DELIVERABLE 3.1
REVIEW OF TRANSPORT AND ECONOMIC MODELS

Report for:
European Commission
Directorate-General for Research and Innovation
1049 Brussels

27 March 2013
Final version – Public

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1. Introduction

1.1 Project background

The European Union turned a new page with the start of the ‘Europe 2020 Strategy’. By replacing the previous Lisbon Strategy (2000 – 2010), the transition process between the two strategy plans coincides with the EU’s hardest economic crisis since its formation. The objective of getting out of the crisis in the context of fiercer competition on the global market with the new emerging economies has made Europe’s competitiveness and economic performance fundamental issues.

In line with the ‘Europe 2020 Strategy’ flagship initiatives, the White Paper of 2011 summarizes the main objectives of the European transport strategy. The objectives help to establish a system that underpins European economic progress and offers high quality mobility services, while using resources more efficiently. As a consequence, it is essential to clarify the relationship between investments in transport infrastructure on economic growth and competitiveness.

Given the above challenges and strategy setting, it is obvious that stronger role and bigger contribution of the transport sector in the improvement of European economic growth and competitiveness are highly expected. It is essential to clarify the relationship between the transport sector and economic growth and competitiveness. Also, it is important to elaborate a framework, so that transport policy intervention effectively improves the European economic growth and competitiveness.

I-C-EU is a project that clarifies the relationship between transport infrastructure investment and its wider economic impacts, in particular competitiveness and economic growth. This will be made possible by exploring the state-of-the-art of the assessment tools, analysing the current and future situation of European economic and competitiveness, and taking into account the current European strategy to improve its economic performance and competitiveness. This concept allows I-C-EU to provide recommendations to the European Commission on making political interventions in order to enhance competitiveness of Europe in relation to the rest of the world as well as between its member countries and regions.

Departing from this concept, the I-C-EU project has four distinct, measurable and verifiable main objectives:

1. To understand the relationship between transport infrastructure, competitiveness and growth.
2. To contribute to the development of a methodology to quantify the impacts of the different investments in transport infrastructure on competitiveness and economic growth.
3. To include the impacts in the assessment methodologies.
4. To make recommendations on the assessment of EU policy regarding competitiveness and regional growth.

1.2 Goal and structure of this deliverable

One of the tasks within the I-C-EU project relates to the review of transport and economic models, which are used in the assessment of transport infrastructure. For this task, three goals are defined:

1. Determine to which degree the effect of competitiveness and regional growth has been considered in past assessments
2. Analysis of ex-ante results and ex-post results of assessments of infrastructure projects
3. Formulation of improvements and recommendations.

This deliverable concentrates on the first objective, determining to which degree the effect of competitiveness and regional growth has been considered in past assessments.

A review of a selection of strategic long term economic and transport models is made. The review determines to which degree the effects of competitiveness and regional growth are considered by the models applied. The analysis concerns the descriptions of models, which are used for major infrastructure projects and mobility plans in the EU, as well as in member states. These models include at EU level: TransTools, ASTRA, SASI, VACLAV, NEAC, World Container Model and CGEurope. At the level of member states we will look at LMS (NL), RAEM (NL), RHOMOLO (BE), Extended Riga Model (LV), RegFIN (Regional Finish CGE model). The analysis provides an overview of the way a selection of models contribute to the determination of effects of competitiveness and regional growth.

The structure of this deliverable is as follows:

Chapter 2 discusses the concept of competitiveness at a spatial level, such as a region, nation or EU.

Chapter 3 provides an overview of the transport system and accessibility as a key concept for competitiveness.

Chapter 4 tries to link the transport system, transport investments and competitiveness.

Chapter 5 reviews the models. A distinction is made between transport models and economic models. Details are laid down in Annex 1 of this report.

Chapter 6 provides a summary with some conclusions and recommendations about the use of a selection of models in the assessment of effects of transport infrastructure investments on competitiveness and economic growth.

2. Spatial competitiveness

2.1 Introduction

Competitiveness has raised more awareness over the past two decades, due to limitations and challenges posed by globalisation. In Smit (2013) this has been explored for the I-C-EU project. This chapter will focus on the concept of 'spatial competitiveness' in section 2.2. Furthermore, the chapter will discuss the measurement of competitiveness, especially at a spatial level in section 2.3. In section 2.4 some conclusions will be drawn.

As the definition and measurement of competitiveness is not without discussion, we will provide a brief overview of the concept and the way it can be measured. It must be clear that we do not aim at being complete concerning the definition and measurement. Rather, we feel the need to link the concept of spatial competitiveness to the transport system, transport policy and the impacts of transport policy measures. This will be further explored in chapter 3.

2.2 The concept of 'spatial competitiveness'

Competitiveness is a term with many definitions. Wikipedia defines 'competitiveness' as follows: *Competitiveness pertains the ability and performance of a firm, sub-sector or country to sell and supply goods and services in a given market, in relation to the ability and performance of other firms, sub-sectors or countries in the same market* (Wikipedia, 2012).

An interesting aspect is that the definition of Wikipedia contains a spatial element by distinguishing national competitiveness from competitiveness of firms and sub-sectors. Concerning the national competitiveness, the World Economic Forum provides another definition: *Competitiveness is the set of institutions, policies, and factors that determine the level of productivity of a country* (WEF, 2012a).
As can be seen, the WEF definition has a focus upon countries. The spatial element of competitiveness is mentioned in the context of national competitiveness. From a geographical viewpoint however, any scale can be applied, whether it concerns competitiveness of cities, regions, provinces, countries or even continents. There is not a need to constrain the spatial element to a certain entity such as a nation. Although the definitions above focus upon nations, the definition can be easily transferred to any other geographical level.

Competitiveness between nations or regions is not without criticism. Krugman (1994) argues that competitiveness is a meaningless word when applied to national economies (and thus local or regional economies). Krugman states that defining competitiveness for a nation is more problematic than defining that of a corporation. Corporations, who perform badly, will go out of business. But countries do not go out of business whether they are happy or unhappy about their economic performance. Measuring competitiveness for example by looking at the trade balance may give wrong impressions, as a trade surplus, which often is seen as positive, may be a sign of national weakness instead of strength.

Concerning the national competitiveness Krugman sees three dangers: wasting government funds to enhance competitiveness, protectionism and bad policy[1].

Blunck (2006) defines competitiveness for a nation as *the ability of the nation's citizen to achieve a high and rising standard of living. In most nations, the standard of living is determined by the productivity with which the nation's resources are deployed, the output of the economy per unit of labor and/or capital employed*. Thus, continuous improvements in productivity will lead to a higher living standard. According Blunck, competitiveness at national level can be measured by looking at level and growth of living standard, the ability of the nation's firms to increase penetration of world markets through exports or foreign direct investments. In line with Krugman, Blunck states that it should be avoided to look at the trade balance. Blunck concludes that '*not all nations have to be 'competitive' by any single definition. Most nations are not 'competitive' by any definition'*.

In 2012 Ernst & Young (2012) published a survey on the European attractiveness. In line with Blunck, they investigate the attractiveness of Europe for foreign direct investments. Also, the survey is based upon the 'perceived' attractiveness of Europe by a panel of international decision makers. Ernst & Young use the term 'attractiveness', but there is a clear link with competitiveness. The report concentrates on just one aspect of competitiveness: foreign direct investments. By using the term attractiveness, Ernst and Young somehow avoid discussion about whether one could use the term competitiveness for a nation.

Although competitiveness has not been addressed thoroughly in this section, one may conclude that defining competitiveness at a national level (or any geographical level) is not a simple task. One could try to provide an approach. Cambridge Econometrics (2003) discerns some elements for macro-economic competitiveness:

- A successful (economic) performance, in terms of raising living standards or real incomes.
- Open market conditions for goods and services by a nation
- Short term competitiveness should not create an imbalance, thus affecting successful performance.

Some limitations have been quoted as well. Competitiveness is judged by the ability to increase living standards and real income, while social and environmental goals are not taken into account. Also, competitiveness is defined in terms of outcome instead of the factors that determine competitiveness.

Concerning national competitiveness Dunn (1994) makes a remark, that *criticising measurement concepts does not imply that the subject of examination itself is meaningless. What methodological and empirical difficulties do call for is the development of better measurement concepts of competitiveness*. Measurement of competitiveness by looking at different factors is another way of trying to get grip on the concept. The next section will look at the measurement of competitiveness at different geographical levels.

1 The article of Krugman led to a vivid debate on competitiveness, see for example Thurow (1994) and Prestowitz (1994)

2.3 Measurement of spatial competitiveness

Thompson (2003) shows in an exploratory article that, despite the debates, worldwide competitiveness is chartered in different countries annually by different indices. However, what these indices measure is uncertain as the concept of competitiveness has no clear or agreed definition. Regarding the factors that contribute to national (and thus regional) competitiveness even less consensus is available. This is also the case for the national competitiveness programs mentioned earlier.

Concerning the factors that contribute to competitiveness, Cambridge Econometrics (2003) performed a study on the influencing factors of regional competitiveness. The study concludes that *the causes of competitiveness are usually attributed to the effects of an aggregate of factors rather than the impact of any individual factor*. Isolating effects is therefore limited. The study looked in more detail at GDP per capita, decomposed into productivity, hours worked per employee, employment rate and dependency rate. Only productivity seemed to be important when growth of GDP per capita is analysed. Indicators that could explain productivity in a region are catching up effects, R&D intensity, specialisation in high-tech activities, spillover effects and the level of workforce education. *Infrastructure effects and investments showed little or no correlation with productivity levels*. This last point suggests that infrastructure is necessary but not sufficient to explain (regional) success.

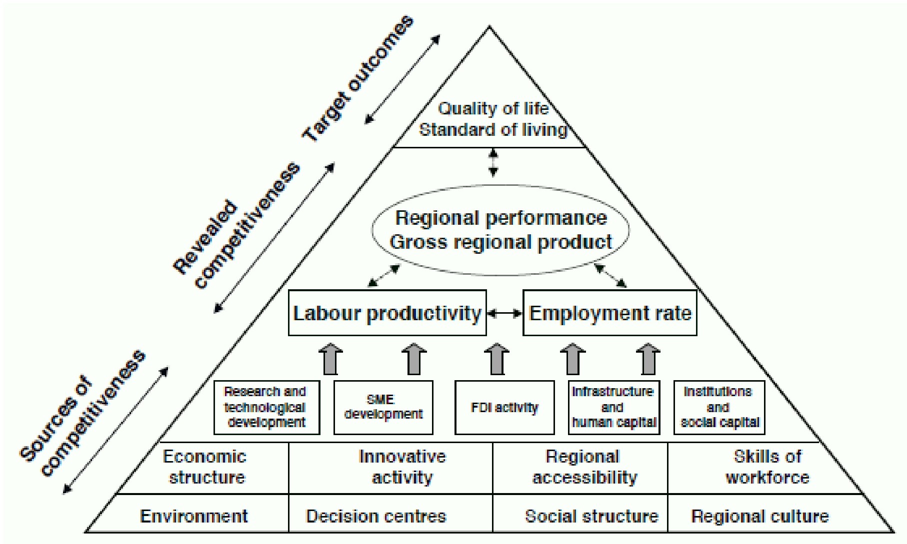
Lengyell (2004) constructed a 'Pyramid Model' of competitiveness, which was enhanced by Gardiner et al (2004). Lengyell distinguishes direct and indirect components concerning factors that influence regional competitiveness. Economic output, profitability, labour productivity and employment rates are important factors. But also success determinants with an indirect impact need to be taken into account such as social, economic, cultural and environmental processes.

