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Item 7 of the provisional agenda
Transport and competitiveness

Transport and competitiveness
Note by the secretariat

Understanding the modern role of transport

1. The attached document was prepared by the secretariat following the request by the Task Force on Transport and Competitiveness. The review of literature was carried out in order to highlight the current thinking about the new role of transport sector and services in the context of global supply chains and their importance for economic competitiveness.

2. Introduction

Understanding the new role of transport is the crucial step in the development of a methodology that will be able to assess the contribution of transport to national competitiveness. This task is far from straightforward and it is further complicated by the fact that the relevant literature, despite being rich in scope, does not provide any simple explanation. In general, the consideration of this issue in literature is characterized by the lack of systematic approach.

This section will evaluate the existing literature and systematize the findings. It will therefore mainly be a literature survey and it will contain references to academic and non-academic literature. The next section describes the methodology used for the review. Section 4 presents the result of the literature review and is divided in six parts. In the first part, section 4.1 summarizes the evidence whether and how transport influences the society in general. In section 4.2 the importance of transport within the supply chain is evaluated and section 4.3 reviews the role of transport in logistics. These first three sections will set the base and are presented in a logical sequence going from the broadest macro level perspective on society as a whole to a more micro level perspective considering only logistics. After the initial three sections it should be more clear what role transport plays a in society, in supply chains and in logistics. The result of these considerations will thus serve as a point of departure for identifying what is the role of transport. Section 4.4 evaluates the characteristics of each mode of transport and their role in society, logistics and in supply chains and the following section 4.4.1 will then get deeper into each mode to assess its characteristics. In section 4.5 characteristics of cross-modal aspects of transport are assessed. Finally in section 5 the findings from the previous sections will be put into a scheme to present a systematic overview of the role of transport.

3. Search methodology

This survey is a study of information on a specific topic from the available literature and also comprises empirical and practical evidence. It is therefore more appropriate to define this review as 'information search'. The first step in a survey is to define the topic. The topic for this project is defined as *the role of transport.* Information on this topic is collected using the following techniques:

(i) Using search engines with *keyword searches.*

The keywords are defined by the individual sections. For example:"The role of transport in the society". The main search engine used is Google Scholar[1].

(ii) Use the *snowball method*: Point of departure is a basic source, the reference in this source are included, if relevant. The references in these references are included, if relevant.

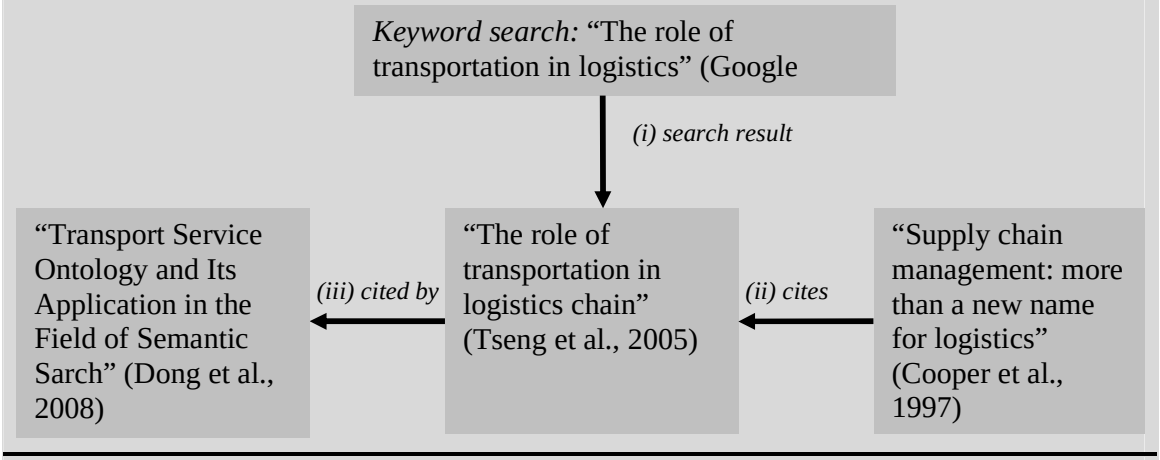
(iii) Use search engines to carry out a *reverse snowball search*: Search for literature referring to the basic source.

(iv) Include insights from the task-force members.

Figure 3.1 illustrates the use of these techniques using actual sources. The figure shows the three steps, where *(i)* is the keyword search method, (ii) is the snowball method and *(iii)* is the reverse snowball method.

[1] http://scholar.google.com

Figure 3.1: An illustration of the literature search methodology



All literature and information identified using these four steps is evaluated. If the literature contains valuable and relevant information it is included.

4. The survey

This section presents the findings from the information search using the techniques presented above. The findings have been divided into five categories. As mentioned earlier, section 4.1 is the broadest macro-oriented view on the role of transport. The next section 4.2 then narrows the research topic to the role of transport in supply chains. The topic is narrowed even further in section 4.3, where the role of transport in logistics is described. Section 4.4 assesses the role and characteristics of each transport mode, while section 4.5 looks across modes to identify common characteristics. The difficulty to identify the role of transport when it is unknown how to measure transport was a challenge throughout the information search.

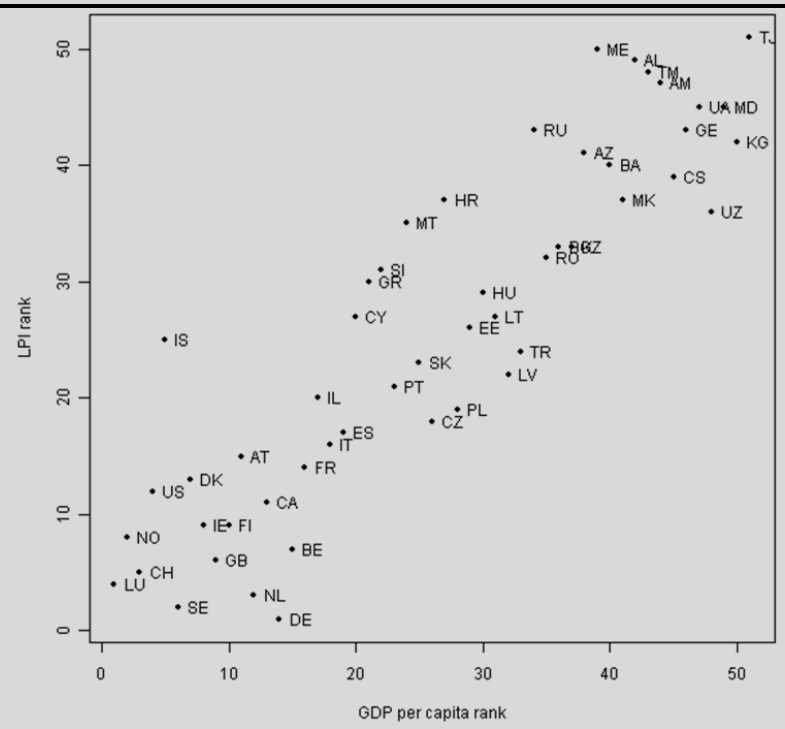
4.1 The role of transport in the society

This section will elaborate on the role of transport for the society. The first part will present some examples of empirical evidence and the second part will then present a number of findings from the theoretical literature.

Empirical Evidence

It is of course challenging to provide empirical evidence when no appropriate measurement method exists. However the empirical evidence is only meant as indication and for this it seems sufficient to apply the Logistics Performance Index (LPI), developed by the World Bank. This metric was evaluated in the previous audit report. The term *sufficient* does not refer to the LPI as not ”good enough”, but rather to the fact, that the LPI measures the logistics performance and not the transport performance, which is not the same. This aspect should be kept in mind when assessing the following empirical evidence.

Figure 4.1: Relationship between GDP per capita and the Logistics Performance Index in 2009



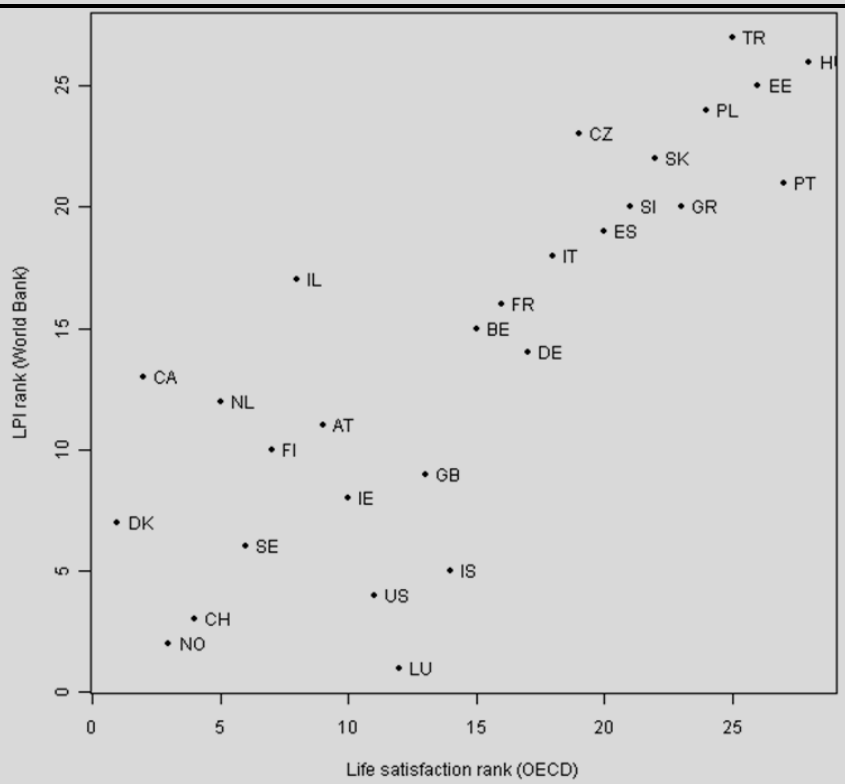
Source: World Bank

Transport and income

The first piece of empirical evidence is a plot of GDP per capita rank against the LPI ranks, which is shown in figure 4.1. If all countries were located along a diagonal 45 degree line, the relationship would be "perfect". The figure shows an almost one-to one relationship between Logistics Performance Index rank and GDP per capita rank. To mention a few of the outliers, island states such as Iceland and Cyprus receive a lower LPI rank compared to their GDP per capita rank. This is to be expected as transport to and from island states, everything else equal, is expected to be more complex. Figure 4.1 shows that there is correlation between LPI and income per capita, but the figure does not reveal any information about causality; i.e. whether a higher LPI score leads to higher income per capita or vice versa. There are reasons to believe that the causality goes in both directions. This observation leads to the following conclusion:

