International Transport Forum

Target: Low-carbon Goods Transportation

A Growth-dynamics Perspective on Logistics and Goods Transportation until 2050

14

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OECD

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July 2014

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[1] This paper is based on a synthesis report (Pålsson et al., 2013) from a Swedish 4-year research project (LETS Goods 2050) that ended in 2013. The concept behind the project was that it is both technologically possible and economically feasible to achieve a low-carbon society by 2050. The research questions focused on the interaction between the development of goods transportation, logistics and CO_2 emissions. The research was conducted in an interdisciplinary group consisting of nine researchers from packaging logistics, technical logistics, economic geography and traffic planning, and headed by Associate Professor Henrik Pålsson. The thoughts and ideas on which the content of the report is based were inspired by and commented on by many people during the research project. We would therefore like to thank everyone who participated in our workshops and seminars and other researchers in the LETS programme. We also thank our financiers: VINNOVA (the Swedish Governmental Agency for Innovation Systems) and the Swedish Transport Administration. Finally, we thank Professor Lars J. Nilsson and Associate Professor Magnus Blinge for their valuable comments on an earlier version of the report.

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1. INTRODUCTION

1.1 Background

The transportation sector is responsible for about 23% of all CO_2 emissions globally and 30% in OECD countries with road being the dominating sector for transport emissions (ITF, 2010). National emissions data are rarely disaggregated by freight vs. passenger transport, but an estimate is that goods transportation accounts for 30-40% of the total road sector emissions in most countries (ITF, 2010). In addition, the trend for CO_2 emissions from the transportation of goods is on the rise, while the increase in emissions from passenger transport has levelled off and emissions from other sectors have decreased. Internationally, based on traditional projections, transportation of goods is expected to continue increasing in step with the GDP, thus doubling by 2050. This trend contrasts sharply with the climate targets set by the EU, which require dramatic reductions in emissions; by 2050, the EU should cut its emissions to 80% below 1990 levels through domestic reductions alone (EU, 2011). The expected effects of on-going or planned measures will not be sufficient to achieve the EU target. On the contrary, CO_2 levels are expected to increase. This is the problem that is the focus of the analysis and discussion in this paper.

1.2 Research concept and objective

The objective of this paper is to introduce a new and somewhat unusual perspective on the relation between growth, transportation measures, logistics and CO_2 emissions. At best, this perspective may help us to understand how various driving forces in economic development can be utilised over time and when various broad measures are most suitable to implement in order to reduce emissions. We hope this perspective can be used as a guide or roadmap. The paper does not contain detailed instructions on how to achieve the target, nor is it a policy document in the traditional sense. Instead, this perspective should be possible to apply by those who have detailed knowledge of business models, institutional conditions, taxes and other policy instruments, and technological and infrastructure development. Measures can only achieve the necessary precision if the proposed perspective is brought together with these detailed fields of expertise. Although this paper is primarily aimed at the research community, our ambition is that it will also provide new dimensions to business community representatives, decision-makers, authorities and industry organisations.

Engineering a precipitous drop in emissions will require both voluntary and mandatory measures affecting a large number of players in the private and public sectors alike, which complicates the regulation of the issue. In principle, emissions can be reduced in three ways: 1) Reducing demand for goods transportation, 2) Streamlining logistics and 3) Technological development. Emissions can be reduced through many different measures in each of these three principal areas. In an attempt to create an overall perspective on how different factors, alone or in various combinations, can be expected to affect the development of transportation work over time, an analytical framework has been created based on the following assumptions:

- Economic growth does not develop in a linear fashion, but in recurring long-term cyclical patterns with distinct differences regarding the strength, direction and nature of the growth.
- Economic rationality, the actions of players and what is technically possible differ widely at different points in time. This is assumed to be crucial to the future development of emissions from the transportation of goods and how they can be reduced through various types of policy instruments, etc.
- The effect of and interaction between various factors at macro level (rate of economic growth, structural transition and transportation intensity) and micro level (companies' actions and implementation of transportation innovations) can be assumed to vary over time.
- The size of "windows of opportunity" and the basic conditions/restrictions for reducing CO_2 emissions are therefore assumed to be closely linked to the specific point in time.