With regard to the objective of regional development programming and the various characteristics and factors influencing competitiveness, Lengyell distinguishes three levels:

- *Basic categories* which measure competitiveness, including income, labour productivity, employment and openness.
- *Development factors* which concern factors that have an immediate impact upon the basis categories.
- *Success determinants*, which comprise social and environmental conditions. These have an indirect impact on the basic categories and development factors.

Lengyell places the characteristics that determine competitiveness on a chart, which form a pyramid. Figure 2.1 provides an overview of this conceptual model.

Concerning the development factors, Lengyell mentions factors that together provide an indication for the regional competitiveness. These indicators comprise research and technological development (RTD), small and medium sized enterprises (SME), foreign direct investment (FDI), infrastructure and human capital, and institutions and social capital. Infrastructure is regarded as to serve competitiveness rather than improve competitiveness, by catering the needs of local sectors and clusters. This seems to be in line with the conclusion of Cambridge Econometrics (2004) on infrastructure.



Source: Gardiner (2004)

Figure 2-1: Pyramid model for regional competitiveness

Concerning the success determinants, Lengyell distinguishes the following:

- Economic structure
- Innovative activity
- Regional accessibility
- Skills in workforce
- Social structure
- Decision centres
- Environment
- Regional identity.

Accessibility is listed as factors that contribute to the (regional) competitiveness. The accessibility, transport networks and geographical location of successful regions seem to be more advantageous than that of other regions. In section 3.3, the concept of accessibility will be further explored.

As an example, the National Competitiveness Council in Ireland uses a Pyramid-Model to address the factors that affect the national competitiveness. It distinguishes policy inputs and essential conditions. The policy inputs are related to the business environment, the physical infrastructure and the knowledge infrastructure. The essential conditions include business performance, productivity, prices and costs, and labour supply. All together this should lead to a sustainable growth. The factors are benchmarked against 21 countries such as Singapore, US, Switzerland, Netherlands, Euro area 16, France and Denmark.

In the NCC report, the physical infrastructure is regarded as an important factor for competitiveness: *Infrastructure quality impacts upon many aspects of a firm's ability to do business – it determines the ease with which goods can be moved and the efficiency of delivering services remotely. The quality of a country's infrastructure also affects the mobility of labour and quality of life. Finally, the stock and quality of infrastructure can affect the attractiveness of the country in the eyes of investors and potential high skilled migrants* (NCC, 2012).

Not only at a national level, but also at EU level, competitiveness has the attention of policy makers. The EU has devised different strategies to make its economy more competitive. The current competitiveness strategy is laid down in the Europe 2020 strategy. The overall goal is to encourage national and regional policies to encourage growth and jobs over the next decade (EC, 2010).

WEF publishes every two years a report on the competitiveness of the EU (WEF, 2012b). The Europe 2020 strategy and its flagships form the starting point for the report. The flagships comprise items such as Digital Agenda, Innovative Europe and Education and training. The competitiveness report provides scores per country, for the EU27 and for US, Japan, Canada and the BRIC countries for each of the flagships. However, using the EU 2020 strategy as a starting point leads to the consequence that transport infrastructure does not have a focus in this report. In line with other studies, WEF defines national competitiveness as a set of factors, policies and institutions that determine the level of productivity of a country.

Concerning competitiveness at the EU level, Schade (2006) completed an analysis into the contribution of transport policies to the competitiveness of the EU economy. The analysis tried to tackle the question how transport contributes to the competitiveness of the EU. It looked at operational costs of transport, congestion, trends, infrastructure and productivity development of transport. Despite all the work, the question on *how transport improves competitiveness could not be provided in a quantitative manner*. Schade (2006) addresses the question in a qualitative way.

2.4 Conclusions

The previous two sections discuss the concept of ‘spatial competitiveness’. This forms an extension of the work by Smit (2013) and will be used to make a link to the transport system in the next chapter. From section 2.1 it can be concluded that the definition is under discussion. As this report is concerned with the way transport and economic models can contribute to the quantification of competitiveness, section 2.2 is of importance for this report. In the literature some evidence has been found that the Pyramid Model by Lengyell/Gardiner is used in different studies to measure competitiveness. At a certain geographical scale, this conceptual model shows that regional performance can be measured by looking at regional gross product, labour productivity and employment rate. These are compared to or benchmarked with other regions or nations.

Regional performance is dependent upon different factors, such as infrastructure and human capital, research and technological development, or foreign direct investments. These can be further extended to factors such as economic structure, social structure and regional accessibility. The measurement of competitiveness is dependent upon more factors than just accessibility. For the moment we will not further elaborate on the different factors that can be included to explore competitiveness, as it seems that frankly every regional indicator could provide some input to competitiveness.

Important to note is that Lengyel and Gardiner both regard labour productivity and employment rate as important indicators for measuring spatial competitiveness. These are consolidated into Gross Regional Product. We will consider these indicators and try to link them to the transport system. The next chapter will explore the relation between the transport system, transport policy and spatial competitiveness.

3. The transport system and accessibility

3.1 Introduction

Large-scale investments in transport infrastructure may have an effect upon competitiveness and growth of an urban area, a region or a nation. To underpin the investments, both transport models and economic models have been used in the past. Transport models are able to capture the direct effects in terms of changes in travel costs or changes in volume of passengers and goods. Economic models are able to also incorporate the indirect effects, such as employment or economic growth.

However, to what extent are models precisely able to provide input for studies that incorporate changes in the transport system, as well as impacts from the transport system upon its macro-environment? This question is focus of this report. In order to answer this question, a conceptual model of the transport system and its macro-environment will be provided. This should help to clarify the relations between investments in the transport system and the macro environment. Section 3.2 provides this conceptual model of the transport system.

Having an overview of the transport system, leads us to the question how changes in the transport system affect the macro-environment and more specifically competitiveness, employment and economic growth. This will be the core of section 3.3, in which a relation between the transport system, competitiveness and economic growth is made, within the context of usage in a transport and/or macro-economic model.

3.2 A conceptual model of the transport system

Every introductory textbook on transport economics states that the essence of transport is derived demand. In order to satisfy needs or activities, people and goods travel or move between geographical different locations. As Button (2003:4) puts it: ‘Possibly the most important characteristic of transport is that it is not really demanded in its own right. (…) The derived nature of demand for transport is often forgotten in everyday debate but it underlies all economics of transport’. This essence implies that the drivers for transport lie outside the transport system, in the macro-environment.

Therefore, the developments in the transport system cannot be understood without a good knowledge of the development of the drivers in the macro-environment. The drivers include different aspects such as: technical and scientific development, economic growth and demographic and social trends. This section describes the transport system and its macro-environment.

The transport system consists of different elements that can be assigned to transport demand and transport supply. The demand side of the transport system comprises trip patterns, transport patterns and traffic patterns. The supply side comprises transport means and services, and infrastructure and its attributes. A conceptual framework for the transport system is used, which is based upon the conceptual models by Van de Riet & Egeter (1998) and Kiel et al (2012). Van de Riet & Egeter regard travel and transport as a set of markets with a dynamic interaction between demand and supply. In this interaction choices are made on both the demand and supply side of the markets. Within the transport system therefore, three different markets are distinguished, the trip market, the transport market and the traffic market (see figure 3.1).

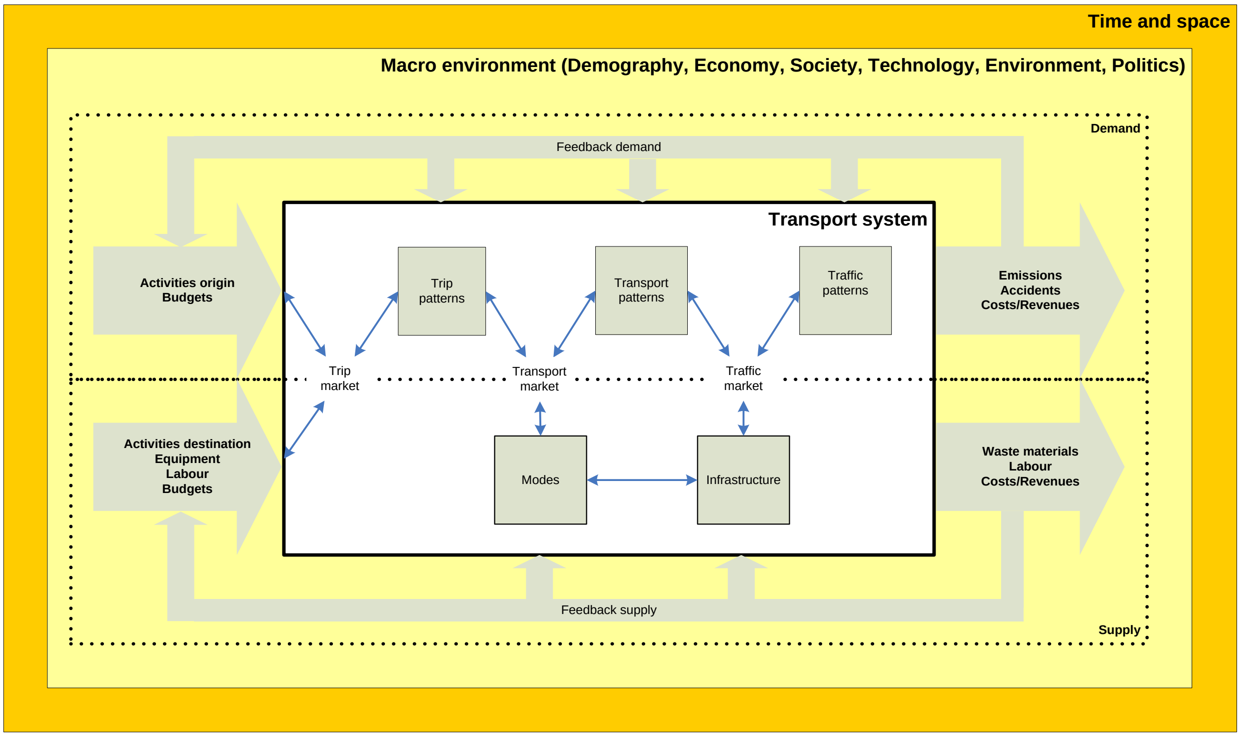


Figure 3-1: Conceptual framework of the transport system

The *trip market* consists of activities to be performed, whose location and time are as yet unknown. The supply side consists of the spatial and temporal distribution of the locations where the activities could be performed and the trips associated with them, as well as how this distribution is perceived. The output of this market consists of a set of trip patterns, an allocation of the activities to locations and times. The trip patterns become the demand side of the transport market.

The *transport market* consists of trip patterns, which demand for vehicles to transport people and freight. The supply side consists of vehicles and services to make the trips. The output of this market is an allocation of trips to vehicles and services, the transport patterns. The transport patterns form the demand side for the traffic market.

The *traffic market* comprises the transport patterns, which demand for infrastructure to accommodate the vehicles and services. The supply side consists of infrastructure and all its attributes such as traffic control systems or timetables. The output is a traffic pattern (see OECD, 2002).

In each of the markets, the balance between demand and supply is affected by changes in volume of freight and passengers, distance, time, costs and perceptions. Except for perception, the variables can be quantified. Perception consists of a qualitative view on different elements in the transport system such as comfort in public transport. For example, if a measure is taken to reduce congestion, this leads to a reduction in travel time and travel cost. Also, the perception using car improves. The key variables provide guidance in thinking about the implications for the transport system and transport policy.

To keep the transport system running, different input is needed. These inputs can be distinguished into input for the demand side and input for the supply side. Concerning the demand side, the input consists of volume of passengers, freight and information, and budgets of households and businesses. On the supply side the input consists of energy for different modes, budgets of governments, operators and providers, manpower for governments, operators and providers (inflow of personnel), equipment such as vehicles, information, education and construction material to build infrastructure.