Finding 4.1.1 *There is a close relationship between transport performance (measured by the LPI) and income per capita.*

Figure 4.2: Relationship between life-satisfaction and the Logistics Performance



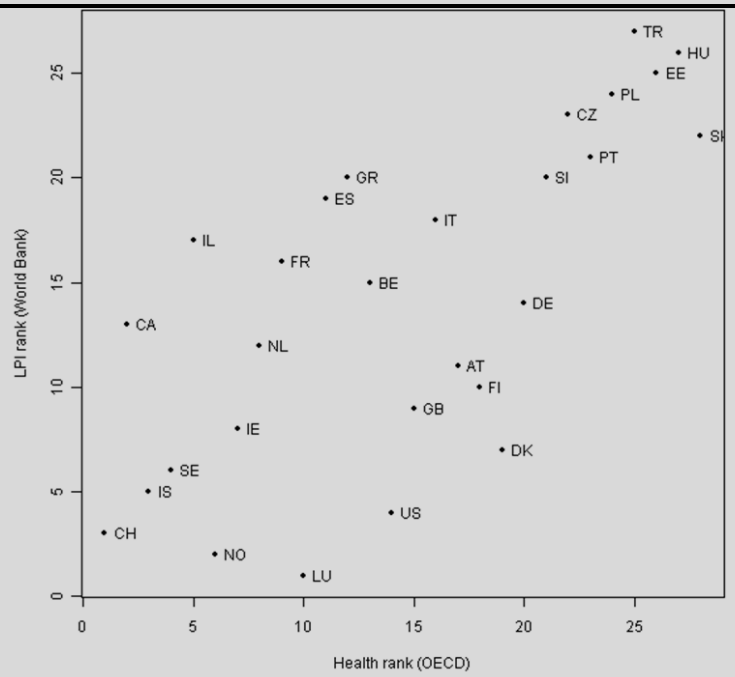
Source: The World Bank and OECD. Note: Data from the World Bank is for 2009 and data from OECD is from 2008.

Transport and life-satisfaction

In recent years, there has been an increasing emphasis on measuring development not only by income, but also by other indicators (see Stiglitz et al., 2009). One alternative index is the subjective rating of life-satisfaction; there are many reasons to believe that transport should be related to life-satisfaction. UNECE study "Transport for Sustainable Development" (2011) shows how transport is important for social inclusion by providing access to education, health care, employment and leisure activities. This theoretical link is confirmed in figure 4.2 which shows a plot of the LPI against the OECD life-satisfaction index. Figure 4.2 includes fewer observations than figure 4.1 because only the UNECE countries that are OECD members are included. But even with less than 30 observations a clear correlation is shown. Again it is important to highlight that this does not reveal anything about a causal relationship. Nevertheless it seems reasonable to conclude:

Finding 4.1.2 *There is a close relationship between transport performance (measured by the LPI) and subjective indication of life-satisfaction.*

Figure 4.3: Relationship between the OECD health index and the Logistics Performance Index



Source: The World Bank and OECD. Note: Data from the World Bank is for 2009 and data from OECD is from 2008.

Transport and health

As already noted, transport is important, among other services, for providing individuals with access to health institutions (UNECE, 2011). There is empirical evidence from the United Kingdom which shows that over a 12 months period 1.4 million people did not seek medical help because of transport problems (UK Social Exclusion Unit, 2002). Another index that is available through the OECD is the health-index which is created based on information of self-reported health and life expectancy.

Figure 4.3 reveals that the relationship between health and LPI is recognizable but weaker than the relationship between LPI and GDP per capita and that of LPI and life-satisfaction. The weaker relationship may be due to the fact that transport is measured by the logistics performance index, which does not capture the transport aspects which are relevant for access to health. Based on both the empirical plot and the evidence from the United Kingdom, it nevertheless seems reasonable to make the following conclusion:

Finding 4.1.3 *Transport performance and the health of the population are correlated.*

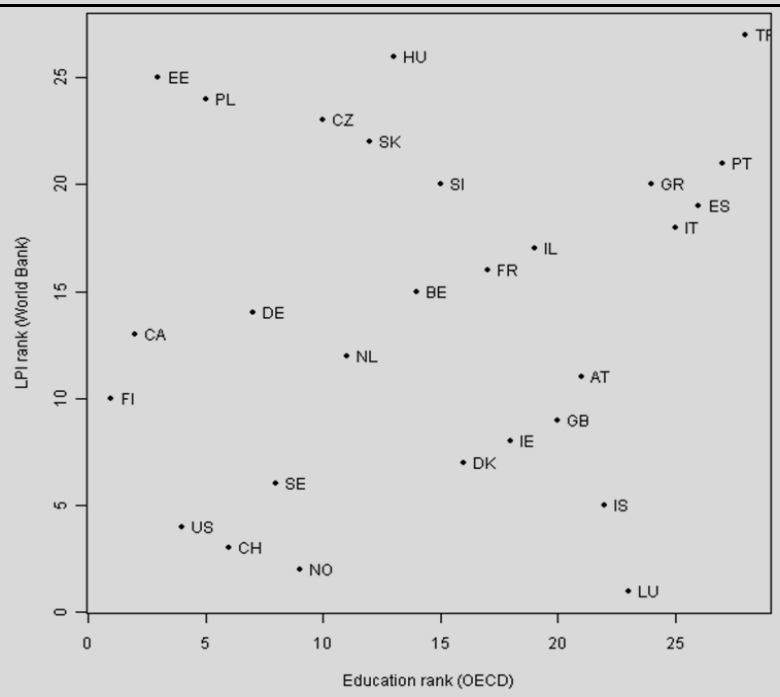
Transport and education

Transport also provides access to education. The UK Social Exclusion Unit (2002) finds that six per cent of 16- to 24-year-olds in the United Kingdom do not attend education because of transport problems. Figure 4.4 shows a plot of the LPI rank against the OECD education index rank. The education index is based on the educational attainment and the PISA scores.

It is seen from figure 4.4 that it is hardly possible to identify any relationship between LPI and transport. The reason is probably – as for health - that LPI measures logistics performance, which is unlikely to encompass the aspect of access to education. This may also be the explanation for the weak relationship between the LPI rank and the education index rank. Nevertheless, based on the empirical evidence from the United Kingdom and the empirical results in figure 4.4, it is possible to conclude the following:

Finding 4.1.4 *Transport performance is correlated with educational attainment.*

Figure 4.4: Relationship between the OECD education index and the Logistics Performance Index



Source: The World Bank and OECD. Note: Data from the World Bank is for 2009 and data from OECD is from 2008.

Theoretical evidence

The average annual labor productivity growth in the US from 1948 to 1965 was 2.6 per cent while for the period 1973-1979 it was only 0.5 per cent (Darby, 1984). In a search for an explanation for this decline several reasons were identified. Since the seminal contribution of Aschauer (1989), the observed decline in public infrastructure investments has been counted as the main explanation. David Aschauer concluded that a one percent increase in the public to private capital ratio leads to a 0.39 per cent increase in private capital productivity. Since then, the idea of a causal relationship between public infrastructure investment and economic development has been referred to as the "Aschauer's hypothesis" (Sturm and de Haan, 1995) or the "public infrastructure hypothesis" (Stephan, 1997). The most thorough studies applying this approach are Ligthart and Suarez (2005), and Bom and Ligthart (2008), who include respectively 49 and 76 empirical studies. They conclude that there is a positive effect of public infrastructure on economic development, but that the magnitude is substantially lower

than in the initial studies because earlier studies ignored statistical issues. Bhatta and Drennan (2003) reviewed literature with an emphasis on the various measurements for economic development and finally Romp and de Haan (2007) concluded that "there is more of a consensus in the recent than in the older literature" which confirms the hypothesis.

Figure 4.5 summarizes the main ideas from academic literature on why transport, in theory, can improve the performance of the private sector.[2]

Figure 4.5: Theoretical mechanisms on how transport affects competitiveness

Behavior		*Impact of transport*	*Literature*
Subcontractors, Human capital, Business partners	*(i)*	Dynamic effects: e.g agglomeration effects, improved labor force, increased competition among subcontractors.	Agglomeration effects are often traced back to Marshall (1890). The concept is often discussed in the literature on New Economic Geography (e.g. Krugman (1991), Zhang (2007)).
↘ ↓ ↙	*(ii)*	Direct effects: e.g. time saving, cost reduction	E.g. labor supply and traveltime/ costs. (see Gibbons and Machin (2006) for a survey).
Firm	*(iii)*	Dynamic effects: improved business partners.	Proximity in production (Burmeister et al, 1997).
↓	*(iv)*	Direct effects: cost reduction, reliability.	New economic geography (e.g. Krugman (1991), Zhang (2007)).
Market	*(v)*	Dynamic effects: e.g. improved access to the market.	