Based on the realisation that growth is not linear but recurs in long-term cyclical patterns, we can assume that economic development until 2020 will differ significantly from that of the period 2020-2050. The years leading up to 2020 are the end of a long growth cycle and will be characterised by weak growth and structural stagnation, while the period 2020-2050 will in all likelihood be the beginning of a new growth cycle, characterised by growth and intense change in which growth takes on an entirely new direction.

This paper's most important contribution to research in the field is that the theoretical framework and calculation models are not based on linear growth projections, which is the predominant assumption in the existing literature and reports in the field. The cyclical view that we promote offers a completely different scope for action and opportunities at various times in comparison with what we see from a linear perspective. Further, we frame the problem in a new way regarding the importance of relationships between factors at macro and micro levels and their consequences for the possibility of cutting CO_2 emissions within various time frames. Thus, the results of our analyses differ from other calculations that have been conducted regarding the future development of CO_2 emissions from the transport sector and our possibilities of managing them.

Until 2020, business community structures, regional and urbanisation structures, business models, logistics solutions, vehicle technology and types of energy remain within the grasp of players in the business and public sectors as well as researchers. During this period, economic growth and structural transformation can also reasonably be predicted. We argue that analyses and development of policy instruments for goods transportation during this period should be based on a holistic perspective, not isolated from other parts of the supply chain. This prevents the risk that reductions of emissions in the transportation system occur at the cost of increases in other areas, such as production facilities or at suppliers. We also argue that policy instruments should be developed in consideration of both the desired evolution of society and the incentives and needs of companies, since both affect each other – many technological and logistical innovations and solutions that reduce emissions are made by companies in the market and in the business climate that society creates. Companies' willingness to take risks and their incentives to create innovation are controlled by society's rules. Often, profit-generating incentives create a greater will to find new solutions and a greater innovative power than limiting regulations. With that said, however, limiting regulations can also stimulate development. For players in the transportation system, the question of regulation is of particular interest, because the goods transportation industry as a whole is reactive. A new regulatory approach is needed to create a more innovative climate that encourages proactive initiative. Thus, it follows that what is needed are "package solutions" of policy instruments in which limiting regulations are developed in parallel with new types of innovation support, and where targeted support and limitations are developed alongside general rules.

In this paper, we also argue that in the coming 10-year period, the aim should be to steer towards a development that, wherever possible, both reduces environmental burden and at the same time enables financially competitive logistics and transportation solutions, such as packaging innovation, increased fill rates and intermodal transportation solutions. To make companies willing to take on risk, we recommend the simplest, clearest regulations possible, which remain in force for a long time, are well known long before their implementation, and have gradually increasing requirements. This reduces the risks for players in the market, thus enabling a dynamic development adapted to gradually tightening regulations.

Beyond 2020, it is likely that the content of growth will differ completely from that of today. If, for example, growth becomes less focused on consumption and labour productivity, and more focused on technologies and services that enhance productivity in the energy and material sectors, the conditions for reducing emissions in the transportation sector may change radically. For this reason, the focus in this paper is on portraying the problems of the period 2020–2050. We discuss how conceivable structural changes may affect governance towards and methods of achieving carbon-neutral goods transportation.