The transport system also produces output. On the demand side one needs to think of different output such as volumes of freight and passengers, travelled time, travelled distances, costs (variable, fixed, energy, external) and revenues, emissions and noise, and victims of accidents. On the supply side output can be found like costs and revenues (for example from pricing), outflow of manpower (think of retirement), waste and damages. Figure 3.1 provides an overview of the input and output of the transport system.

The input and output of the transport system consists of key variables with a relation to the macro-environment. Knowledge of the key variables helps to understand which levers exist that may influence the transport system. Also, it helps to understand what output is produced by the system. Both input and output of the transport system are affected by external drivers, as well as by policy measures. Especially, the output has significant impacts on society, economy and environment.

The transport system is constantly affected by external drivers. As Goodwin (2002) states: to understand the developments in the transport system it is important to identify the fundamental drivers that affect the system. The drivers are beyond the control or influence of the organisations in the transport system. The drivers are not directly subject to transport policy control. On the other hand it is important to be aware of the drivers for carrying out different activities, such as the development of transport policy measures. In other words, it is important to analyse the macro-environment of the transport system.

The drivers of the transport system can be categorised as Demography, Economy, Society, Technology Environment and Politics (DESTEP). This is in line with management and organisation theory, where the analysis of the macro-environment of an organisation follows similar categories (Paul, 2010)[2]. It helps organisations to think about their environment and the opportunities and threats that lie within it. It incorporates the different perspectives and provides a logical structure for further discussions and proactive decision making. It is as a strategic starting point in thinking about what the drivers mean and how they affect an organisation, or as in our case, the transport system.

[2] Several categories exist like PEST or STEP. The only difference with DESTEP is the combination of drivers. In PEST, demography and society are combined. A different category does not have an impact upon the outcomes in this report.

The drivers in the macro-environment affect the transport system in one way or another. These have different implications for the transport system. Some affect the demand side in the first place, such as changes in Demography. Some will affect the supply side, such as Technology and some affect both. It is important to show where the implication occurs in the transport system, as this eases to make a link between the transport system and its macro-environment.

As an example, it is expected that ageing of the European population (Demography) will have an implication for the demand side of the transport system. Elderly people will perform different activities, such as more leisure and less work. This will have a further implication for the transport and traffic patterns. Also, more elderly people imply fewer youngsters. This may have an implication for the use of modes such as public transport to school.

3.3 The concept of accessibility

In chapter 2 we have seen that the measurement of competitiveness can be linked to –regional– accessibility. Accessibility is an essential concept in transport studies. However, as with the concept of ‘competitiveness’, defining ‘accessilibity’ is not without discussion, several definitions exist. As Peter Gould (1969) states it: ‘Accessibility is a slippery notion…one of those common terms that everyone uses until faced with the problem of defining and measuring it!’. This section provides some thoughts about the term ‘accessibility’ and how to measure it in relation to competitiveness.

Litman (2012) provides a comprehensive overview of literature into ‘accessibility’. According Litman, accessibility can be evaluated from many perspectives that need to be taken into account when performing an analysis on accessibility:

> *Accessibility refers to people’s ability to reach goods, services, activities and destinations (opportunities), which is the ultimate goal of most transport activity. Many factors affect accessibility, including mobility (physical movement), the quality and affordability of transport options, transport system connectivity, mobility substitutes, and land use patterns. Accessibility can be evaluated from various perspectives, including a particular group, mode, location or activity. Conventional planning tends to overlook and undervalue some of these factors and perspectives. More comprehensive analysis of accessibility in planning expands the scope of potential solutions to transport problems.*

Litman found different factors that affect accessibility. These comprise transportation demand, mobility, transportation options, user information, integration of the transport system, affordability, mobility substitutes, land use factors, transport network connectivity, roadway design and management, prioritization and inaccessibility. Litman concludes that there is no single indicator to capture accessibility. In fact it depends on the goal of the study how accessibility should be measured.

Geurs & Van Wee (2013) review different concepts of accessibility as well. They define accessibility as:

> *The extent to which land- use and transport systems enable (groups of) individuals to reach activities or destinations by means of a (combination of) transport mode(s) at various times of the day (perspective of persons), and the extent to which land- use and transport systems enable companies, facilities and other activity places to receive people, goods and information at various times of the day (perspective of locations of activities).*

Given the definition, Geurs et al (2013) describe two different perspectives for accessibility. Concerning the perspectives, they distinguish accessibility seen from the origin (what activities can I reach or do I have access to) and accessibility seen from the destination (catchment area in which people or goods are located to reach me within a certain amount of time or costs). Related to the transport system, these perspectives are related to the demand and supply side (see figure 3.1). For both perspectives, different characteristics play a role such as income category, car ownership, type of industry, modes, or geographical scale.

Concerning the indicators of accessibility, Geurs et al (2013) make a distinction between infrastructure-based accessibility measures, location-based accessibility measures, person-based accessibility measures and utility-based accessibility measures. Infrastructure-based measures are related to analysing the transport system itself, such as length of networks, level of congestion or speed. The location-based measures analyse the accessibility of locations at a macro level. The person-based measures relate to the accessibility at an individual level. Utility-based analyse the benefit people derive from access to spatially distributed activities (see de Jong et al, 2005).

Another overview of accessibility measures is provided by Scheurer et al (2007). Scheurer also concludes that there is no agreement about an accessibility index that is most suitable for the assessment of urban and regional land use and transport system. Every measure has its drawbacks and weaknesses. The choice of an accessibility indicator depends upon the objective of the study.

Based upon the reviewed literature, there are a few criteria for the choice of a suitable accessibility measure in relation to spatial competitiveness:

- The measure needs to include a spatial level (location, region, nation)
- The measure needs to include both the supply and demand side of a location
- The measure should include both freight and passenger transport
- The measure should contain the economic value in order to ease the link to economic variables such as GDP
- The measure should be fit for use in forecasts

Based upon these criteria, some accessibility measures can be dropped, such as transport system measures (such as distance, network length). Both location-based measures and utility-based measures seem potentially interesting to link with the concept of competitiveness. The reason for this is that both measures can be used at a spatial, macro level. They also include both the supply and demand side of a location. However, utility-based measures are difficult to express in money terms. They are also difficult to explain to practitioners and therefore less used, despite the increasing academic interest (see de Jong et al, 2005). Therefore, we will use a location-based accessibility measure, expressed in generalised costs.

In the National Policy Strategy for Infrastructure and Spatial Planning (2011), the Dutch Ministry of Transport also proposes an accessibility measure based upon generalised transport costs. The measure can be differentiated into different characteristics such as regions, freight and passenger transport, purposes, commodities or time-of-day. As generalised transport costs are used, it is also possible to include aspects like perception, comfort or reliability. The measure has been further improved since the Policy Strategy was published (see Hoogendoorn-Lanser et al, 2012). The accessibility indicator was improved among other things to provide information for a region as well as for freight and passenger transport.

In Snelder et al (2012) the indicator was presented for freight transport. The accessibility indicator is the weighted average generalised transport costs for all incoming and outgoing flows in a region. It can be used not only for freight transport but also for passenger transport. The indicator is as follows:

$$I_{iv} = \frac{\sum_{g}\sum_{j}\left(T_{jivg} * V_{jivg} + T_{ijvg} * V_{ijvg}\right)}{\sum_{g}\sum_{j}\left(d_{ji}^{XY} * T_{jivg} + d_{ij}^{XY} * T_{ijvg}\right)} \quad \forall i,v$$

With:
V = Generalised transport costs per tonne (euro/tonne)
v = Index for mode
g = Index for commodities
i, j = Index for origin i and destination j zone
T = Weighting factor for volume
d^{XY} = Distance as the crow flies (km)
I_{iv} = Accessibility indicator (Euro / Tonkm)

This accessibility indicator can be extended to passenger transport as well, by using different indices (like replacing commodities by purposes). The accessibility indicator can be expressed in Euro/PassengerKm. Based upon the work of Hoogendoorn-Lanser en Snelder, we propose to use the accessibility indicator that they propose. For passenger transport the indicator has the same structure as for freight transport. The level of detail of the indicator depends upon the level of detail (dimensions) of the transport model used.

Concluding, the concept of accessibility provides different perspectives and different indicators for measurement. Related to the objective of this study, accessibility should be measured at a spatial level, such as a region or nation. In reviewing the transport and economic models (see chapter 5), the measurement of accessibility is taken into account.

4. The relation between transport system and competitiveness

4.1 Introduction

Having provided an overview of the transport system and accessibility, this chapter pays attention to the relation between the transport system and competitiveness. First this chapter will look into the relation between transport investments and the economy (see section 4.2). Section 4.3 addresses a link between the transport system, competitiveness and economic growth.

4.2 Relation between transport investments and economy

Large-scale investments in transport infrastructure have been traditionally evaluated assuming the equivalence between direct and indirect economic effects (Jara-Diaz, 1986), which is only correct under -generally non-guaranteed- perfect competition assumptions. Despite this common practice there is still no consensus amongst economists as to how the benefits and costs of large infrastructure projects should be determined. The discussions regarding the desirability of, for instance the Betuwe railway line, illustrates this. The focus has been, in particular, on the magnitude of 'indirect' and 'strategic' effects, that is effects on parties other than the direct users of the infrastructure (indirect effects) and those factors that have a favourable effect on the long-term development of the (regional) economy, such as effects relating to firm location (strategic effects).

The link between the transport sector and the rest of the economy has been recently discussed extensively in the economics literature for a number of reasons. Two are worth mentioning when the welfare effects of transport infrastructure improvements at an aggregate level are compared to those arising in the transport sector itself.

- On one hand, an intense debate at an empirical level was initiated by Aschauer (1989) in a study on the elasticity of aggregate output with respect to public capital. A key role is given in this literature to "core-infrastructure", of which roads, ports and railways are major components. Once elasticities are used to calculate public capital social rates of return, an excess with respect to private capital returns is found and usually explained as reflecting aggregate general equilibrium effects not accounted for in traditional cost-benefit analysis (CBA).
- On the other hand, and coincidentally at a similar time, developments towards a more formal spatial economic theory starting with Krugman (1991). Krugman gave transport costs a central role in determining the configuration of the economy through the influence on workers and firm's location decisions, trade flows and regional incomes. Some recent papers have used these theoretical developments, usually dubbed as new economic geography (NEG), to construct and calibrate models addressing the economy-wide benefits arising from improvements in transport infrastructure, to

compare them later with benefit estimations arising from a conventional CBA exercise. Venables & Gasiorek (1999) and Brocker (1998) are representative cases, finding quite different orders of magnitude in these comparisons (Hvidt & Jensen, 2004).

The consequences of transport infrastructure improvements have been analysed with spatial general equilibrium models and in particular with two rather conventional types of NEG models. The interesting implication for transportation literature arising from this kind of models is to give transport costs a more sophisticated role in the economy, as compared to the traditional competition protection role already present in spatial price equilibrium models of the Enke-Samuelson tradition. Those models emphasized production specialization and were widely used in earlier literature of the topic addressed here and in transportation networks modelling in general (Jara-Diaz and Triez, 1982; Lakshmanan et. al, 2001, Takayama and Judge, 1971).

In spatial general equilibrium models (like RAEM for the Netherlands, see chapter 5) besides transport, also the labour market and the housing market are included. Production, consumption (households) and transport are modelled to assess consequences of infrastructure. Models can be different depending on the geographical scope (number of regions) and the number of sectors that are included. These models usually show effects on the prices of goods and income levels. In chapter 5 the economic models, including the spatial general equilibrium models, are reviewed. The next section will pay attention as how to link investments in the transport system with economic growth and competitiveness.

4.3 Transport system related to competitiveness and economic growth

Turning to figure 3.1, it can be seen that the transport system is depended upon and embedded in a macro-environment, containing demography, economy, society, technology, environment and politics. The transport system is both affected by these drivers and has an impact upon (some of) these drivers.

