ones are improved. KPIs on filling grades have been used in the public debate about infrastructure, in which policy makers have argued that investments in new infrastructure can be avoided by filling up vehicles better. A directness KPI might be used similarly. The current debate is often confusing considering the complex relationships between supply chain, logistics and transport chain detours.

Transport operators and transport co-ordinators would obviously be helped by further insight into detours and a corresponding directness KPI in their aspiration of improving their operations. TSBs need the data for estimating their ecological footprint and for informing consumers of the actual distances their products have covered. Operators might also benefit from knowing how their sourcing and location decisions affect transport chain detours, but the use of a KPI might not be the most efficient way to acquire that knowledge.

6.2 How can a directness KPI be designed?

Freight transport directness is covered in the literature and KPIs have been suggested before. Sanchez-Rodrigue *et al.* (2010) use a key ratio called the *average length of haul* capturing routeing inefficiencies and Rodrigue *et al.* (2009) suggest a definition for a *detour index*:

> A measure of the efficiency of a transport network in terms of how well it overcomes distance or the friction of space.

They measure it as the straight distance divided by the real transport distance; the closer the detour index gets to one, the more spatially efficient the network is and most networks would fit on an asymptotic curve approaching but never reaching one. They mention topography as a good indicator of the detour index.

Samuelsson and Tilanus (1997a) define the *detour factor* more narrowly than the broad interpretation used in this article. Since they use several factors for measuring distance efficiency, they limit the detour factor to capture detours due to route distribution (*ibid.*, p. 145):

> The detour factor (…) is defined as the single distance between the depot and destination i multiplied by the size of shipment i[2], summed over all shipments i, divided by half the total length of the roundtrip multiplied by vehicle capacity. Since the return trips are already dealt with by the backhaul factor, here we only deal with the forward trips, considering half the distance of the roundtrips to be forward trips.

They observe that the detour factor was getting increasingly serious and the road hauliers had few options for improving it, except for calculating it into their freight rates and allowing the TSBs to decide upon the size of consignments. The panel of experts interviewed by Samuelsson and Tilanus (1997a and 1997b) assessed the detour factor to be 0.62 and found that there was some room for improvement.

A critical aspect when designing the KPI is to define beneficial transport work and how it is actually performed. If a TSB calculates the transport work created by its flows it would generally be based on straight lines between the supply chain stages, or slightly more accurately using distance tables specific to each traffic mode or the distances given by route planning tools. It would rarely capture

[2] Author note: i might be better referred to as j in the second instance.

transport chain detours and thus a smaller transport work would be reported than what is reported by TSPs operational data. Different KPIs would be interesting for comparison, but would be difficult to use in measuring full supply or logistics chains and consolidation networks serving multiple supply chains.

Another issue is that traffic work measured as vehicle-kilometres is a blunt conception since it does not take the vehicle capacity into account. Resource consumption is not directly proportional to load weight or volume and thus the directness KPI should not favour the use of small vehicles. Better measures would capture the capacity utilisation in weight (percentage of used capacity in tonnes times distance, % of tonne-metres) or volume (for instance by measuring the percentage of used capacity in cubic metres times distance, % of m^4). Ülkü (In press, pp. 4-5) addresses the issue by using the ratio of "the actual weight of goods carried to the maximum weight that could have been carried on a laden trip".

Measuring and comparing actual distance with a straight line would contribute useful knowledge, but such analysis would be even more interesting if the detours could be decomposed first. It would be of less interest to capture physical and political causes for detours in a directness KPI since they are external to the TSPs and beyond their scope of improvements in the short run. The focus should instead be at the operational and the internally induced non-planned and commercial causes. The last category is particularly interesting since it involves the TSBs and can be used for the concurrent improvement of logistics and transport chains.

A particular problem with the decomposition is to allocate detours properly. An example is that terminals are often located in the proximity of good infrastructure raising the question whether detours are attributed to infrastructure supply, the operation of consolidation networks or the use of intermodal transport services. This is difficult to solve and must be considered when designing the KPI and when taking actions to improve the KPI.

6.3 How can a directness KPI be measured, monitored and implemented?

The design of KPIs should be aligned with the practical and economic possibilities of repeated measuring. An example is including transport when measuring and calculating carbon footprint at an item level as put forth by McKinnon (2010) but he assessed it as currently being too toilsome and resource consuming to do on a regular basis.