As the figure shows, this link can be divided into five mechanisms: (i) Firms receive intermediate goods, share knowledge and cooperate with business partners and employ a labor force. A good transport performance attracts more firms (business partners), subcontractors and a qualified labor force. These dynamic effects lead to an increased performance of an individual firm. (ii) There is a direct effect of better transport services, if the employees', intermediate goods and business partners can reach the firm quicker, safer and more reliable through improved infrastructure. (iii) Transport efficiency may affect the firms' internal structure. It may for instance be possible to operate with a head-quarter and plant structure or to organize all activities in one location dependent on type of production process. (iv) Customers can be served at lower costs, more reliable and faster. This leads to direct cost reductions. (v) The improved access and better infrastructure leads to better market access, and consequently the firm can operate with lower inventories and avoid overproduction.

Figure 4.5 only summarizes the main findings in academic literature; the link between transport and competitiveness/private sector productivity is evident. There are numerous other

[2] For a thorough treatment and graphical representation see Banister and Berechman (2000, p. 41) who present a "causality paradigm of the relationship between transport infrastructure investment and economic development".

contributions to this topic in literature that supports this conclusion. To mention one, Tseng et al. (2005) also highlights that transport is important for competitiveness stating that:

> *"The role that transportation plays in logistics system is more complex than carrying goods for the proprietors. Its complexity can take effect only through highly quality management. By means of well-handled transport system, goods could be sent to the right place at right time in order to satisfy customers' demands. It brings efficacy, and also it builds a bridge between producers and consumers. Therefore, transportation is the base of efficiency and economy in business logistics and expands other functions of logistics system. In addition, a good transport system performing in logistics activities brings benefits not only to service quality but also to company competitiveness."* (Tseng et al., 2005)

Summing up all this evidence, leads us to conclude that:

Finding 4.1.5 *There is a solid theoretical link between transport and national competitiveness.*

Conclusion

The empirical research indicates that good transport performance is related to high income per capita, as well as a high score in the OECD life-satisfaction index and the OECD health index. Other empirical sources have also shown that transport is important for education, health, employment and social inclusion. It is thus possible to conclude that the empirical evidence confirms that transport is important for the society.

The theoretical literature supports this empirical evidence. Literature explaining the mechanisms for why transport increases competitiveness is rich and solid. Considering findings 4.1.1 to 4.1.5 it is possible to make the following conclusion.

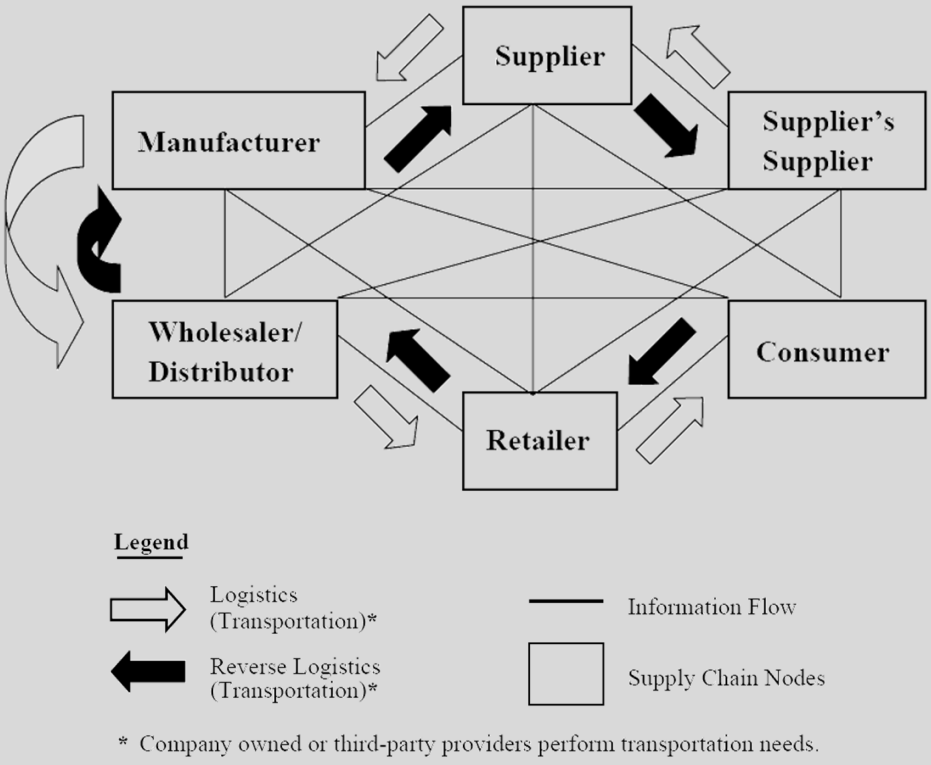
Conclusion 1: *Transport is important for society. It increases competitiveness and social inclusion. This is confirmed by both empirical and theoretical evidence.*

4.2 The role of transport in the supply chain

What is a supply chain?

Supply chain management is becoming increasingly important with the spread of globalization and as the world has becomes more interlinked. Supply chains consist of all stakeholders involved from the initial supplier to the final consumer. This process varies considerably from product to product and from country to country; it is therefore not possible to provide a generally valid description of a supply chain. Figure 4.6 illustrates one example of a supply chain. The figure reveals that transport is involved in a number of activities within the supply chains. Especially for products with physical transportation needs, the role of transport is obvious, as transport is needed to move a good from one stakeholder to the other. It is however relevant to ask whether the role of transport goes beyond this and whether transport can be regarded as a part of a supply chain that is independent of the other elements. Moreover it is important to investigate how transport can make the supply chain more efficient.

Figure 4.6: An illustration of a supply chain



Source: Krumwiede and Sheu (2002)

Literature on role of transport in the supply chain

The paper "Supply Chain Management: More Than a New Name for Logistics" by Cooper et al. (1997) is a keystone in literature with more than 1,000 citations according to Google Scholar[3]. Cooper et al. (1997) provide a description of supply chain management in which they decompose supply chain management into ten components. The authors then evaluate thirteen academic studies according to how they describe a supply chain and which of the ten elements are included. Table 4.1 is a replication of table 2 in Cooper et al. (1997), with a number of modifications, in which these ten components are presented. The last two rows are not included in the original table. The second to the last row indicates the number of studies that includes this component. The last row indicates whether this component is related to transport.

[3] According to a search carried out in May 2011.

Table 4.1: Components of Supply Chain Management

	Power and leadership structure	*Product structure*	*Management methods*	*Risk and reward structure*	*Organization structure*	*Culture and attitude*	*Planning and control*	*Product flow facility structure*	*Work structure*	*Information flow structure*
Houlihan (1985)		✓	✓		✓	✓	✓	✓	✓	✓
Jones and Riley (1985)			✓		✓	✓	✓	✓	✓	✓
Stevens (1989)					✓	✓	✓	✓	✓	✓
Ellram and Cooper (1990)	✓			✓			✓	✓	✓	✓
Lee and Billington (1992)								✓	✓	✓
Cooper and Ellram (1993)			✓	✓	✓	✓	✓	✓	✓	✓
Hewitt (1994)				✓	✓		✓	✓	✓	✓
Scott and Westbrook (1991)		✓						✓	✓	✓
Towill et al. (1992)		✓					✓	✓	✓	✓
Hammer (1990)			✓	✓	✓	✓	✓	✓	✓	✓
Andrews and Stalick (1994)			✓	✓	✓	✓	✓		✓	✓
Cooper and Gardner (1993)	✓			✓		✓	✓	✓	✓	✓
Lambert et al. (1996)			✓	✓		✓	✓			✓
Frequency	2	3	6	7	7	8	11	11	12	13
Transport	No	No	No	No	?	No	Yes	Yes	?	Yes

Source: Cooper et al. (1997) (but modified)

According to this ranking, it appears that the least important aspect is ”Power and leadership” structure which according to the description provided by Cooper et al. (1997) does not involve transport. The second lowest rated component is "Product Structure”. Whether this component involves transport is not clear, but it seems likely that the product structure is not related to transport. Third is "Management Methods”, again transport is very unlikely relevant for this component. The fourth component is "Risk and reward structure”, which does not include transport, while in the fifth - "Organization Structure”, transport may have an impact.

Transport does not only affect the ”Culture and attitude” directly, but it is directly involved in ”Planning and control”, which eleven out of thirteen authors mention as a component of

supply chains. Moreover transport is clearly involved in the "Product flow facility structure", which is regarded as important by eleven out of thirteen authors. The second most important component according to this table is "Work structure" which may include transport. Transport is definitely included in the most important component "Information flow facility structure", especially today, fourteen years after the publication of this table when information flows are real-time and essential part of transportation process.

To sum up, transport is definitely included in three out of the four most important components of a supply chain.

Finding 4.2.1 A literature survey from 1997 shows that transport is a very important component of supply chains. Transport affects the supply chain through a number of mechanisms: (1) Planning and Control, (2) Product flow and (3) Information flow.

Using a source from 1997 it is possible to identify that transport affects the supply chain efficiency not only through moving freight from point A to B, but also by providing a channel for the information flow and in the planning and control within the supply chain. This highlights the importance of real-time information on transport flows.

The importance of transport in modern supply chains is also highlighted by Morash and Clinton (1997), who state that:

> *"In a global and deregulated environment, transportation's contribution to international supply chain structure takes on new and* ***increased importance****. Without transportation's* ***active participation*** *in structural supply chain design, transportation capabilities, such as* ***reliability****, time compression, and just-in-time delivery cannot be successfully implemented for total cost minimization and costumer value enhancement."(Morash and Clinton, 1997)*

In this quotation a number of key factors of transport characteristics that are important to the supply chain are mentioned:

(i) transportation's contribution to international supply chain structure is increasing in importance.