Investments in the transport system are made on the supply side, in both modes and infrastructure. These investments may concern different elements, such as renewal of a vehicle fleet, improvement of logistic services or new railway lines. All these investments are supposed to have an impact in the first place upon the trip, transport and traffic markets. Through changes in the key variables of these markets, a new equilibrium will be established. The key variables of the transport system concern travel distance, travel time, travel costs, volume of passengers and volume of freight. Changes in one of these key variables lead to a change in output of the transport system.

As an example, one may consider a new toll road between two urban areas. The introduction of the connection leads to a difference in travel time and travel costs in the first place. Travel time will diminish, while the improvement of the rail service will probably lead to higher travel costs. This will in turn also lead to an increase in passenger volume. Thus, within the transport system, a change might be expected in the equilibriums of the trip market, the transport market and the traffic market. Looking at the demand side of the transport system, it might be expected that emissions will increase, accidents will diminish and the general costs will decrease. On the supply side of the transport system changes occur in revenues from the toll road.

As mentioned in the previous section, the consequences of transport infrastructure investments have been analysed with models, such as the spatial general equilibrium models as well as land-use models. These models contain different modules for items such as labour market, production and consumption, or income levels. It will be clear that this is not part of the transport system, but rather belong to the macro-environment of the transport system. This has some consequences for the review of transport models, as these models usually have a focus upon the transport system. They address for example the different markets of the transport system.

As we have seen in the previous chapter, accessibility can be seen as one of the key outputs of the transport system. So, the transport models should at least be able to provide accessibility as an output, or results with which accessibility can be calculated. However, this is not sufficient output. Accessibility needs to be linked to competitiveness. Looking at the pyramid model by Gardiner and Lengyell (see section 2.3), the authors used the term 'accessibility' without defining it. The impact of accessibility upon competitiveness shows a gap. Both accessibility and competitiveness do not have *one* well defined definition. Concerning accessibility, there are different perspectives, geographical scales, users and indicators. This is also the case for competitiveness. Concluding, there are different ways to link accessibility to competitiveness. There is not one path that can be followed to connect accessibility to competitiveness.

The economic models (spatial general equilibrium models or LUTI models) are able to address the issue to connect transport investments to economic growth. There exists a large amount of literature with a consensus on the mechanisms on how changes in the transport infrastructure affect economic and productivity growth. A reduction of transport costs may cause a change in costs for the private sector. Furthermore, it may increase specialisation and labour division. Also, it may lead to changes in factor markets and firm location decisions (see Schade, 2006). The review of economic models will reveal to what extent these models are able to connect the changes in the transport system to changes in economic growth.

4.4 Conclusions and recommendations

This chapter provides a relation between the output of the transport system and competitiveness. Changes in the transport system lead to changes in distance, time, costs and perception. All together these are consolidated into a change in generalised costs. A change in generalised costs has an impact upon the economy and thus elements in the economy such as competitiveness. These elements concern employment and economic growth in term of gross regional product.

To quantify the effects of a change in the transport system, transport models are applied. For the quantification of larger economic effects, such as employment and gross regional product, economic models are used. In order to use these models, they should be able to take changes in the transport system into account. The next chapter will review both transport and economic models and their capability to assess the impact of changes in infrastructure upon economic growth and employment.

5. Review of transport and economic models

5.1 Introduction

This chapter provides a review of a selection of transport and economic models, in order to assess their ability to contribute to the quantification of competitiveness, in terms of employment and gross regional product.

First, some transport models are being reviewed in the light of accessibility and competitiveness in section 5.2. These models include BASGOED, Extended Riga Model (ERM), Great Britain Freight Model (GBFM), Landelijk Modelsysteem (LMS), National Transport Model Denmark (NTMD), TransTools, Vaclav and World Container Model.

In section 5.3 some macro-economic models are being reviewed. This comprises the models ASTRA, CGEurope, RAEM, RegFin, RHOMOLO and SASI.

5.2 Transport models

The transport models reviewed in this report comprise Landelijk Modelsysteem (LMS), BASGOED, Extended Riga Model (ERM), Great Britain Freight Model (GBFM), National Transport Model Denmark (NTMD), VACLAV, TransTools and World Container Model (WCM). These models capture passenger of freight transport. ERM and TransTools capture both passenger and freight transport.

Annex 1 provides an overview of a selection of transport models with their characteristics and their contribution to the assessment of wider economic effects such as employment and gross regional product. A review is made of the input, the sub-models and the output of the transport models.

As can be seen the transport models differ in scope and dimensions. Some are international, while others have a national or regional level. Also the application level differs, most models are built for strategic purposes, while a few are built for tactical purposes. The dimensions show differences concerning modes, purpose, commodity and time-of-the-day.

The models all have their strengths and weaknesses in relation to the assessment of the impact of transport infrastructure investments upon accessibility and competitiveness. All transport models produce output that can be used to derive the accessibility indicator. However, all transport models reviewed, except ERM and TransTools are partial, in the sense that the models regard either passenger transport demand or freight transport demand. This poses limitations upon the direct usability of the models in relation to competitiveness. When one would need an overview of the impacts of transport infrastructure investments, both types of demand should be taken into account.

Also, the number of modes included in the models may lead to partial results. For example, those models that only take road and public transport into account, give partial results in relation to the accessibility indicator. As the impact upon accessibility should be assessed for the whole transport system, this may lead to deviations if not all modes are included. Some characteristics, strengths and weaknesses of the reviewed models are provided below.

BASGOED

BASGOED is the national freight transport model for the Netherlands. The model includes all relevant freight transport modes, except for air and pipelines. The relevance of these modes is less when expressed in volume (tonnes) transported. For freight transport, BASGOED provides the necessary output. However, as with the LMS, the results are partial. BASGOED is not able to produce results for passenger transport. A combination with the LMS and with TIGRIS XL would solve this problem.

Concluding, BASGOED provides a good insight in the accessibility of freight transport, when taking the volumes into account. BASGOED does not have a direct relation with competitiveness. For this purpose a link with TIGRIS XL or RAEM is needed.

Extended Riga Model (ERM)

The ERM both comprises passenger and freight transport. For passenger transport the model includes car driver, train and public transport by bus, tram and trolleybus. Slow mode is not included. For freight transport the ERM includes road and rail transport. Sea transport is only included internally to take mode shift into account. The ERM is an urban model, which is able to assess transport policy measures at a regional level. A weak point is the data availability and its sub-models, which are based upon elasticities and not on estimations from surveys.

Accessibility can be calculated from the modelling results. However, there is no link with competitiveness. The model does not possess of an interface with an economic model, despite the fact that the model is used in cost-benefit analysis. Due to a lack of sufficient data, no feedback loops between transport and economy were modelled.

Great Britain Freight Model (GBFM)

The GBFM is a general purpose freight transport model, which captures road, rail and sea transport. The model does not have a direct relation with passenger transport, nor with an economic model. For this purpose a link can be made with the DfT's national transport model. The GBFM does include commodities. Also, the model has a network and assignment procedures.

The results from the model allow the estimation of the accessibility of regions in Great-Britain. Accessibility of region can be compared when looking at freight transport. For an overview of the general accessibility of a region, information about passenger transport should be included from the national transport model. The model is not capable of predicting changes in GDP and employment. There is no relation with competitiveness.

Landelijk Modelsysteem (LMS)
The LMS is a national passenger transport model for the Netherlands. Freight transport is only taken into account for road freight. The model is capable to calculate the accessibility for different regions. This is done on a detailed level, taking different purposes, modes and periods of the day into account. Although the model covers all relevant passenger modes internally, the model does not supply all results. The model only produces output for car driver and rail transport. As only road freight transport is taken into account, this also poses a drawback on the calculation of the general accessibility of a region. The LMS has an interface with TIGRIS XL, which makes it possible to assess changes in GDP and employment, due to changes in accessibility.

Concluding, the LMS is able to calculate the accessibility of a region (given the formulae in chapter 4), but the result is only partial. The total accessibility of a region for all modes cannot be calculated directly from the results from the LMS. Only if other passenger modes are included in the output, as well as if freight transport is fully included, the general accessibility of a region can be calculated. It is possible to derive intermediate results by mode from the LMS, but this requires expert knowledge of the system. The model does not have a direct relation with competitiveness. Other models (including an interface) are needed for this purpose.

National Transport Model of Denmark (NTMD)
The NTMD is a strategic and tactical national passenger transport model for Denmark. The model captures all passenger modes. Freight transport is not modelled by the NTMD. The results of the model allow the calculation of accessibility of a region. As the model is national, accessibility can only be compared at the level of regions within Denmark.

A drawback is that the accessibility would only include passenger transport. To include the accessibility of freight transport for regions, additional information is needed. The model does not predict changes in GDP or employment. Instead, employment is input for the model. A direct relation with competitiveness does not exist. For this purpose a macro-economic model is needed.

Trans-Tools
Trans-Tools is a European wide strategic transport model. It comprises a passenger and freight transport model. Furthermore, the model includes an economic model. Trans-Tools includes all relevant modes, though it does not include the slow modes. The model is able to calculate the change in the accessibility of regions due to policy measures or infrastructure investments. Although slow modes are not included, it is assumed that the accessibility will be fairly accurate as slow modes usually concerns intrazonal traffic. Through the economic model, Trans-Tools is also able to capture changes in GDP and employment. These indicators have a relation with competitiveness. Trans-Tools seems to be able to show impacts on international competitiveness due to investments in infrastructure.

VACLAV
Vaclav is a passenger transport model at a European level, with approximately 1350 zones. The model includes relevant modes, such as road, rail, coach and air. Slow modes are not included. It is assumed that these mainly concern intrazonal transport. VACLAV produces partial results, as it does not include all freight transport. Road freight transport does play a role, but this mode is exogenous for Vaclav. The NEAC model delivers input for road freight transport. Though the model can be used stand alone, it is

often used in combination with ASTRA (and NEAC). The model produces output that allows one to calculate the accessibility of a region. However, the results are partial, only passenger transport is taken into account.

Vaclav does not predict changes in employment and GDP and thus has no direct relation with changes in competitiveness. However, its results can be used as input for the ASTRA model.

World Container Model

A strategic explanatory model for the movement of container volumes on a global scale has been developed. The objective of the model is the ability to assess shifts in route and port use as a result of changes in, among other things, port characteristics, network characteristics and local or global price policies.

The model is able to predict the yearly container flows to and from all countries using 437 major and minor container ports around the world, and taking into account more than 800 realistic maritime container line services. Import, export and transshipment flows of containers at ports are distinguished by the model.

The model was calibrated against observed 2006 data.

5.3 Economic models

The economic models reviewed in this report comprise RAEM, CGEurope, RHOMOLO, ASTRA SASI and RegFin. The models all have their own characteristics, strengths and weaknesses.

ASTRA

ASTRA is a system dynamic model of Europe. The system covers macro-economics, regional economics, transport and environment. The system is able to simulate different types of transport policy. Both passenger and freight transport demand is included in the model. All modes are included for both types of demand. The model distinguishes purposes and commodities at an aggregated level. A drawback of the system is, that it does not possess of a network. Travel time, distance and costs serve partly as input. These inputs are delivered through an interface with other models such as VACLAV.

ASTRA is able to calculate changes in GDP and employment. The input and output also allow the calculation of the accessibility of regions. However, for details concerning accessibility, an interface with network models is needed. ASTRA has a link with impacts upon competitiveness, as the system has the capability to assess changes in GDP and employment.

CGEurope

CGEurope is a spatial general equilibrium model for a closed system of regions covering the whole world. All of regions are treated separately and are linked through endogenous trade. The model is comparative-static, which means that for each scenario analysis two equilibria are compared. The model covers the whole transport system and is able to predict the economic impact of changes in the transport infrastructure (investments).