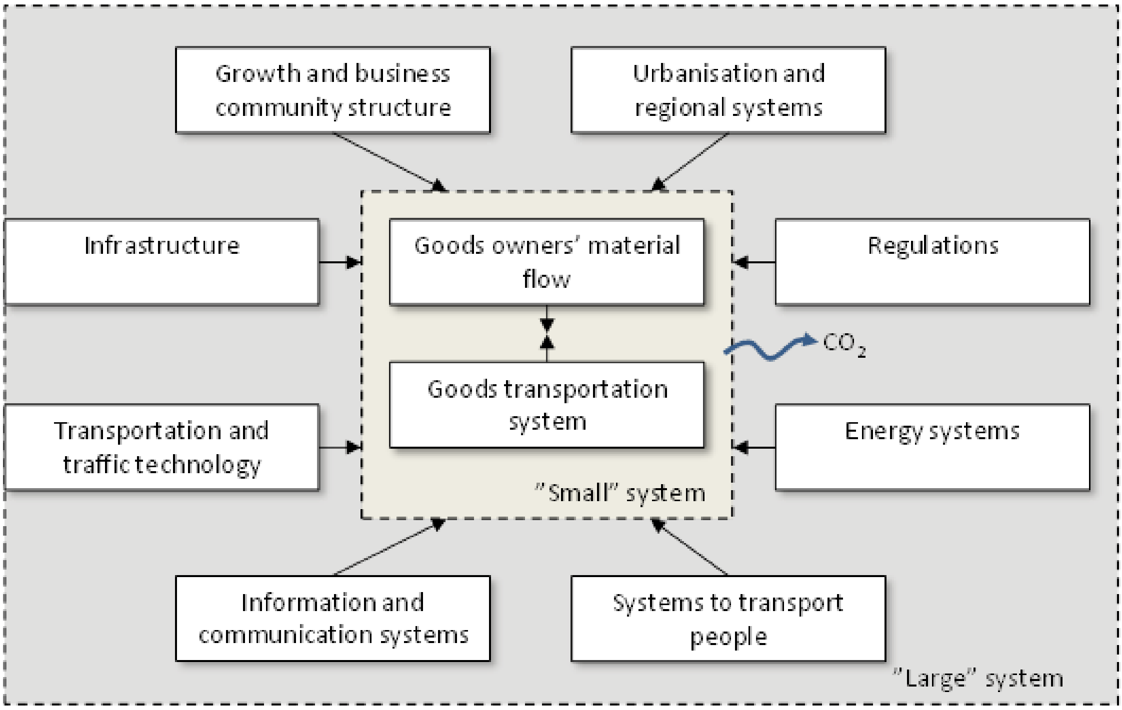
The remainder of this paper is set up as follows: Chapter 2 discusses the goods transportation system and systems in its environment. Chapter 3 theoretically and empirically analyses how GDP development, structural changes, technological development and logistics decisions have affected emissions from the transportation of goods in the period 1990–2010. In chapter 4, we apply our perspective to the future using actual and estimated data with references to a global context. We test out various lines of development and combinations of macro and micro factors to inform the discussion on what is hypothetically possible to achieve in the form of CO_2 reduction in the transportation of goods. Lastly, chapter 5 discusses development possibilities for the period 2020–2050.

2. THE GOODS TRANSPORTATION SYSTEM AND SYSTEMS IN ITS ENVIRONMENT

The goods transportation system as a whole is affected by decisions made by a wide range of players. This makes it difficult to gain an overall perspective of the system and understand how different types of decisions are made and affect one another. Since the regulations aiming to reduce CO_2 emissions are designed to cause one or more players in the goods transportation system to make other decisions, we need to understand the relationships between the players.

To describe and discuss this complex situation, we place the goods transportation system into a frame of reference consisting of a “small system” and a “large system”. The small system comprises players that have a direct impact on CO_2 emissions from transportation of goods, through their decisions regarding logistics and transport. The large system comprises players and subsystems that define the frameworks for what decisions are possible and financially profitable for those in the small system.

Figure 1. **The goods transportation system***



* The small system (including the material flows of goods owners) and the large system (including external factors)

2.1 The “small” system

On the operational level, the goods transportation system can be viewed as a network of nodes consisting of factories, terminals and shops. These are interconnected with links, which are transports of goods using various modes of transport. We can talk about a transportation system when referring to an individual company, but in this paper we are referring to the national transportation system for goods, an aggregation of all companies’ transportation systems within Sweden’s borders. In each individual transport in the system, either the sender or the recipient usually acts as the *transportation buyer*, procuring transportation from a *transportation producer*. Most commonly, a *freight forwarder* coordinates demand and consolidates the goods from several transportation buyers, so that multiple transportation jobs are carried out at once using the same vehicle along a set route, and then back along a return transport route. Transportation producers control the goods transportation system in operational terms, as they are the ones that plan and carry out the transportation of goods. These activities affect the volume of emissions. Although transportation producers have great potential to influence costs, quality parameters and emissions, their decisions are made based on the requirements of transportation buyers.