(ii) reliability, time compression and just-in-time delivery is important!

(iii) transport not only affects costs, but also the (costumer) value of the good.

This leads to the following finding:

Finding 4.2.2 *Transport is important for total cost minimization and customer value enhancement in the supply chain.*

Conclusion

Important question is whether the role of transport in the supply chain goes beyond moving goods from point A to B and whether this process can be handled separately from the remaining supply chain activities. In that case the only aspects of transport that matters for supply chain efficiency would be time and costs. However, the literature clearly indicates that transport plays an integrated role in supply chains. It is involved in information flows, the organizational structure and of course the traditional role in terms of transport of goods. The important conclusion is thus, that transport cannot be regarded as a separate element of the

supply chain. Transport is interlinked with other activities and for transport to improve the supply chain efficiency, much depends on increasing transports ability to work together with the other operators of the supply chain. This implies that information about goods transport flows should be available in real-time and delivery should be flexible and reliable.

Summing up, it is possible to make the following conclusions about the role of transport in supply chains:

Conclusion 2: *Transport is important for the overall performance of the supply chain.*

(i) the importance of transport is increasing (Morash and Clinton, 1997).

(ii) transport is involved in the most important elements of supply chains (Cooper et al., 1997).

(iii) reliability, real-time information and just-in-time delivery are key aspects for transport in supply chains (Cooper et al., 1997).

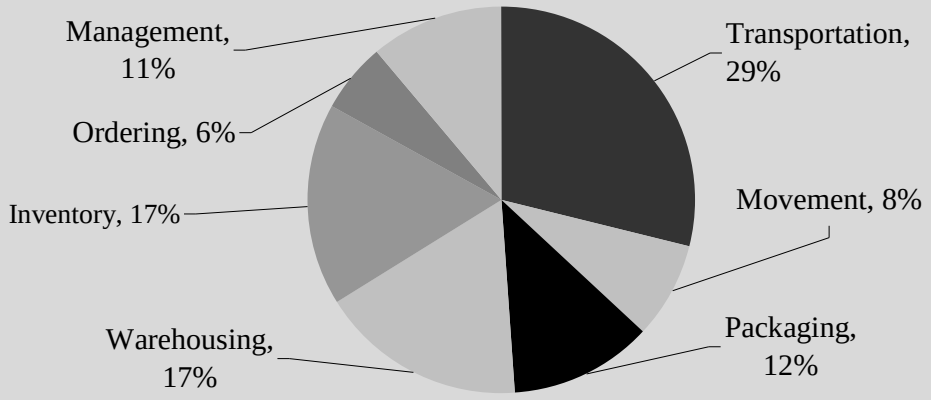
(iv) Transport cannot be regarded as a separate and independent element of the supply chain. (Morash and Clinton, 1997)

4.3 The role of transport in logistics

Empirical evidence

The empirical evidence about the relationship between transport and logistics performance is mainly based on transport costs. Tseng et al. (2005) discuss the "Interrelationships between transportation and logistics" in which the discussion starts from estimates of components of logistics costs and is based on data from 1998. Figure 4.7 replicates the estimates presented in Tseng et al. (2005). No details about how these cost ratios are estimated is presented, the numbers should therefore only be used as indicators. The estimates confirm the importance of transport in logistic chains.

Figure 4.7: Cost ratio of logistics items



Source: Tseng et al. (2005)

Despite the numbers not being up-to-date, they prove that transport plays a significant role in logistics costs as it constitutes almost one-third of logistics costs. Add to this that transport is also involved in some of the other activities such as Movement, Ordering, Inventory and

Warehousing. This is due to the fact that transport has become a moving warehouse. Morash and Clinton (1997) mention that:

> *"As such, operational planning and reengineering may allow for* ***transportation and information to serve as substitutes for warehousing and inventory costs.*** *In particular, time compression strategies of expedited transportation, increased inventory velocity, and minimum dwell-times can reduce pipeline inventory, safety stocks, and cycle stocks. As a result, total supply chain costs may be minimized." (Morash and Clinton, 1997)*

This quotation highlights the fact, that transport can reduce costs not only directly through transport costs, but also indirectly by lowering costs of other components of logistics. Gunasekaran et al. (2004) present numbers from 1990 showing that 40% of United Kingdom's GDP was spent on distribution and logistics related activities. Since transport constitutes a major share of logistics costs and logistics costs constitute a significant share of National income, the role of transport – through logistics – in the society is clearly significant. Stajniak and Romanow (2008) also highlight that "the biggest share in the logistics cost structure belongs to transport costs"; which they underline with an estimate of 40% of the logistics costs related to transport. This leads to finding 4.3.1.

Finding 4.3.1 *Transport is an important part of logistics, measured by costs.*

Theoretical evidence

Several of the dynamics explained in figure 7.5 refer to logistics activities. These are:

(i) Time saving and cost reduction.

(ii) Proximity in production (Burmeister and Colletis-Wahl, 1997).

(iii) New economic geography effects (Krugman, 1991).

These effects have already been mentioned in the section on supply chains. Transport can affect logistics directly through a reduction in time and costs. But it can also reduce the need for inventories, the costs for managing and several other logistics costs. Additional to these effects are the numerous dynamic mechanisms. For instance the dynamics explained by new economic geography. High transport performance can lead to a periphery-core system, where firms operate in a core and serve the periphery from plants in the core. If transport is highly efficient, this can be more ideal than having plants in both markets. This mechanism will lead to a clustering of firms and human capital. It will thus be easier and cheaper for firms to recruit human and physical capital, which in turn will improve the logistics performance.

Finding 4.3.2 *Transport can improve logistics performance through a number of dynamic mechanisms, for instance by attracting firms and human capital, which in turn leads to clustering and multiplier effects.*

Since the mentioned definitions and descriptions of supply chains, logistics and transport express that transport is an important element in supply chains, and since logistics has been described as "the part of the supply chain process that plans, implements, and controls the efficient flow and storage of goods….", it is clear that transport is an important part of logistics. Tseng et al. (2005) applies a fairly general description of the role in logistics activities, by noting that "Transportation plays a connective role among the several steps that result in the conversion of resources into useful goods in the name of the ultimate consumer" (Tseng et al., 2005), but he elaborates on this description by stating that "The role that

transportation plays in logistics system is more complex than carrying goods for the proprietors."

Finding 4.3.3 *Transport has a connective role in logistics that goes beyond carrying goods from A to B.*

Conclusion

This section concludes the first part of the literature survey. It has been shown that transport is important for the society and for the supply chain efficiency. The supply chain efficiency is mainly affected by transport through improvements in logistics efficiency. This last section has first empirically shown that transport is an important component of logistics, and second, based on theoretical literature it has been clarified that transport can affect logistics (and thereby supply chain) efficiency through a number of dynamic and indirect mechanisms.

Conclusion 3: *Transport is an important element of logistics:*

(i) *Transport is a major cost component of logistics (Tseng et al., 2005; Gunasekaran et al., 2004; Stajniak and Romanow, 2008)*

(ii) *Transport can reduce the need for warehousing through time compressions (reliability, just-in-time delivery and real-time information) (Morash and Clinton, 1997)*

(iii) *Transport can improve logistics efficiency through dynamic effects by promoting clustering of firms, leading to a greater degree of proximity in production (Burmeister and Colletis-Wahl, 1997; Krugman, 1991).*

4.4 The role of each transport mode

Types of transport

The last section identified a number of general characteristics of transport important for its role for the society. To get a more detailed understanding, the role of each transport mode will now be considered. Costs, time savings, reliability and real-time information are characteristics of transport that are important for increasing supply chain and logistics efficiency. These characteristics are typical across transport modes, but each mode plays its role in transport chain and has specific characteristics that are important for its efficiency. At this point it is necessary to consider which transport modes to include into analysis. Tseng et al. (2005) divides transport logistics into three types:

(i) Air logistics

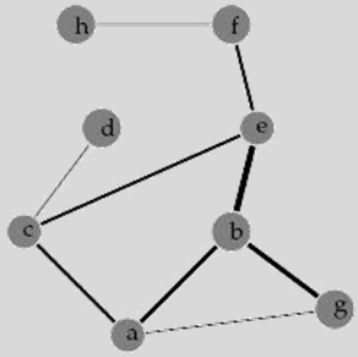
(ii) Maritime logistics

(iii) Land logistics

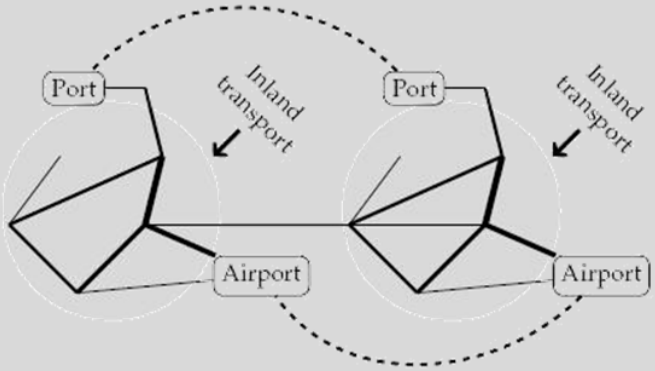
This distinction is based on the following arguments: (1) Air and maritime transport differ fundamentally from land transport since they depend on the existence of network nodes (ports), while land transport is dependent on the existence of network paths; (2) Air and maritime transport have a comparative advantage in long distance transport compared to inland transport; (3) Air transport differs from maritime in terms of its advantages, flexibility and speed but disadvantage is its high costs per unit of transport. Maritime transport can carry high volumes; it is relatively cheap compared to air transport, but is slow.

Figure 4.8: The network structure of transport

(a) A traditional network structure



(b) The network structure of transport



Inland transport modes are characterized by paths, while air and maritime transport is characterized by nodes.