Directness data is currently inexpensively accessible at the vehicle, vessel and unit load levels with the use of GPS tracking devices. Individual consignments, however, are generally covered inside such units and need to be connected to data on which transport equipment is used for allocating distances to the consignments. Radio frequency identification (RFID) technology is realistic for capturing the nodes the consignments have passed, but not the lengths of the links used between the nodes. A combination of GPS and RFID can however supply the needed data.

Methods of decomposing the routes used for identifying individual causes of detours require further development and attributing vehicle detours to individual consignments would also imply significant allocation problems in consolidation networks.

The next issue is how the KPI can be used for improving transport chain performance in practice. Assuming that data can be captured and be allocated properly to individual consignments and some types of detour causes, the data then must be interpreted and further decomposed into the types of causes that cannot be directly measured. Methodologies certainly require refinement and there will be a need for compromises regarding the level of detail for many years to come.

6.4 Potential consequences of using a directness KPI

It is acknowledged that travelling the theoretically shortest distance is not an end in itself, and detours are often explained by rational decisions. Maximising the directness KPI is also, as mentioned in Section 1, simply achieved by using less well-loaded or smaller vehicles and avoiding changes of traffic mode if geography does not stipulate it. For instance, it is rarely claimed that a courier service is more efficient than the regular mail system simply because the delivery is more direct.

An obvious option would be to disregard the market forces by collective optimisation of all freight flows. A compromise is to allow inter-carrier consolidation in certain areas to decrease the detours due to routeing, as explained by Nemoto (1997). This approach is generally accepted by TSBs and competition authorities in crowded city centres and sparsely populated regions, but it raises the question of under which conditions advantages of TSP co-operation outweigh the lost incentives for improvements gained from the market forces.

Another problem with using detours or directness as a KPI is that this only partially measures efficiency and is likely to contradict other efficiency KPIs. The TSPs consolidate to save on the total mileage of the vehicle fleet subject to meeting the TSBs' demands, rather than minimising consignment distances. This might be changed if TSBs start to demand short paths for their consignments. One example is locally produced food that is sensitive to consumers' attitudes; retailing chains are likely to appreciate direct transport although routing through warehouses are likely to be more efficient. Another example is the aforementioned use of vendor managed inventory for better use of transport resources.

Furthermore, detours complicate the debate on which traffic mode best promotes ecological sustainability. There might be consensus of the emissions per kilometre for different types of vehicles and vessels, but this must be aligned with real travelled distances to determine the best mode. A striking example is that road transport can compete with feeder shipping between Hamburg and Copenhagen regarding CO_2 emissions since the ships double the Danish peninsula Jutland.

7 Conclusions

The article aims to contribute to the understanding of how transport distance, and the corresponding costs and external effects, can be decreased while improving the competitiveness and sustainability of transport services. The conclusions of the article are in accordance with those put forward by Samuelsson and Tilanus (1997a and 1997b), which is a result of the similar approaches. The main point is that this is a highly theoretical exercise that should not be used to pinpoint inefficiencies but to identify areas for improvements.

There are significant methodological barriers to overcome before a transport chain directness KPI can be widely used for performance management. Vehicle detours have to be allocated to consignments and the detours have to be decomposed into different causes before the KPIs will be useful in practice focusing on areas transport service buyers and providers can influence.

Decisions on detours belong in the industrial domain, but they enter the public or political domains in discussions of whether freight transport in general or the individual traffic modes specifically bear their full social costs. Industry does not take detours just for the fun of it, but the public has a case when business economic decisions do not mirror their full social costs. Moreover, consumers are increasingly concerned about not only how products are produced, but also how they reached the store shelves.

Calls from industry for infrastructure investments are frequently met by policy makers with arguments that the current infrastructure is not being fully utilised. The political debate is underpinned with statistics showing low load factors leading to bickering about why they are so low. The issue of transport distances reaches the political debate when discussing supply chain and logistic chain designs with distant sourcing and centralisation of manufacturing and warehousing, but the freight transport industry is, thus far, rarely scrutinised regarding directness. It might just be a matter of time until this happens, and then it would be useful to have some structured thoughts about the reasons for detours.

Further work is needed to shed more light on the issue of directness. The planned steps include developing graphical depictions of the different types of detours, quantifying the actual and relative directness for representative transport services and analysing the difference between the transport work required by shippers and the transport work reported by the transport operators. The consequences of detours and the potential of decreasing them are other areas requiring further analysis.

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