CGEurope is able to assess changes in GDP and employment. The input allows the calculation of accessibility, but CGEurope in itself is not able to calculate the accessibility. The system however is able to contribute to changes in competitiveness, measured in changes in GDP and employment.

RAEM

RAEM is a dynamic, national economic model for the Netherlands, covering different economic aspects. The model possesses of different modules for the assessment of changes in household indicators such as income and consumption budget, labour, passenger and freight transport, trade, and sectors such as industry and government. RAEM includes both passenger and freight transport demand for different purposes or commodities. Modes are not explicitly taken into account. One could state that RAEM implicitly takes all modes into consideration. The model does not include a network. Assignment of flows is not possible. The time and costs of trips partly need to be derived from other (network) models.

With the input and output of RAEM it is possible to calculate the accessibility of regions on an aggregate level. Changes in infrastructure can be dealt with at an aggregated level, as a network model and an assignment model are not included. RAEM is able to assess the changes in GDP and employment at a higher aggregation level. This gives RAEM a link to assessing changes in competitiveness.

RegFin

RegFin is a static CGE model that is constructed by using a non-arithmetic modelling subprogram MPSGE inside the GAMS modelling environment. Recursive dynamics have been introduced in the model. As a CGE model, RegFin is different from the other CGEs mentioned in this section, as it is not specifically developed for the purpose of transport policy studies. The model is for generic purposes, despite the fact that it has been used on some occasions in transport studies.

The model is not able to calculate an accessibility indicator. As the model is not yet fully capable of capturing the impacts of transport investments, the question is whether it could contribute to questions related to transport infrastructure investments and competitiveness. The model might be adapted to include transport infrastructure investments to its full extent (including generalised costs and passenger and freight flows). If this is made possible, the model will be able to calculate changes in GDP and employment.

RHOMOLO

RHOMOLO is a model which was developed, in the same line as RAEM, for the analysis of European policies on the regional level. Each European country in Rhomolo consists of several regions, connected by goods and material flows, investment flows and migration. Rhomolo contains a detailed representation of each region's economy, modelling various households, types of production sectors and multiple government levels. In comparison with RAEM, the regions that are modelled are larger (NUTS-2), which affects the type of modelling used for the labour market. No commuting is modelled between regions, as this does not make sense considering the size of the region.

RHOMOLO was specifically developed for the analysis of the European Cohesion Policies (ECP) and integrated a lot of aspects from both endogenous growth theory and New Economic Geography. It is more detailed on the sectoral level than RAEM and contains a better dynamic module. However, it lacks (like RAEM) an integrated network model. The type of indicators one can get from RHOMOLO are similar to RAEM.

SASI

SASI is a recursive model of socio-economic development in Europe. SASI belongs to the LUTI type of models. SASI covers both passenger and freight transport. The model consists of a (part of) the TEN network. The system is able to calculate the accessibility of regions itself, though the output also allows the calculation of different accessibility measures. SASI uses physical networks to calculate indicators like travel time and travel costs, which enable the calculation of accessibility of regions. Changes in the transport system, such as investments in the transport infrastructure, have an impact upon economic indicators such as GDP and employment. Wegener (2008) states that impacts on regional competitiveness will be taken into account, through indicators such as subsidies, taxes and labour costs.

Related to our discussion about competitiveness, Wegener regards competitiveness as a set of indicators that contribute to competitiveness, rather than having one indicator. Concluding, the system seems rather complete, though on an aggregate level. Details such as congestion, purposes or time-of-day are not included in the model.

6. Summary, conclusions and recommendations

6.1 Summary and conclusions

In this report we have been reviewing transport and economic models. Special attention was given to the capability of these models to assess the impacts of transport investments upon competitiveness. Before reviewing the models, we discussed competitiveness and accessibility, as these seem to be two aspects in this project that have a central role.

Concerning competitiveness, we came to the conclusion that providing a definition, which is in line with the transport and economic models, is difficult. Different definitions exist and these are not without debate. Especially, when related to a spatial context, such as a region or nation, competitiveness has received a lot of attention and debate. The solution that we chose in this report was not to define competitiveness, but rather to look for indicators that contribute to a change in competitiveness. The pyramid model by Lengyel/Gardiner provides a visual overview of the way one could address competitiveness through indicators. Changes in employment and GDP play an important role and these two indicators were chosen for the review of the models.

Lengyel/Gardiner state that changes in both employment and GDP are driven by different factors. Among these drivers they mention accessibility. Changes in the accessibility have an impact upon changes in employment and GDP. Two remarks have to be made in this context. First, both authors do not describe how changes in accessibility change employment and GDP. Second, they do not define accessibility, which is also crucial.

Accessibility is the next step in this report. There are different definitions available for the calculation of accessibility. Like with competitiveness we concluded that it is difficult to provide a good definition. Instead we defined some criteria for a good accessibility indicator. Accessibility should be measured at a spatial level, it should include both the supply and demand side of a region, it should include passenger and freight transport in order to be complete, it should contain some economic value in order to ease the link with economic variables and it should be fit for use in forecasts. We chose a general accessibility indicator that covers the criteria. This indicator is described in Snelder (2012). A slightly adapted version was proposed in this report.

Having described both competitiveness and accessibility, we paid attention to the link between the two. We came to the conclusion that there is a link from accessibility to competitiveness. However, whether the link is strong or weak (is there a large or small impact) cannot be retrieved from the literature. The literature acknowledges the link, but revealed evidence is not available. Instead modelling exercises do exist. Our conclusion is that the link between transport investments and their impact upon competitiveness does exist, but it is a weak link as revealed evidence is hard to find.

Based upon the discussion on competitiveness and accessibility, a review of transport models has been made. The following conclusions can be drawn:

- To assess competitiveness for regions, the information needed has to be complete. However, most transport models provide partial information. On one hand either passenger or freight transport demand is included, on the other hand modes are missing.
- From the results of the transport models an accessibility indicator can be derived. However, due the fact that most models provide partial results, the overall accessibility to a region is difficult to assess.
- In order to assess the overall accessibility, different models need extra information, either from a passenger model or a freight model. If possible, an interface between the two is needed in other to calculate the overall accessibility of a region. In some cases such as LMS and BASGOED this is already available, in other cases such as TransTools and ERM the model contain both passenger and freight demand.
- The transport models possess of an assignment model, which is essential for accessibility. It predicts travel distance, travel time, travel costs and volumes for both passenger and freight transport. In the case of passenger transport usually congestion is taken into account, which is not the case for most freight transport models.
- From the results of transport models, except one (TransTools), it is not possible to assess the impacts upon economic indicators such as GDP and employment. At least an interface and a macro-economic model are needed for this purpose. TransTools includes an economic model, which allows a feedback from the transport system to the economy, and thus indicators such as GPD and employment.

Next to the transport models, economic models (macro-economic, system dynamic, LUTI) were reviewed. The following conclusions can be drawn from these models:

- From the input and/or output of the economic models, it is possible to derive an accessibility indicator for regions. However, due to the aggregated level of the economic models, modes, purposes and commodities are not always included in full detail.
- Networks and assignment models are usually not part of these models (except for SASI). A link or interface to a transport model is needed, in order to include detailed information about travel time, distance and costs.
- The economic models are able to predict changes upon GDP and employment, due to changes in the transport system. These may include changes in transport infrastructure due to investments as well as changes due to measures like pricing. Changes in transport infrastructure usually have effect if these can be described in terms of changes in transport costs.

Given the review of transport and economic models, an overall conclusion is that both types of models have their pros and cons. In order to capture impacts of changes in the transport system due to investments, the ideal situation is to use both types of models in combination. For this purpose an interface between the two is needed. In some cases, this interface already exists, such as the interface between LMS and TIGRIS XL or between ASTRA and VACLAV.

6.2 Next steps

We reviewed transport and economic models of different kind. The next step consists of modelling case studies. The cases concern projects that were performed in the past and for which models and modelling results are available. From the conclusions, we have the following recommendations for the case studies:

- If possible include results from both passenger and freight transport models. This allows the calculation of the general accessibility to and from regions.
- Make an interface to an economic model in order to also capture the impacts of transport policy measures upon GDP and employment.
- Look into more detail to what extent the models in question are able further improve the link between accessibility and competitiveness.

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Ernst & Young	http://www.ey.com/attractiveness
Greece	http://www.antagonistikotita.gr/english/
Ireland	http://www.competitiveness.ie/
Wikipedia	http://en.wikipedia.org/wiki/Competitiveness
World Economic Forum	http://www.weforum.org/issues/global-competitiveness

Annex 1: Review of transport models

BASGOED (Netherlands)

Characteristic	Description
Summary	This is a simple forecast model for freight transport. The model serves to assess strategic Dutch national policy measures for freight transport. The main output comprises O/D matrices per mode and commodity per year. The system also comprises of an economic model that serves as a base for the production and attraction of freight transport.
Policy relevance	General policy relevance for freight transport, , cost-benefit analysis
Geographical Scale	National (Netherlands)
Time Horizon	Base year 2010 Forecast year 2020 and 2030 for one background scenario
Scope of the model	National, strategic model
Transport domain	Freight transport by road, inland waterways, rail and sea
Modes	Road, inland waterways, rail and sea
Type of transport modelling	- Economic model (based on make-use tables) - Distribution model - Mode choice model
Integration with other models	The results of BASGOED consist of OD matrices. These matrices are assigned in other models like BIVAS (inland waterways), RGM (road transport), LMS (road transport) and ROUTGOED (rail).
Proprietor	Rijkswaterstaat DVS (NL)
Applications	The model system is new and has not yet been used in transport policy studies.
Network definition	The model does not posses of an assignment model. The input comprises a level-of-service which is a straight forward skim of the networks for the different modes.
Zoning system	Approximately 77 zones (NUTS2), about 40 in the Netherlands and about 37 abroad
Socio-economic data	Level-of-service for road, rail and inland waterways Costs for road, rail and inland waterways
Base matrix	The base matrix for 2010 is based upon empirical data such as traffic counts and road side surveys.
Generalised Cost functions	The model does not contain generalised costs. The costs are input into the model (such as distance, time and costs)
Purposes/Commodities	For freight transport 10 NSTR chapters are distinguished. Oil and oil products comprise 1 NSTR chapter, but in the model this chapter is split into 2 subchapters
Periods of the day	No periods of the day, the timing is one year
Background scenarios	In principal one background scenario is available, for different future years
Assignment	No assignment model available. For this other models are used.
Type of the results	O/D matrices by commodity and mode. Distance, time and costs are input into the model
Literature	De Jong et al (2010)
Calculation accessibility	From the results of this model system, the accessibility can be

Characteristic	**Description**
	calculated for freight transport. In fact, this has been done by Snelder (2012)
Calculation GDP, employment	No calculation of GDP and employment
Relation with competitiveness	No direct relation available

Extended Riga Model (Latvia)