Figure 4.8 illustrates the key difference between sea/maritime transport and inland transport modes. A traditional network structure with paths and nodes (from a to h) is presented in figure 4.8a. Nodes could in this case be humans and the paths could be e-mail exchanges. A transport system differs from this traditional network structure in the sense that air and maritime transport are characterized by nodes only, while the inland transport is characterized only by paths. This is illustrated in figure 4.8b.

Table 4.2: Description of transport logistics by Tseng et al (2005)

Type	*Description*
Air freight logistics	It provides the delivery with speed, lower risk of damage, security, flexibility, accessibility and good frequency for regular destinations. Yet, the disadvantage is high costs. Reynolds-Feighan (2001) claim that air freight logistics is selected 'when the value per unit weight of shipments is relatively high and the speed of delivery is an important factor'. The characteristics of air freight logistics are that: (1) airplanes and airports are separated. Therefore, the industries only need to prepare planes for operation; (2) it allows fast delivery at far away destinations; (3) air freight transport is not affected by relief. Research data show that the freight transport market keeps growing. Given the trend of global markets, air freight logistics also has to adjust their services.
Maritime logistics	Maritime industry plays an important role in international freight. It can provide a cheap and high carrying capacity conveyance for consumers. Therefore, it has a vital position in the transportation of particular goods, such as crude oil and bulk freight. Its disadvantage is that it takes longer time and its schedule is strongly affected by the weather factors. To save costs and enhance competitiveness, current maritime logistics firms tend to use large-scaled ships and cooperative operation techniques. Moreover, current maritime customers care about service quality more than the delivery price.
Land Logistics	Land logistics is a very important link in logistics activities. It extends the delivery services for air and maritime transport from airports and seaports. The biggest advantage of land logistics is the high accessibility level in land areas. The main transport modes of land logistics are railway transport, road freight transport and pipeline transport. Railway transport has advantages like high carrying capacity, lower influence by weather conditions, and lower energy consumption while disadvantages are high cost of essential facilities, difficult and expensive maintenance, lack of elasticity of urgent demands, and timely organization of railway carriages. Road freight transport has advantage of cheaper investment funds, high accessibility, mobility and availability. Its disadvantages are low capacity, lower safety, and sometimes slow speed. The advantages of pipeline transport are high capacity, less effect by weather conditions, cheaper operation fee, and continuous conveyance; the disadvantages are expensive infrastructures, harder supervision, goods specialization, and regular maintenance needs. The excessive usage of land transport also brings many problems, such as traffic congestion, pollution and traffic accidents. To improve the efficiency and reliability of land transport in future a revolution of transport policies and management is required, e.g. pricing.

Source: Tseng et al. (2005)

Descriptions of each type of transport logistics by Tseng et al. (2005) is presented in table 4.2. Two other types of logistics are mentioned: "Express Delivery" and "E-commerce" (Tseng et al., 2005). It should be noted, that authors do not consider inland waterway transport, but include pipelines. Waterway transport is here included in inland transport. Description by

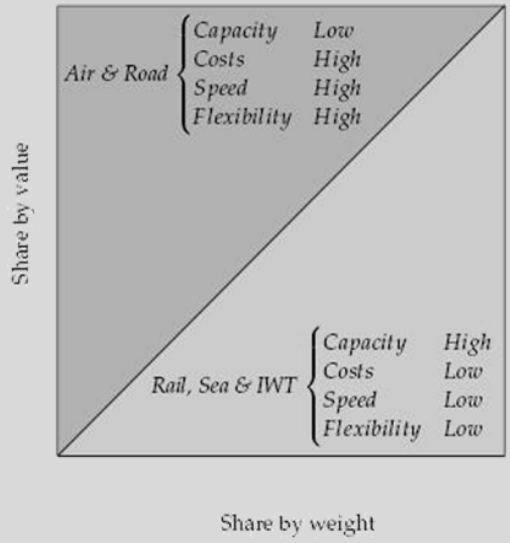
Tseng does not only give information about which modes are important in logistics, it gives two additional pieces of information: First, it explains a useful distinction in three types of transport logistics: maritime, air and land. This leads to the following findings:

Finding 4.4.1 *Transport should be divided into three distinctive modes: air, maritime and inland transport.*

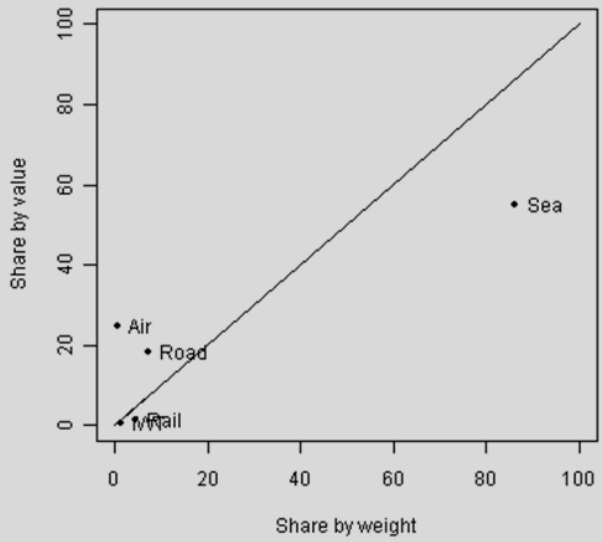
Second, it provides a description of the characteristics of each transport mode. For example air and maritime transport should, according to Tseng be dominant for international transport, while land transport is "a very important link", which connects the international transport to the end consumer. In terms of international transport, air transport has advantage when speed and flexibility are important, while maritime transport has its comparative advantage for low costs and high volume transport operations.

Figure 4.9: Modal split of freight transport

(a) Theoretical predictions



(b) Trade to and from EU27 in 2010



Source: Eurostat

Figure 4.9 graphically summarizes descriptions by Tseng. Figure 4.9a is an illustration of the theoretically expected modal split. Air and road transport are flexible and fast, but relatively costly, these modes are therefore expected to have a relatively higher share when freight is measured by value. Rail, sea and inland waterway transport on the other hand are expected to have relatively higher shares when measured by weight because of the higher carrying capacity and lower costs. Figure 4.9b confirms theoretical predictions in figure 4.9a. The figure shows the modal split of freight transport to and from the EU27 based on Eurostat's Foreign Trade database. Air and road transport have higher shares when measured by value than when measured by weight, and vice versa for inland waterway, rail and sea transport. Sea transport is the overall dominant mode for international transport. When measured by weight, sea transport has a share of 86%, while when measured by value it is 55%, this confirms that sea transport is used for goods with a low value/weight ratio. Air transport on the other hand used for goods with a high value/weight ratio; measured by value air transport constitutes 25% of all transport to and from the EU27, while measured by weight it is less than one per

cent. It is also seen from figure 4.9b that, as expected, air and maritime transport are the dominant modes for international freight transport.

Tseng also highlights that road transport is less reliable due to congestion issues and vulnerability to weather conditions, while rail transport is more reliable. Rail transport may therefore be used for goods with constant delivery needs, where flexibility is less important than reliability.

The descriptions of Tseng together with the empirical evidence shown in figure 4.9b lead to the following two findings:

Finding 4.4.2

(i) Sea and air transport should dominate in long-distance (international) transport. Inland transport modes should dominate short-distance (domestic) transport.

(ii) Air and road transport are used for goods with high value per weight. Inland waterway transport, rail and road are used for transport with a low value per weight. Rail, sea and inland waterway transport may also be beneficial for goods with constant delivery needs because the inflexibility and low speed are less relevant for these deliveries, while reliability is of great importance.

Conclusion

The last section considered the role of the different transport modes. This led to findings about the optimal categorization of transport modes and second, about the role of each mode in transport chains. In summary, we can conclude:

Conclusion 4:

(i) For optimal results, transport operations should be divided into maritime, air and inland transport.
<u>Reason</u>: air and maritime transport efficiency depends on the quality of network nodes (ports), while the inland transport performance depends on the quality of the network that connects nodes (tracks, roads, channels, etc.).

(ii) Air and road transport are flexible, fast, but expensive modes and will therefore be more efficient for high value per weight goods, while inland waterway transport, rail and sea transport are less flexible, slow, but cheap and with a high carrying capacity. These modes should therefore be used for goods with a low value per weight or when transport needs are very constant.

The characteristics of air transport

This section touches upon the role of air transport in the society today. It has been shown that in logistics and supply chains the role of air transport is characterized by being:

(i) fast and flexible

(ii) expensive

(iii) dependent on network nodes (airports)

(iv) because of its relatively high costs and high flexibility, it should mainly be used for goods with a high value per weight.

(v) as it does not require network infrastructure it may be optimal for reaching remote areas.

There are further aspects to consider that are relevant for description of the role of air transport.

Theoretical considerations

According to the description in table 4.2, air freight transport should be dominant in international transport. It is important not to forget, that it relies on inland transport modes to reach the final market. This transport mode is flexible as it only relies on the existence of nodes (airports) at the departure and arrival point, while there is no need for infrastructure and investments between the two points. Air freight logistics is described by Tseng as ”necessary for many industries and services to complete their supply chain and functions”. The advantages are speed, low risk of damage, security, flexibility, accessibility, and frequency. The main disadvantage however is the price.

The first observation that can be made for air transport is thus that it depends on the number and quality of airports. As described by Tseng as long as airports are available, goods can more or less be shipped wherever needed. Whether every airplane can leave and arrive at an airport depends on the size of the airport.

Finding 7.4.3 *The performance of air- transport depends on the existence of airports.*

Moreover Tseng states that…”The future tendencies of air freight development are integration with other transport modes”. This leads to the following finding:

Finding 7.4.4 *The performance of air-transport depends on the integration with inland transport modes.*

For just-in-time and door-to-door services air-transport depends on inland transport modes. Air transport can rarely connect the initial supply and the final consumer without the use of inland transport modes (Tseng et al., 2005).

Finding 7.4.5 *Air transport depends on inland transport modes for engaging in just-in-time and door-to-door services.*

Empirical evidence

In line with the general disadvantage of air transport, Lai et al. (2004) assessed the self-reported performance of logistics suppliers and find that for air and sea transport, the factor ”Reduce transportation costs” is assessed with a score of 3.59, which is considerably lower than total mean of 3.93. It is also lower than all the reliability factors that range from 3.84 to 4.13. This (together with the description by Tseng et al. (2005) leads to the following finding:

Finding 4.4.6 *Transport costs are less important for air-transport. Air freight operators focus on other aspects for improving the performance.*

Conclusion

Summing up the findings for air-transport performance it is possible to make the following conclusion:

Conclusion 5: *Air transport is characterized by:*

- *flexibility*
- *speed*
- *high costs*
- *no network requirements*
- *dependent on airports (network nodes)*
- *dependent on integration with other transport modes*

- *mainly used for goods with a high value relative to weight*
- *dependent on inland modes for engaging in just-in-time and door-to-door services.*

The characteristics of maritime transport

The last two sections have already revealed a number of characteristics that describe the role of maritime transport. These are:

(i) high carrying capacity

(ii) low costs per volume

(iii) depends on network nodes (ports)

(iv) inflexible

(v) as maritime transport does not require network infrastructure it may be optimal for reaching remote areas with access to the sea.

The main advantages of maritime transport are cheap and high carrying capacity conveyance (Tseng et al., 2005), while the main disadvantages are longer time and schedule strongly affected by weather factors.

Theoretical considerations

Maritime transport is very similar to air transport in the network structure, as it only depends on the existence of network nodes (ports). There is however one important limitation for maritime transport which is not relevant for air transport; the network nodes can only be created at coast lines. Land-locked countries are therefore naturally disadvantaged. This leads to the following conclusion:

Finding 4.4.7 *Maritime transport does – like air transport – only depend on the existence of network nodes (ports). These can however only be created at coastal areas.*

Due to its high carrying capacity and relatively low costs maritime freight transport should be dominant in international transport, but at the same time, it relies on inland transport modes to reach the final market. Transport mode which only relies on the existence of nodes (such as air and sea) depends on the existence of a network to reach the final consumer. This leads to the following finding:

Finding 4.4.8 *The performance of sea transport depends on the integration with inland transport modes.*

Comparing air and maritime transport it is seen that while air transport has its strength in flexibility and speed, maritime transport has its strength in volume and price. ”To save costs and enhance competitiveness, current maritime logistics firms tend to use large-scale ships and cooperative operation techniques” (Tseng et al., 2005). This implies that the benefits of maritime transport will only be enjoyed if the necessary port infrastructure – allowing ships with large carrying volume to load/unload – exists. This leads to the following finding:

Finding 4.4.9 *The main advantage of maritime transport is the ability to carry large volumes. The performance of sea transport therefore depends on the quality of ports and their ability to serve large ships.*

Other aspects of maritime transport mentioned by Tseng are real-time information, accurate time windows and good tacking systems, which to some extent support the evidence that reliability is important.

Finding 4.4.10 *Sea transport efficiency depends on reliability and the access to real-time information.*

Empirical evidence

The literature is somewhat unclear about the importance of costs for maritime transport. On one hand it is stated that the main advantage is that it is cheap (Tseng et al., 2005), on the other hand Lai et al. (2004) find that maritime transport suppliers self-assess their performance in costs lower than in reliability. Moreover Tseng et al. (2005) also find that customers of maritime logistics care more about quality than price. Thus, it seems safe to say that costs are less important for maritime transport:

Finding 4.4.11 *Transports costs are less important than reliability and quality in maritime transport.*

Conclusion

Maritime transport has many similarities to air transport - both modes should and are dominating in international transport and have similar network structure. However, sea transport differs from air transport in terms of its limited flexibility, slow speed, high carrying capacity and low costs. Summarizing these findings leads to the following conclusion:

Conclusion 6: *The role of sea transport is characterized by:*

- *high carrying capacity*
- *low costs (while importance of costs is ambiguous)*
- *transport of low value per weight goods*
- *transport of goods with constant demand*
- *inflexible*
- *slow*
- *quality depends on reliability*
- *quality depends on access to real-time information*

The characteristics of the role of inland transport

Inland transport covers rail, road and inland waterways[4]. In section 4.4 the classification of transport into: (1) air, (2) maritime and (3) inland transport was explained. The inland transport modes are grouped together because:

- inland transport modes differ in the network structure to air and sea transport by being dependent on paths rather than nodes.
- inland transport modes are less efficient for long distance transport than air or maritime transport.
- air and maritime transport depend on inland transport to connect to the inland market (end consumer).

In order to identify their individual characteristics and differences, each transport mode will be discussed separately in this section. One may for example argue that inland waterways and rail transport have a number of advantages over road transport in terms of carrying capacity

[4] Pipelines are sometimes also included as transport mode, but not in this project.

and environmental efficiency; while on the other hand road transport has a number of advantages in terms of flexibility and speed. To identify these different views, a brief analysis is needed.

Rail transport

Tseng et al. (2005) highlights the following characteristics of rail transport:

- high carrying capacity
- robust to weather conditions
- high energy efficiency
- high facility costs
- difficult and expensive maintenance
- inflexible
- inefficient/slow planning

It is quite difficult to accommodate specific or individual transport requests, and therefore, rail transport has - like sea transport – mainly advantage for standardized transports with constant demands:

Finding 4.4.12 *Due to its high degree of reliability but lack of flexibility, rail transport is, advantageous for standardized transports with constant demand. It could be considered as an inland parallel to sea transport.*

A railway network requires a number of investments that are typically higher than road investments. The efficiency of railway transport is very dependent on these investments, in contrast to road transport. Loading and unloading of trains typically require special additional infrastructure. If the railway infrastructure is not regularly maintained, capacity for unloading and loading may be reduced, moreover depreciated tracks may lead to reduced travel speed.

Finding 4.4.13 *Rail transport requires higher investments and more costly infrastructure maintenance (compared to road transport) which are crucial for the efficiency of rail transport.*

Once the infrastructure and rail equipment is in place, the rail transport has potential of being relatively cheap due to its high carrying capacity and high energy efficiency.

Finding 4.4.14 *Railways have a high carrying capacity and energy efficiency and can therefore be a cost and environmentally efficient transport mode.*

Compared to road transport railway transport operations are coordinated and managed. Congestion issues are therefore often a lesser problem than in road transport. Moreover as Tseng et al. (2005) state railway transport is less affected by weather conditions.

Finding 4.4.15 *Railway transport is reliable both in regard to congestion, and weather variations.*

Road Transport

A number of characteristics regarding the role of road transport have already been identified. These are:

- depends on network paths rather than network nodes for efficient operation;

- relatively low investments and maintenance costs (compared to the other modes);
- high flexibility;
- relatively low carrying capacity.

Most of these aspects are very much in contrast to rail transport. Road transport only depends on the existence of roads; no unloading facility is needed for most road transport arrangements. Moreover, the moving equipment, i.e. cars and trucks, costs considerably cheaper to operate than all other modes.

Finding 4.4.16 *Road transport has low investment and maintenance requirements. Efficiency can be maintained at low costs.*

These low investments and maintenance costs are countered by relatively high operational costs due to lower energy efficiency compared to for example rail transport. Tseng mentions a number of other aspects that characterize road transport:

- high accessibility;
- high mobility;
- high availability;
- low capacity;
- low safety;
- low speed.

It is worth noting, that it's low speed in contrast to air transport. For international transport, there is a clear distinction between the roles of sea versus air transport. But for inland transport the distinction between rail and road transport is less clear. Road transport is typically not as sustainable as rail transport, at least not with respect to environmental sustainability and health. It is also less safe and less energy efficient.

Finding 4.4.17 *Road transport has a number of sustainability issues with respect to environment and health (mainly road safety).*

Stajniak and Romanow (2008) state that …"It must be clearly emphasized that road transport is not only responsible for the moving process but is also the basic element of particular logistics systems. Without any knowledge of road transport it is impossible to create an effective and efficient logistics system for customer in contemporary economic conditions." Unfortunately, no more details are revealed, but the statement continues… "The role is undoubtedly different depending on the complexity of logistics process and delivery service level".

Inland waterway transport (IWT)

Inland waterways transport is a mode which shares some characteristics with both maritime and rail transport. It has many of the advantages of maritime transport, but depends, like rail transport, on the availability of paths, i.e. inland waterways. The similarities between rail and inland waterway transport are:

- high carrying capacity;
- high energy efficiency;
- high safety (compared to road transport);
- high degree of reliability;

- inflexible.

Inland waterways are much like sea and rail transport in terms of carrying capacity and costs.

Finding 4.4.18 *Inland waterway transport has a hig carrying capacity and low operational costs.*

Inland waterways are sustainable in terms of energy efficiency and health.

Finding 4.4.19 *Inland waterway transport has a high degree of environmental sustainability and safety.*

In terms of investments needs, inland transport differs slightly to rail transport. There are relatively low investment needs in paths as they are typically are based in natural waterways. However the operation depends on the existence of ports.

Finding 4.4.20 *Inland waterway transport has low maintenance and investment requirements for the network paths, but requires port infrastructure.*

Conclusion

Inland transport, as described by Tseng et al. (2005) is connecting air and maritime transport to the inland market and acts as a logistics extension. Therefore, the main advantage is its connectivity.