Characteristic	Description
Summary	This is a general purpose forecast model for the mobility of both passengers and freight transport and traffic. The model serves to assess strategic policy measures to draft and underpin mobility plans. The main output comprises O/D matrices per mode, purpose or commodity and time-of-day, and loaded networks per mode. Passenger transport and freight transport are modelled separately, but combined for assignments.
Policy relevance	General mobility policy relevance, pricing measures, public transport layout, development of infrastructure, traffic management and usage measures
Geographical Scale	Urban (Riga Agglomeration)
Time Horizon	Base year 2005 Forecast year 2020 and 2030 for one background scenario
Scope of the model	Urban, strategic model
Transport domain	Mobility of persons by cars and public transport Freight transport by road and rail
Modes	Car Driver, Rail and Bus/Tram/Trolleybus. Road and rail freight
Type of transport modelling	The Extended Riga Model consists of a number of sub-models: Freight Transport Model with: - Level-of-service for road and rail - Trade model - Mode choice model - Assignment model for rail transport (road freight is combined with passenger cars) Passenger Transport Model with: - Level-of-service for road, rail and public transport by bus/tram/trolleybus - Calculation of production/attraction - Distribution model - Mode choice model (elasticities) - Assignment model for road and public transport
Integration with other models	No integration with other models
Proprietor	Ministry of Transport, Latvia
Applications	The model system has been used in transport policy studies over the past 15 years. The system served strategic purposes such as mobility plans and the assessment of infrastructure projects. The Riga Mobility Plan (2010) was one of the studies in which the ERM was used.
Network definition	More than 30000 links constitute the road network
Zoning system	Approximately 400 zones
Socio-economic data	Number of inhabitants (total) Number of cars Number of jobs (total)

Characteristic	Description
	Territory size (ha)
Base matrix	The base matrix for 2005 is based upon empirical data such as traffic counts and road side surveys.
Generalised Cost functions	Based upon the output matrices for distance and time, generalised costs can be calculated. The model does not contain detailed costs information
Purposes/Commodities	The following purposes are distinguished: Work Business Other Road freight trips (no commodities) Rail freight trips (no commodities)
Periods of the day	Average working day, AM peak, PM peak, Off peak
Background scenarios	In principal one background scenario is available, for different future years
Assignment	For road, public transport and rail.
Type of the results	O/D matrices by purpose, mode and time-of-day, Loaded Network, Distance matrix, Travel time matrix
Literature	Witteveen+Bos et al (2010)
Calculation accessibility	From the results of this model system, the accessibility can be calculated for passenger and freight transport at a detailed urban level. The details concern mode, purpose, time-of-day and zoning.
Calculation GDP, employment	No calculation of GDP and employment
Relation with competitiveness	No direct relation available

GBFM - Great Britain Freight Model (Great Britain)

Characteristic	Description
Summary	This is a general forecast model for road freight transport and traffic. The model serves to assess strategic policy measures in Great Britain. The main output comprises O/D matrices per mode and commodity
Policy relevance	General road freight transport policy
Geographical Scale	National (Great Britain) and GB to rest of the world
Time Horizon	Not restricted
Scope of the model	National, strategic model
Transport domain	Freight transport by road, rail and sea
Modes	Road, rail and sea
Type of transport modelling	GBFM consists of - Matrix building (Generation and Distribution) - Multimodal assignment model (mode choice and assignment)
Integration with other models	The model was designed to be part of the DfT's national transport model. It also works as a stand-alone freight model.
Proprietor	MDS-Transmodal (UK), Department for Transport (UK)
Applications	Many applications
Network definition	Approximately 30000 links constitute the road network
Zoning system	Two digit postcode regions
Socio-economic data	Trade data (import/export) by country and commodity (ton) Development of GDP Territory size (ha)
Base matrix	Originating from UK trade statistics, maritime statistics, national road and rail O/D matrices
Generalised Cost functions	Realistic transport costs
Purposes/Commodities	NST2 digit and SITC 2 digit commodities
Periods of the day	None – flows are annual.
Background scenarios	Not applicable
Assignment	Multimodal assignment for road, rail and sea
Type of the results	Detailed O/D matrices and traffic assignments
Literature	Newton (2004)
Calculation accessibility	From the results of this model system, the accessibility can be calculated for freight transport at a detailed level. The details concern road, commodity and zoning.
Calculation GDP, employment	No calculation of GDP and employment
Relation with competitiveness	No direct relation available

Landelijk Modelsysteem (Netherlands)

Characteristic	Description
Summary	This is a general purpose forecast model for the mobility of passengers (both transport and traffic). The model serves to assess strategic policy measures for the development and use of infrastructure for road and rail. The system supports transport policy development and decision making. The main output comprises O/D matrices per mode, purpose and time-of-day, and loaded networks per mode. Road freight transport is added to the system by an O/D matrix. The model supplies the user with summary tables on network use, car kilometres, congestion hours and no. of trips.
Policy relevance	General mobility policy relevance, pricing measures, parking area management, infrastructure expansion, shift between transport modes, traffic management and usage measures
Geographical Scale	National (The Netherlands, 34000 sq. km)
Time Horizon	Base year 2004 Forecast year 2020, 2030 and 2040 for different background scenarios
Scope of the model	National, strategic model
Transport domain	Mobility of persons by cars, public transport and slow mode (bikes, pedestrians)
Modes	Car Driver and Rail. Internally the system also consists of Car Passenger, Public Transport by Bus/Tram/Metro and Slow Mode. For these modes only synthetic forecasts exist.
Type of transport modelling Formulation7	The Netherlands National Model System consists of a number of sub-models: - Level-of-service for road, rail, public transport by bus/tram/metro, slow transport - Calculation of tour frequencies (including licences and car ownership) - Mode/time-of-day/destination choice - Assignment model - Feed-back congestion effects
Integration with other models	TIGRIS XL: A spatial-economic model
Proprietor	Rijkswaterstaat DVS
Applications	The model system has been used in different transport policy studies over the past 25 years. The system served for different strategic purposes such as visions, policy documents, infrastructure projects and pricing studies. The Amsterdam Orbital study (1990) was one of the studies in which the LMS was used.
Network definition	More than 80000 links constitute the road network
Zoning system	Approximately 1500 zones
Socio-economic data	Number of inhabitants by sex and age Number of households Number of employees by sex Number of cars (base year)

Characteristic	Description
	Number of jobs (agriculture, services, other) Territory size (ha)
Basematrix	The base matrix for 2008 is based upon empirical data such as traffic counts and road side surveys.
Generalised Cost functions	Based upon the output matrices for distance, time and costs, generalised costs can be calculated.
Purposes/Commodities	The following purposes are distinguished: Home-Work Business Other Freight trips (no commodities)
Periods of the day	Average working day, AM peak, PM peak, Off peak
Background scenarios	In principal 4 background scenarios are available, for different future years
Assignment	For both road and public transport by rail.
Type of the results	O/D matrices by purpose, mode and time-of-day, Loaded Network, Distance matrix, Travel time matrix
Literature	Reports are available in English and Dutch
Calculation accessibility	From the results of this model system, the accessibility can be calculated for passenger transport at a detailed level. The details concern mode, purpose, time-of-day and zoning.
Calculation GDP, employment	No calculation of GDP and employment
Relation with competitiveness	No direct relation available

National Transport Model (Denmark)

Characteristic	Description
Summary	The model was originally built on the initiative of the Danish Road Directory, in order to start a process building a National Transport Model. It is though not a very detailed model, and mainly for tactical analyses. Only passenger transport is included.
Policy relevance	The model can answer some tactical policy issues concerning traffic impacts of infrastructure projects concerning changes in infrastructure, supply, traffic policies, socio-economic development and changes in land use. However, since the model does not include operational modules, capacity issues (both on roads and rail) cannot be analysed, and public transport in areas with low frequencies (time-table dependent modelling) cannot be answered. The model cannot answer strategic questions, i.e. changes in land use and car ownership due to changes in the supply (infrastructure, etc.). Accordingly, it is mainly relevant for project evaluation for road traffic. It includes modules for car-ownership and trip frequency and is accordingly more strategic than many tactical models. The model takes into account a number of socio-economic variables concerning population, occupation and work places, income, car ownership, land use, etc. The supply variables are mainly time and costs.
Geographical Scale	National, Denmark
Time Horizon	The model estimates trips during one "average" working day, rush hour and weekend.
Scope of the model	The model is a tactical model, describing short and semi-long term traffic impact of new infrastructure projects. The model describes short-term changes in demand (trip-frequency), choice of destination (including commuting), mode and route. It does not describe changes in location of households and firms, and car-ownership is modelled externally
Transport domain	Passenger transport.
Modes	Car, bus, train, airplane, bicycles and walk
Type of transport modelling	Car-ownership Trip frequency Choice of destination and mode. Assignment use EMME/2 standard procedures
Integration with other models	Zone-system of other transport models are coordinated with the National Model.
Proprietor	The Road Directory, Ministry of Transport, DSB and Banestyrelsen
Applications	The model is in use and is being updated, although less insensitively than prior
Network definition	The Road Network describes speed, length and traffic counts. The first version had approx. 2,600 nodes and 10,000 links. The rail network includes routes, driving times, frequencies, fares, and traffic counts for average weekdays, rush hours and

Characteristic	Description
	weekends respectively. New versions of the network have been implemented.
Zoning system	About 1,000 zones.
Socio-economic data	The following zone-data are used: - Population segmented after sex, age and job category - Households segmented after income, car ownership and family type - Job segmented on branches
Base matrix	The base matrices (OD flows between zones) are based on surveys (the national traffic survey) following by a calibration towards traffic counts (car matrices), and for the public transport different counts.
Generalised Cost functions	For the car network: -Free travel time (no congested travel time), driving length (correlated with costs) For the public transport network: - Fares, travel time and frequencies
Purposes/Commodities	The demand models are different for each trip purposes - Business - Private long distance trips - Commuting trips - Leisure trips, week days - Shopping trips, weekdays - Other trips, weekdays - Leisure trips, weekends - Shopping trips, weekends - Other trips, weekends
Periods of the day	Peak and off-peak
Background scenarios	All input variables concern background scenario
Assignment	The standard version use EMME/2 assignment procedures; non-capacity dependent for car traffic and frequency based assignment for public transport.
Type of the results	- Flows and travel times on the network, OD-matrices, supply variables.
Literature	Rich et al (2010)
Calculation accessibility	Based upon the output, the calculation of accessibility is possible, though only for passenger transport
Calculation GDP, employment	No calculation of GDP and employment
Relation with competitiveness	No relation with competitiveness

Trans-Tools (Europe)

Characteristic	Description
Summary	This is a general forecast model for both passenger and freight transport and traffic. The model serves to assess strategic European policy measures and to infrastructure plans. The main output comprises O/D matrices per mode, purpose or commodity and time-of-day, and loaded networks per mode. Passenger transport and freight transport are modelled separately, but combined for assignments. The system also comprises of an economic model in which the transport model results are fed back.
Policy relevance	General mobility policy relevance, pricing measures, development of infrastructure, cost-benefit analysis
Geographical Scale	International (EU27, accession countries and Norway + Switzerland)
Time Horizon	Base year 2005 Forecast year 2020 and 2030 for one background scenario
Scope of the model	International, strategic model
Transport domain	Mobility of persons by car, rail and air Freight transport by road, inland waterways, rail and sea
Modes	Car, Rail, Air for passenger Road, inland waterways, rail and sea
Type of transport modelling	Trans-Tools consists of a number of sub-models: Freight Transport Model with: - Level-of-service for road, rail, inland waterways - Trade model - Mode choice model - Logistic model - Assignment model Passenger Transport Model with: - Level-of-service for road, rail and air - Calculation of production/attraction - Distribution model - Mode choice model - Assignment model for road and public transport Economic model with: Based upon the CGEurope model
Integration with other models	TRANSTOOLS is used with ArcGIS. There are no direct interfaces to other models
Proprietor	European Commission DG MOVE (EU)
Applications	The model system has been used in transport policy studies such as TEN-STAC and TEN-CONNECT. The system served strategic purposes such as assessment and prioritization of infrastructure corridors for road, rail and inland waterways.
Network definition	More than 50000 links constitute the road network
Zoning system	Approximately 1300 zones (NUTS3) for road transport. For

Characteristic	Description
	freight transport by inland waterways and rail NUTS2 is used (approximately 400 zones)
Socio-economic data	GDP development Number of inhabitants Number of cars Number of jobs Territory size (ha)
Base matrix	The base matrix for 2005 is based upon empirical data such as traffic counts and road side surveys.
Generalised Cost functions	Based upon the output matrices for distance and time, the generalised costs can be calculated. The model does not contain detailed costs information
Purposes/Commodities	For passenger transport, the following purposes are distinguished: Work Business Other For freight transport 10 NSTR chapters are distinguished. Oil and oil products comprise 1 NSTR chapter, but in the model this chapter is split into 2 subchapters
Periods of the day	Average working day, AM peak, PM peak, Off peak
Background scenarios	In principal one background scenario is available, for different future years
Assignment	For road, rail and inland waterways
Type of the results	O/D matrices by purpose/commodity, mode and time-of-day, Loaded Network, Distance matrix, Travel time matrix
Literature	Hansen (2011)
Calculation accessibility	From the results of this model system, the accessibility can be calculated for passenger and freight transport at a detailed level. The details concern mode, purpose/commodity, time-of-day and zoning.
Calculation GDP, employment	Changes in GDP and employment can be calculated through the economic model CGE.
Relation with competitiveness	Through the economic model, there is a relationship with competitiveness. However, this is not modelled explicitly. The economic model is capable of calculating changes in GDP and employment.