Air and maritime transport have their comparative advantage in international logistics, and land transport modes are able to connect these long-distance transport modes to the local market. Moreover as Tseng notes, the fundamental difference between maritime and air transport on one side and inland transport, is that the two former depend on ”nodes” at the destination and departure points, but not between these (there are no roads or track requirements). On the other hand, the inland transport modes are less dependent on the nodes at departure and arrival points, but very much dependent on their connections. Note however, that both rail and IWT are somewhere in between, as they still require ports/stations, but also require tracks and waterways. Inland transport modes are very different in their characteristics but should nevertheless be categorized in one group. One may argue that a mixture of road vs. rail/IWT is optimal to achieve a balance between accessibility, flexibility vs. safety, reliability and carrying capacity. Since rail transport requires large investments and inland waterway transport either requires large investments or depends on the natural existence of waterways, the optimal composition of inland transport may vary from country to country.

Summing up these findings, it is possible to make the following conclusion:

Conclusion 7: *Inland transport has a number of common characteristics, these are:*

- *connecting air and maritime transport to the final market;*
- *dependent on network paths;*

Rail transport is characterized by:

- *high carrying capacity;*
- *low operational costs, but high maintenance and investment needs;*
- *high energy efficiency;*
- *high safety;*
- *inflexibility;*
- *relatively high reliability.*

Road transport is characterized by:

- *low carrying capacity;*
- *high operational costs, but low maintenance and investment needs;*
- *low energy efficiency;*
- *low safety;*
- *flexibility;*
- *reliability issues.*

Inland waterways transport is characterized by:

- *a high carrying capacity;*
- *low operational costs;*
- *inflexible;*
- *high safety;*
- *reliability.*

4.5 Cross-mode aspects

It is necessary to consider a number of characteristics of transport that are valid across modes. These universal characteristics should be considered for each mode or separately as general aspect of the transport system.

What matters for modern transport systems?

Section 4.5 is divided into two parts. First part will consider various aspects of transport that are important for all transport modes and how the role and characteristics of each transport mode are considered. The second part of this section will consider aspects of transport that add a new dimension, that is, characteristics that are important for the functioning of transport, but which cannot be attributed to a single transport mode.

Quality versus price

Gunasekaran et al. (2004) assessed the importance of different supply chain performance measurement metrics. Regarding the importance of supplier metrics, it is worth noting that the most important metric is “Supplier delivery performance”. Moreover, it is found that “firms regard the supplier’s capability to reliably deliver goods in a timely fashion as more important than price “(Gunasekaran et al., 2004). Regarding the delivery performance, three key elements are found to be important:

1) ”quality of delivered goods”

2) ”on time delivery of goods”

3) ”flexibility of service systems to meet costumer demand”

Summing up, there is indication that quality, timeliness and flexibility are key factors important for firms deliveries and supplies, as Gunasekaran et al. (2004) puts it, ”price has increasingly become an order qualifier rather than an order winner.” This leads to finding 7.5.1.

Finding 4.5.1 *Quality, timeliness and flexibility are key factors for firms deliveries and supplies. Price is less important than timeliness.*

There is also evidence, that reliability is more important than speed. Morash and Clinton (1997) find that …"It is often more important that delivery times be reliable and consistent rather than solely fast. To achieve an integrated supply chain, members depend on reliable deliveries for their own production and sales efforts. Inconsistent supply performance can raise production costs". (Morash and Clinton, 1997).

Finding 4.5.2 *Timeliness is as least as important as speed.*

Morash and Clinton (1997) highlight another important aspect of transport in modern supply chains - the issue of quality:

> *Another dimension of transportation reliability is the absence of shipment loss and damage which is also important for supply chain performance. Although the direct costs to supply chain members of replacing lost or damaged materials can be high, the indirect can be even higher. Among these indirect costs are: lost sales, decreased customer loyalty, market share loss, production down-time, and re-ordering costs"*.

This quote is supported by empirical evidence. In the same study, firms in the United States and Japan were asked about the most relevant and important capabilities of transportation and logistics, "Reliability of transportation logistics" scored highest in Japan and second highest in the United States (behind Customer service). Other important aspects were "Information systems support" (both countries), "Flexibility for customers" (mainly US), "Customization of Transportation and Logistics Service Offerings" (mainly US) and "Low logistics costs" (only Japan).

Finding 4.5.3 *Reliable quality of delivery is important in modern supply chains. Costs due to unreliable deliveries are higher than the direct costs of replacing lost or missing material.*

Standardization versus customization

Modern supply chains require both a degree of standardization and customization of transport solutions:

> *"Standardization of transportation and logistics processes, and policies is an important integrative capability. Standardization makes supply chain flows and activities more predictable and less susceptible to an exceptions basis.[...] A final transportation capability involves customization of transportation offerings. Customizing transportation attributes for specific market segments or different supply chain members can further increase integration of supply chains."* (Morash and Clinton, 1997).

Finding 4.5.4 *There is a trade-off between standardization (reliability and predictability) and customization (flexibility) in providing optimal transport service.*

Standardization is needed in the regular production process without unexpected changes in quantity, location, delivery sequencing, items or time. Customized and flexible transport services are demanded to fulfill last-minute customer demands. Lack of flexibility can "raise inventory carrying costs, ordering costs, the cost of lost sales, and production costs." (Morash and Clinton, 1997).

Country specific characteristics

Supply chains are complex and differ from country to country and from sector to sector. The optimal supply chain depends on the institutional setting and the type of good produced. It is therefore necessary to understand that optimal supply chains and the role of transport in these may vary from country to country.

> *"In a deregulated and global environment, the role of transportation has broadened and expanded to international supply chain integration. To understand the relationships between international sourcing and transportation, country-specific supply chain structures and capabilities need to be investigated and compared"*. (Morash and Clinton, 1997)

It is important to note when assessing and considering the performance of transport systems that:

Finding 4.5.5 *The role and characteristics of transport can differ between countries because of numerous objective and subjective reasons.*

Conclusion

Flexibility, reliability, timeliness, costs and customizations are aspects that are relevant for all transport modes. Some modes have already been identified as more reliable than others. However, this does not imply that the less reliable transport modes can not improve reliability.

Conclusion 8: *Quality, timeliness, reliability and flexibility are key aspects of transport and are regarded more important than costs. Standardization is desired in regular services and customization is desired to meet last-minute changes in supply. Moreover country specific factors should be considered when assessing and describing the role of transport systems.*

A cross-mode dimension

The previous section discussed aspects and characteristics of transport that are relevant for all transport modes. These are relevant in describing each transport mode individually. This section deals with aspects of transport that are also valid across modes, but which can be regarded as a separate dimension of transport process.

Real time information

Another important cross-modal aspect of transport in modern supply chains is the ability to integrate into other aspects of the supply chain:

> *Transportation capabilities also are influenced by external supply chain integration, which involves a firm's links with material suppliers, carrier partners, and customers.[...] Transportation information sharing may involve exchange not only of operational data but also of tactical and strategic information among supply chain partners. As such, a key concept is end-to-end "pipeline visibility" at*

the operational, tactical and strategic level".
(Morash and Clinton, 1997)

It is thus of major importance to receive real-time information about every transport segment process, which enables firms to change plans and make adjustments in supply chain at any point in time. This is confirmed by an empirical study by Morash and Clinton (1997) among companies in Australia, Japan, Korea and the United States.

Empirical testing confirmed that on a scale ranging from one (agree) to five (disagree), the statement "Key to strategic alliance is information sharing" receives average scores in the range 1.63 to 2.51. Real-time information on transport flows is crucial for integration of transport in the supply chain. Morash and Clinton (1997) also ask whether internal coordination among (1) transportation, (2) logistics, (3) sales, (4) procurement, and (5) manufacturing, has increased compared to five years earlier, when it obtained a score between 1.65 and 1.94. There is sound evidence that:

Finding 4.5.6 *Real-time information about the transport process is a key in integration of transport with other parts of the supply chain.*

Environmental sustainability

Another dimension of transport role in logistics is its environmental performance. Environmental efficiency is increasingly becoming a concern for the private sector as customers are becoming more aware of the importance of environmental sustainability.

> *"Logistics and transport systems give rise to a wide set of externalities, many of them environmental. Transport is the fastest growing energy consumer in the European Union, with a 47% increase since 1985 compared with 4.2% for other sectors (Whitelegg 2003). This leads to growing pressure, as society becomes more aware of the issues surrounding sustainable development, for freight* ***transport to perform in a more sustainable manner*** *(Potter et al. 2002b). [...] The report concluded that an emission per item measure (the quantity of emissions produced by the processes in the value stream a product passed through from the conception to consumption) would be the most applicable top-line indicator[...]"*(Mason and Lalwani, 2006)

Based on a literature review Harris et al. (2007) conclude that:

> *" if environmental assessment is incorporated as part of infrastructure modeling then there is a possibility of achieving both economic and environmental savings. Every logistics design should include industry specific environmental assessment to prevent pollution and save the environment."(Harris et al., 2007)*

Awareness about environmental sustainability is increasing in the society. This is also reflected on the role of transport:

Finding 4.5.7 *Environmental sustainability is becoming increasingly important for transport suppliers in supply chains.*

Corporate Social Responsibility

It is not only the issue of environmental sustainability that has gained importance. Other social aspects also affect the value of a good supply chain and Corporate Social Responsibility is today an important part of most companies' strategy. .

> *"In recent years, the need for companies to act in a socially responsible manner and to show support for more sustainable development has become more influential."*(Mason and Lalwani, 2006)

As transport is a major part of the supply chain and therefore of the overall production process, it is important that transport services are in line with the overall social responsibility strategy. This leads to the following finding:

Finding 4.5.8 *Social responsibility is important for the performance of transport systems.*

Security

Urciuoli et al. (2010) evaluated the issue of transport security and how it affects transport performance. Firstly they state that:

> *"The introduction of security in transportation networks is fundamental to preserve the integrity of cargo moved around the world and thereby avoid disruptions and fear and havoc to our communities." Urciuoli et al. (2010)*

The impact of security measures on transport performance is evaluated using three case studies. These experiences are assessed on five dimensions: 1) quality, 2) transit time, 3) costs, 4) reliability and 5) flexibility. In all cases it is found that transit time and costs are increased. In three out of four cases it is found that reliability is negatively affected and in all cases it is flexibility which is affected. Quality is not affected in any of the three sources. Urciuoli et al. (2010) therefore conclude that ... enhancing security within an organization implies an increased workload and costs borne by terminal and transport operators.

Finding 4.5.9 *Security may also be regarded as a part of the social responsibility of transport operators, at least in terms of the externalities of transport security. However, security is also directly relevant for the transported goods and operator; it is therefore relevant to conclude that transport performance is affected by security.*

Safety

Safety is definitely also a part of the social responsibility of transport operators. Due to its great importance and many challenges it is however necessary to mention safety as a specific issue.

Tseng et al. (2005) note that safety issues are one of the downsides of road transport. Transport safety is important for human health as mentioned by Mason and Lalwani (2006).

Finding 4.5.10 *Transport safety is an important element of transport performance.*

Conclusion

A number of cross-mode aspects of transport, which are not intrinsic to each mode but are associated with transport services, have been identified. These aspects are summarized in the following conclusion:

Conclusion 9 *In addition to the characteristics of each transport mode, transport performance depends on:*

- *Safety;*
- *Security;*
- *Social responsibility;*
- *Environmental Performance;*
- *The access to real-time information on transport flows.*

5. Systematize the Role of Transport

The literature on supply chain performance measurement is rich, but it lacks systematization. This is confirmed by a thorough review of Shepherd and Günter (2006). They present a survey of performance measurement systems and metrics of supply chains based on analysis of some 362 articles and books dealing with this issue. This led to a number of interesting findings:

- ”There have been relatively few attempts to systematically collate measures for evaluating the performance of supply chains”
- ”Moreover, there is a no consensus over the most appropriate way to categorize them.”
- ”The overall proportion of the measures identified substantiates the argument offered by Beamon (1999), that there is a disproportionate focus on cost (42 per cent)”.

This underlines the importance of some sort of systematization. Having identified a number of characteristics of the transport system and its role in modern supply chains, it is now possible to put these elements into a system. Table 5.1 summarizes the conclusions from the previous sections.

Table 5.1: Summarizing findings on the role of transport

Conclusion 1	Transport is important for society. It increases competitiveness and social inclusion.
Conclusion 2	Transport is important for the overall performance of supply chains.
Conclusion 3	Transport is an important element of logistics: *(i)* Transport costs are a major cost component of logistics (Tseng et al., 2005; Gunasekaran et al., 2004; Stajniak and Romanow, 2008) *(ii)* Transport can reduce the need for warehousing through time compressions (reliability, just-in-time delivery and real-time information) (Morash and Clinton, 1997) *iii)* Transport can improve logistics efficiency through dynamic effects by promoting clustering of firms, leading to a greater degree of proximity in production (Burmeister and Colletis- Wahl, 1997; Krugman, 1991).
Conclusion 4	*(i)* Transport should be divided into maritime, air and inland transport. Because: air and maritime transport efficiency depends on the quality of network nodes (ports), while the inland transport performance depends on the quality of the network that connects nodes (tracks, roads, channels, etc.). *(ii)* Air and road transport are flexible, fast, but expensive modes and will therefore be more efficient for high value per weight goods, while IWT, rail and maritime transport are relatively inflexible, slow, but cheap and with a high carrying capacity. These modes should therefore be used for goods with a low value per weight or when transport needs are very constant.
Conclusion 5	Air transport is characterized by: ▪ flexibility ▪ speed ▪ high costs ▪ no network requirements ▪ dependent on airports (network nodes) ▪ dependent on integration with other transport modes ▪ mainly used for high value per weight goods ▪ is dependent on inland modes for engaging in Just-In-Time and door-to-door services.
Conclusion 6	The role of sea transport is characterized by: ▪ high carrying capacity ▪ low costs (while importance of costs is ambiguous) ▪ transport of low value per weight goods ▪ transport of goods with constant demand ▪ inflexible ▪ slow ▪ quality depends on reliability ▪ quality depends on access to real-time information

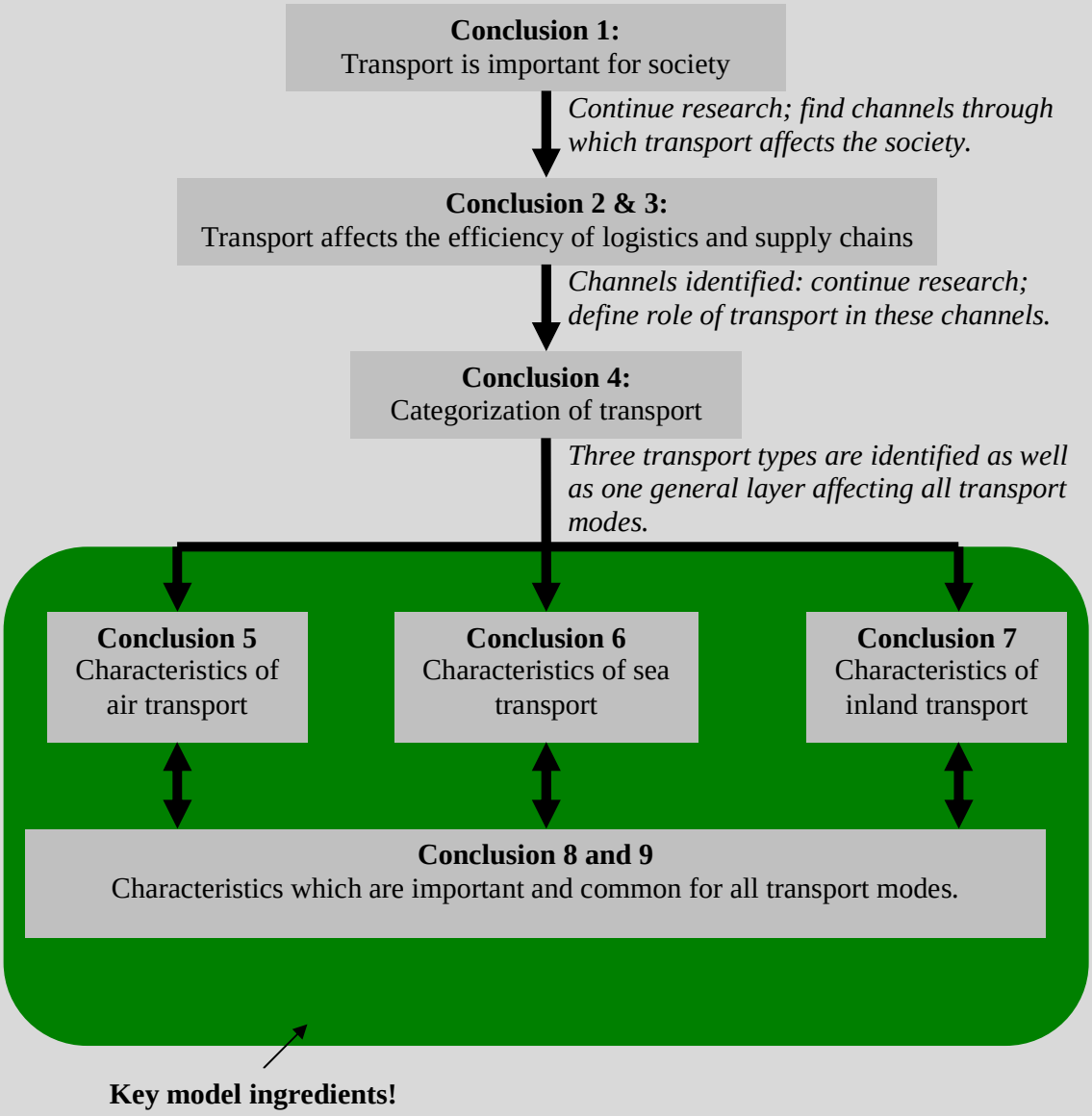
Continued on the next page

Table 5.1 (continued): Summarizing findings on the role of transport

Conclusion 7	*Inland transport has a number of common characteristics, these are:* ▪ *connecting air and maritime transport to the final market* ▪ *dependent on network paths* *Rail transport is characterized by:* ▪ *a high carrying capacity* ▪ *low operational costs, but high maintenance and investment needs* ▪ *high energy efficiency* ▪ *high safety* ▪ *inflexibility* ▪ *reliability* *Road transport is characterized by:* ▪ *a low carrying capacity* ▪ *high operational costs, but low maintenance and investment needs.* ▪ *low energy efficiency* ▪ *low safety* ▪ *flexibility* ▪ *reliability issues* *Inland waterways transport is characterized by:* ▪ *a high carrying capacity* ▪ *low operational costs* ▪ *inflexible* ▪ *high safety* ▪ *reliable*
Conclusion 8	*Quality, timeliness, reliability and flexibility are key aspects of transport and are regarded to be more important than costs. Standardization is desired in regular services and customization is desired in last-minute changes. Moreover country specific factors should be considered when assessing and describing the role of transport systems*.
Conclusion 9	*In addition to the characteristics of each transport mode transport performance depends on:* *(i) Safety* *(ii) Security* *iii) Social responsibility* *´iv) Environmental Performance* *(v) The access to real-time information on transport flows.*

For each transport mode relevant characteristics have been identified. Characteristics of each mode have been identified and cross modal aspects have been described. Figure 5.1 illustrates these findings.

Figure 5.1: Summarizing findings on the role of transport



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