Vaclav (Europe)

Characteristic	Description
Summary	This is a network-based Europe-wide forecasting model for passenger traffic. The model structure follows a four-step approach. It serves to assess strategic European policy measures and to infrastructure plans. The main output comprises O/D matrices per mode, purpose and time-of-day, and loaded networks per mode.
Policy relevance	General mobility policy relevance, pricing measures, development of infrastructure, cost-benefit analysis
Geographical Scale	International (EU27, accession countries and Norway + Switzerland)
Time Horizon	Base year and different forecast years
Scope of the model	International, strategic model for Europe
Transport domain	Mobility of persons by car, rail, coach and air
Modes	Car, Coach, Rail, Air
Type of transport modelling	Passenger Transport Model with: - Trip generation - Distribution model - Mode choice model - Assignment model
Integration with other models	VACLAV has an interface with ASTRA. Also, VACLAV has been used in conjunction with NEAC.
Proprietor	University of Karlsruhe (KIT)
Applications	The model system has been used in transport policy studies such as TEN-STAC. The system served strategic purposes such as assessment and prioritization of infrastructure corridors for road, rail and inland waterways.
Network definition	The road network consists of the main roads in Europe, altogether approximately 100 000 links. The rail network consists of approximately 5 000 links.
Zoning system	Approximately 1350 zones (NUTS3) for road transport. This includes EU27, Norway, Switzerland, Russia, Belarus, Ukraine and Balkan countries.
Socio-economic data	Income per capita by household types GDP per capita Car availability Employment rate Number of working places Number of school places GVA per capital and economic sector Number of inhabitants by age category Territory size (ha)
Base matrix	The base matrix is based upon empirical data such as traffic counts and road side surveys.
Generalised Cost functions	Logsum mode costs, total travel costs, value of time.
Purposes/Commodities	For passenger transport, the following purposes are distinguished: Business

Characteristic	Description
	Private Holiday
Periods of the day	Average weekday, within and outside summer holidays, weekends, AM/PM Peak, off peak
Background scenarios	For different future years, different scenarios can be applied
Assignment	For road transport
Type of the results	O/D matrices by purpose/commodity, mode and time-of-day, Loaded Network, Distance matrix, Travel time matrix
Literature	Kraft et al (2010)
Calculation accessibility	From the results of this model system, the accessibility can be calculated for passenger transport at a NUTS3 zoning level. The details concern mode and purpose.
Calculation GDP, employment	No calculation of GDP and employment
Relation with competitiveness	No direct relation available, though an interface with ASTRA exists

World Container Model (Europe)

Characteristic	Description
Summary	In order to analyse possible shifts in future container transport and the impacts of transport policies thereon, TNO developed a strategic model for the movement of containers on a global scale in partnership with the University of Delft and TML . The challenge was to design, estimate and validate a model that combines a consistent description of worldwide container flows and transportation services on a global scale, combined with a port choice model and route choice model. The route and port choice procedure uses an improved logit choice model, that takes into account overlaps between alternative routes in the network. This improvement is particularly important for cases where routes are analysed that compete against a bundle of existing routes (such as the Trans-Siberian railway). The model takes into account transport times, tariffs and time sensitivity of goods. It describes yearly container flows over the world's shipping routes and through 437 container ports around the world, taking into account more than 800 maritime container line services. Import, export and transhipment flows of containers at ports, as well as hinterland flows are distinguished. The model is calibrated against publicly available port throughput statistics. Scenario analyses done with the model include the effect of low speed shipping, the increase of land based shipping costs, the impact of major infrastructures such as the Trans-Siberian rail line and the opening of Polar shipping routes.
Policy relevance	Impact assessment of: new harbour; changed port's characteristics (e.g. larger terminal); modifications of the network (a polar cap path, new container line services); pricing policy (ports, inland); and changed trade flows between countries
Geographical Scale	Global
Time Horizon	Base year (2006) and different forecast years
Scope of the model	World, strategic model for Europe
Transport domain	International (between countries) container movement including trade, logistics and network
Modes	Maritime container flows and multimodal container flows overland
Type of transport modelling	It's a transport model of based on containers O/D matrix between countries.
Integration with other models	Transtools network is used to derive actual cost for European countries
Proprietor	TNO, University of Delft, TML
Applications	The model is being applied for the European Commission's Trans European Networks programme and the Rotterdam Port Authority, to develop long term forecasts.
Network definition	•437 container ports around the world

Characteristic	Description
	•848 container line services
Zoning system	236 countries. Countries are connected to a number of ports (user-defined)
Socio-economic data	
Base matrix	O/D matrix of container flow 2006 (per commodity group)
Generalised Cost functions	
Purposes/Commodities	NSTR1 commodity groups and empty containers: 1. Agricultural product 2. Food stuffs 3. Solid mineral fuels 4. Petroleum Products 5. Ores and Metal 6. Iron steel metals 7. Minerals 8. Fertilizers 9. Chemicals 10. Vehicle Machinery/other 11. Empty containers
Periods of the day	Not relevant
Background scenarios	
Assignment	Maritime flows and multimodal (overland) flows in container line services
Type of the results	Flows in 10 different type of commodities and for empty containers
Literature	Carlier et al (2011)
Calculation accessibility	
Calculation GDP, employment	No calculation of GDP and employment
Relation with competitiveness	Some proxy of indicator of competitiveness i.e. total volume of the container ports in terms of TEU

Annex 2: Review of economic models

ASTRA (Europe)

Characteristic	Description
Summary	The ASTRA model was developed by TRT and Fraunhofer Institute. It is a System Dynamic Model of Europe. The model is composed by four modules (macroeconomics, regional economic, transport and environment) and simulates the impact of different pricing and taxation policies on the European transport system
Policy relevance	The model is able to predict impacts on transport performance, environment, and vehicle fleet.
Geographical Scale	International – Europe
Time Horizon	1990 - 2030. Years until 2010 are used for calibration, years 2010 - 2030 for forecasts.
Scope of the model	In the ASTRA modelling approach, mobility prediction is the result of an interaction process among four different components: transport, economy, land-use and environment. The tool is capable to illustrate the reciprocal influences among transport and ecological and socio-economic systems, providing useful insights into the question of whether transport policies are really moving towards sustainability
Transport domain	Passenger and freight transport
Modes	Passenger: Car, Bus/Coach, Train, Air, Slow modes Freight: Truck, Train, Inland navigation, Maritime
Type of economic modelling	The following modules - Population and social structure (household types and income groups) - Economy (incl. input-output tables, government, employment and investment) - Foreign trade - Transport (incl. demand estimation, mode split, transport costs and infrastructure networks) - Vehicle fleet - Environment (incl. emissions, CO_2, fuel consumption)
Integration with other models	ASTRA has been used in combination with VACLAV and NEAC. Currently a link is made with TRANSTOOLS.
Proprietor	Fraunhofer Institute (D) & TRT (IT)
Applications	Different policy scenarios for example for TEN-STAC. Currently the model is adapted in the ASSIST project. A link with TRANSTOOLS will be made.
Network definition	A network is not explicitly modelled. Overall capacity of transport infrastructure (roads, rails, ports, airports) in regions is modelled and a speed-flow curve is calibrated for each infrastructure.
Zoning system	NUTS2 regions in Europe, EU27 plus Norway and Switzerland.
Socio-economic data	Official statistics for: population by age and professional status, households by size and car ownership, GDP, disposable income, population, fuel taxes and expenditures investments, fixed capital, employment by sector. EUROSTAT for input-output matrix (25 sectors). Furthermore vehicle fleets, vehicle

Characteristic	Description
	purchasing and scrapping.
Base matrix	The matrix per O-D pairs do not have a unique geographical meaning, each pair is further divided into distance bands to distinguish local traffic from longer distance traffic
Generalised Cost functions	For modal split generalised costs includes perceived costs or tariffs plus the monetary value of time and a modal constant. For the distribution of trips a 'generalised time' is used (i.e. cost is transformed in time units)
Purposes/Commodities	The passengers unit used in the matrix is passengers. The demand matrix is segmented by income groups. Freight transport is segmented into bulk, general cargo and unitized cargo (such as containers).
Periods of the day	The model works on a quarterly basis and produces results by year
Background scenarios	All the macroeconomic and demographic base variables are exogenous. In the reference scenario, transport costs, vehicle prices, load factors, etc. are supposed as fixed.
Assignment	The assignment is simplified as the software cannot cover physical transport networks.
Type of the results	Transport performance, transport vehicle fleet, economic (GDP, employment, consumption), environment, social impacts (such as accidents)
Literature	Fermi et al (2011)
Calculation accessibility	Based upon this description, it seems possible to derive an accessibility indicator at an aggregate level
Calculation GDP, employment	Calculation of changes in GDP an employment is possible.
Relation with competitiveness	There is a relation with competitiveness, in the sense that changes in GDP and employment are affected by changes in the transport system.

CGEurope (Europe)

Characteristic	Description
Summary	CGEurope is a spatial general equilibrium model for a closed system of regions covering the whole world. All of regions are treated separately and are linked through endogenous trade. The model is comparative-static, which means that for each scenario analysis two equilibria are compared.
Policy relevance	CGE is confined to the regional welfare from the use of transport infrastructure
Geographical Scale	International – Europe
Time Horizon	1990 - 2030. Years until 2010 are used for calibration, years 2010 - 2030 for forecasts.
Scope of the model	In the CGEurope, mobility prediction is the result of an interaction process among four different components: transport, economy, land-use and environment. The tool is capable to illustrate the reciprocal influences among transport and ecological and socio-economic systems, providing useful insights into the question of whether transport policies are really moving towards sustainability
Transport domain	Passenger and freight transport
Modes	All modes are implicitly included
Type of economic modelling	The following modules - Production markets (intermediate and final goods output) - Households (capital, labour output, final goods input) - Input markets (capital & labour input) - Producers (input markets input)
Integration with other models	CGEurope has been used in combination with other models NEAC and SASI. Currently the model is part of TRANSTOOLS.
Proprietor	University of Kiel
Applications	Different policy scenarios for example for in the TEN-CONNECT, ASSESS and the IASON project.
Network definition	A network is not explicitly modelled, instead costs and time form input for the model.
Zoning system	NUTS2: 235 regions in Europe: 218 internal zones, 13 external zones, and 4 rest of the world.
Socio-economic data	Regional data GDP, Value added, Employment, Regional demand National accounts data Trade flows Economic sector data Manufactured products, Market services, Agriculture, Forestry, Fishery products, Fuel and power products, building and construction, non-market services (NACE classes compatible) Transport cost data Passenger transport flows
Base matrix	A matrix with passenger and goods flows at NUTS2 level
Generalised Cost functions	For modal split generalised costs includes perceived costs or tariffs plus the monetary value of time and a modal constant.

Characteristic	Description
	For the distribution of trips a 'generalised time' is used (i.e. cost is transformed in time units)
Purposes/Commodities	Passenger flows are distinguished by mode. Freight good flows are distinguished by economic sector
Periods of the day	The model works on a quarterly basis and produces results by year
Background scenarios	CGEurope uses different background scenarios, for example in IASON network scenarios have been used.
Assignment	The system does not perform assignments.
Type of the results	Changes in economic indicators per region (GDP, employment, consumption)
Literature	Bröcker et al (2001)
Calculation accessibility	It seems not possible to derive an accessibility indicator at an aggregate level from the output of the model.
Calculation GDP, employment	Calculation of changes in GDP an employment is possible.
Relation with competitiveness	There is a relation with competitiveness; changes in GDP and employment are affected by changes in the transport infrastructure.

RAEM (Netherlands)

Characteristic	Description
Summary	The RAEM 3.0 model is a dynamic, recursive over time, model, involving dynamics of capital accumulation and technology progress, stock and flow relationships and backward looking expectations. The recursive dynamic structure is composed of a sequence of several temporary equilibriums. The first equilibrium in the sequence is given by the benchmark year 2006. In each time period, the model is solved for equilibrium, given the exogenous conditions assumed for that particular period. The equilibriums are connected to each other through capital accumulation. Thus, the endogenous determination of investment behaviour is essential for the dynamic part of the model. Investment and capital accumulation in year t depend on expected rates of return for year t+1, which are determined by actual returns on capital in year t.
Policy relevance	RAEM has been used in different studies to assess the impacts of infrastructure investments.
Geographical Scale	National (Netherlands)
Time Horizon	2006 base year and any future year
Scope of the model	The model is a strategic model which serves a macro-economic level.
Transport domain	The model takes account of both passenger and freight transport
Modes	Modes are not explicitly taken into account
Type of economic modelling	Modules for - Households incomes, savings and consumption budget - Households utility maximization - Households welfare - Labour market and migration - Passenger transport and commuting - Monopolistic competition - Firms profit maximization - Business trips - Interregional trade - External trade - Investment sector - Governmental sector - Market equilibrium - Freight trade and transport services, changes in stock - Economic indicators - Recursive dynamics
Integration with other models	RAEM can be used in conjunction with other models, however currently no interfaces exist. A RAEM light model has been made for Hungary.
Proprietor	TNO/TML
Applications	Different applications with RAEM have been made.
Network definition	No network, average travel time, costs and distance are computed in advance.

Characteristic	Description
Zoning system	40 NUTS3 zones (Dutch COROP zones)
Socio-economic data	- National Social Accounting Matrix - Bi-regional input-output tables - Regional production, value added and labour per sector - Transport data (passenger trips) - OD matrix commuting - OD matrix migration - Interregional trade flows - Regional unemployment -International trade
Base matrix	OD trips 2002 as aggregated data (NUTS3) from surveys (OVG/MON). Freight matrix in tonnes between NUTS3 for 2002.
Generalised Cost functions	Time and monetary costs of trips included
Purposes/Commodities	Purposes: - Commuting - Business - Services/personal care - Education - Shopping - Visits - Other social recreation - Round trips/hiking - Other Commodities/Sectors 15 in total - Agriculture - Mining and quarrying - Manufacturing - Electricity, gas and water supply - Construction - Trade and repair consumer services - Hotels, restaurants and café - Transport - Storage and communication - Financial services - Business services, renting, real estate - Public administration (includes defence and collective social security) - Education - Health and social work - Culture, sports, leisure
Periods of the day	No periods of the day included
Background scenarios	The main background scenarios (WLO) are applied.
Assignment	No assignment model
Type of the results	Per NUTS3 region, different economic indicators such as changes in employment . RAEM has been used in different studies for different clients such as EU, Ministry of Transport and Public Works (NL), Regional authorities
Literature	Ivanova et al (2007)

Characteristic	Description
Calculation accessibility indicator	It is possible to calculate the accessibility indicator, though not on a detailed level.
Calculation GDP, employment	Changes in GDP and employment are calculated
Relation with competitiveness	RAEM is able to predict changes in GDP and employment due to transport investments. In this sense there is a relation with competitiveness

RegFin (Finland)

Characteristic	Description
Summary	RegFin is a static CGE model that is constructed by using a non-arithmetic modelling subprogram MPSGE inside the GAMS modelling environment. Recursive dynamics have been introduced in the model.
Policy relevance	The model is relevant for: technology, productive capital and investment-savings behaviour, accumulation of debt/wealth, labour, and production.
Geographical Scale	National (Finland)
Time Horizon	Different future years are possible.
Scope of the model	In RegFin, mobility is not taken into account explicitly
Transport domain	In RegFin, passenger and freight transport are included implicitly
Modes	All modes are implicitly included
Type of transport modelling	The following modules - Production structure - Demand structure - Unemployment - Net migration - Foreign and domestic trade - Equilibria
Integration with other models	Unknown
Proprietor	University of Helsinki & IRWIR/PAN
Applications	Different applications have been made for example for the regional economic effects of bio energy potential, and the socio-economic effects and regional effects of the development of the Turku-Pori Highway 8.
Network definition	A network is not explicitly modelled
Zoning system	NUTS3 in Finland (20 zones)
Socio-economic data	Regional data GDP, Value added, Employment, Regional demand National accounts data Trade flows Economic sector data Manufactured products, Market services, Agriculture, Forestry, Fishery products, Fuel and power products, building and construction, non-market services (NACE classes compatible) Transport cost data Passenger transport flows
Base matrix	No base matrix
Generalised Cost functions	No generalised costs for transport
Purposes/Commodities	Not modelled implicitly, though commuting seems to be modelled together with migration.
Periods of the day	The model works on a quarterly basis and produces results by year
Background scenarios	RegFin is able to use different background scenarios
Assignment	The system does not perform assignments.

Characteristic	**Description**
Type of the results	Different economic indicators per region , such as GDP, employment, households income, taxes, trade
Literature	Kinnunen (2007) & Törmä et al (2007)
Calculation accessibility	RegFin in itself is not able to calculate an accessibility indicator
Calculation GDP, employment	Changes of GDP and employment are taken into account
Relation with competitiveness	Due to the previous line, one could state that RegFin is able to assess the impacts upon competitiveness.

Rhomolo (Belgium)

Characteristic	Description
Summary	This is an spatial general equilibrium model on the level of the EU regions. A test-case of the model was produced for 5 countries and is since then expanded to the whole EU27. The model is similar to RAEM, but contains less detail on the part of the labour market (no commuting). However its dynamic features are more pronounced and it is able to distinguish the effects of R&D spending on regional level.
Policy relevance	RHOMOLO was oriented towards the ex-ante and ex-post analysis of ECP (European Cohesion Policy).
Geographical Scale	Regional (NUTS-2 level) of EU-countries
Time Horizon	Base year 2007 Forecast year 2007-2030
Scope of the model	Regional, strategic model
Transport domain	None, there is no transport network integrated within the model. Only changes in the transport costs between the regions can be used as an input.
Modes	All modes together
Type of transport modelling Formulation	Armington trade elasticities between the regions
Integration with other models	None at this time, however it could be possible (in theory) to integrate a transport network model
Proprietor	Rijkswaterstaat DVS
Applications	Analysis of the impact of ECP on 5 countries (Germany, Poland, Slovak Republic, Czech Republic and Hungary)
Network definition	None
Zoning system	NUTS-2
Socio-economic data	National and regional accounts EUROSTAT budget survey data
Basematrix	Social accounting matrix (SAM) for each region National account data
Generalised Cost functions	Based upon the output matrices for distance, time and costs, generalised costs can be calculated.
Purposes/Commodities	30 commodities consumed on regional level
Periods of the day	Yearly simulations
Background scenarios	Standard growth scenario with fixed growth rate
Assignment	N/A
Type of the results	Economic indicators (GDP, employment, prices, productivity, incomes)
Literature	Ivanova et al (2010)
Calculation accessibility	Can be calculated from the freight data
Calculation GDP, employment	GDP and employment calculated directly, by sector
Relation with competitiveness	Direct relation via accessibility measures and productivity

SASI (Europe)

Characteristic	Description
Summary	The SASI model is a recursive simulation model of socio-economic development of regions in Europe subject to exogenous assumptions about the economic and demographic development of the European Union as a whole and transport infrastructure investments and transport system improvements, in particular of the trans-European transport networks (TEN-T). The SASI model differs from other approaches to model the impacts of transport on regional development by modelling not only production (the demand side of regional labour markets) but also population (the supply side of regional labour markets). A second distinct feature is its dynamic network database maintained by RRG Spatial Planning and Geoinformation based on a 'strategic' subset of highly detailed pan-European road, rail and air networks including major historical network changes as far back as 1981 and forecasting expected network changes according to the most recent EU documents on the future evolution of the trans-European transport networks.
Policy relevance	The model is able to predict different output indicators, such as GDP and employment.
Geographical Scale	International – Europe
Time Horizon	Base year data 1981 – 2011 (per 5 years). Years until 2011 are used for calibration. Years from 2011 onwards are used for forecasts. In principle any year can be predicted.
Scope of the model	SASI models different socio-economic indicators per region. These are the result of an interaction process among the different components in the model. Transport, economy, land-use and demography.
Transport domain	Passenger and freight transport
Modes	Road, rail, air and waterways
Type of transport modelling	The model has the following submodels: - European developments - Regional accessibility - Regional GDP - Regional employment - Regional population - Regional labour force - Calculation socio-economic indicators
Integration with other models	SASI has not been used in conjunction with other models
Proprietor	Spiekermann & Wegener Urban and Regional Research
Applications	SASI has been used if different EU studies, such as IASON, ESPON, STEPS and SETI.
Network definition	The model uses strategic road, rail, air and waterway networks, which are subsets of the trans-European network.
Zoning system	1330 NUTS3 regions in Europe. EU27, Norway, Switzerland, Albania, Bosnia-Herzegovina, Croatia, FYR Makedonia and Serbia.
Socio-economic data	Per region:

Characteristic	**Description**
	GDP per capita by industrial sector, labour productivity by industrial sector, endowment factors, labour force, transfers, population, GDP, labour force by sex, employment by industrial sector, quality of life indicator, educational attainment, fertility rates, mortality rates
Base matrix	SASI does not contain a base matrix, showing the number of trips between an O/D pair.
Generalised Cost functions	The costs used in SASI, comprise general transport costs of passenger and freight transport by different modes. One should think of operational costs, border waiting cost, travel costs or ticket costs. The cost functions are derived from the SCENES project and reflect the value of time.
Purposes/Commodities	SASI does not model purposes or commodities. Instead it does take industrial sector into account.
Periods of the day	The model works on a yearly basis and produces results by year. Past data consists of 5-year cohorts
Background scenarios	Different scenarios have been used in the past in the application of SASI
Assignment	The model does not contain an assignment model. The networks are used to calculate travel times and costs between regions and for regional accessibility.
Type of the results	Different socio-economic indicators
Literature	See Wegener (2008)
Calculation accessibility	SASI calculates the accessibility indicator itself, based upon potential accessibility. Based upon the description in this report, it is also possible to derive the accessibility indicator as described.
Calculation GDP, employment	Calculation of changes in GDP an employment is possible.
Relation with competitiveness	There is a relation with competitiveness, in the sense that changes in GDP and employment are affected by changes in the transport system. Regional competitiveness is considered to be built in into the model (see Wegener, 2008). This will be linked to factors such as subsidies, taxes and labour costs.