The operative decisions in the goods transportation system depend on the orders placed by goods owners and other transportation buyers. The transportation decisions of these organisations are based on logistics decisions regarding the location of production facilities and warehouses, production planning, stocking and service targets, all of which define the frameworks of what distance, speed and reliability requirements must be met by the transportation producers. This in turn affects the choice of mode of transport, vehicle fill rates and the speed of the vehicles in the goods transportation system. So what we describe as the small system does not just consist of the goods transportation system itself, but also of the players who contract transportation and request specific transports under contract. Changes in the logistics decisions of transportation buyers in order to affect emissions from the goods transportation system may be achieved as the result of internal motivations, such as enhanced profitability or long-term competitive edge, or the result of external forces such as government policy, etc.

2.2 The “large” system

The large system consists of a number of players and subsystems. The economic growth and business community structure have a great impact. The total volume and rate of growth of the economy reflect the aggregated demand for goods and services, which has a direct impact on the overall demand for transportation. Other aspects of growth are equally important – which industries grow and decline, and how work is divided up between industries and regions, changes over time, affecting both the location of the business community and its value intensity in the economy. This in turn affects the development of transportation of goods and the opportunities to reduce CO_2 emissions.

Urban planning and local regulations indirectly affect the goods transportation system through the conditions they create for transportation of goods and delivery of products. There are municipal plans and several local (traffic) provisions and regulations that affect the goods transportation system in urban areas. Examples include time restrictions on the loading and reloading of goods, environmental zones, restrictions on idling and congestion fees. Municipal planning also affects the location of transportation infrastructure and terminals.

There are furthermore regulations on several levels. The government is for instance active in the goods transportation field setting policy targets and guidelines. The government also controls the focus and scope of the national traffic infrastructure and works with other countries regarding international connections and routes. Partly in collaboration with other governments, the government also establishes regulations for who can provide and finance infrastructure, and frameworks and regulations for the goods transportation market. In addition, the government plays a central part in funding and taxing the transportation system. Finally, the government administers forms of subsidies such as transport subsidies and government procurement of transport services. In addition to government regulations and controls, the national goods transportation system and its development are also affected by transnational collaborations and international regulations.

The energy system delivers energy to other subsystems, in the form of electricity or fuel. This requires both production and distribution, which in turn require facilities and infrastructure, part of which coincides with the transportation infrastructure. This means that the energy system indirectly affects emissions from the “small system” in two ways: in part by determining the type and quantity of fuel that is transported by road and sea, and in part by determining what technology can be used in vehicles and infrastructures. Furthermore, the passenger and goods transportation systems affect one another e.g. competing for the same infrastructure, and in some cases for space on the same space on the same vehicles such as planes, ferries and trains. There are also logistical decisions, such as the locations of warehouses, factories, shopping centres or transfer terminals, which affect the scope of transports of both people and goods and their distribution over various modes of transport.

The large system also consists of the Information and communication system (ICT) available. Historically, ICT and transportation technology have always developed in constant interaction with one another. ICT has been both a substitute for transports and an enabler for the development of transportation. The net result has produced a close parallel of the growth curves of both technological fields.

Also the transportation and traffic technology is part of this framework. Technological developments and decisions about their use can exist in both the small system and the large system since energy efficiency in the goods transportation system can be increased through more energy-efficient vehicles in the large system and also by using vehicles more energy-efficiently in the small system. The proportion of renewable energy in the transportation sector can be increased through e.g. the use of biofuels in existing engines, various types of electrical power or hydrogen fuel and electrofuels produced from renewable electricity. Technical changes in vehicles and fuels affect emissions from the goods transportation system without any changes being made by the players in the small system. However, some of the innovation required to make the technology usable requires active customers – goods owners and transportation companies. Players in the small system are the only ones who can add parameters requiring greener vehicles in transportation procurements.

What infrastructure is available in the large system creates the conditions for what modes of transport can be used, and therefore indirectly affects emissions from transports. Various initiatives are underway, for example green corridors and “motorways on the sea”. All of these initiatives are intermodal transportation routes that utilise integrated logistics planning to take advantage of the best of every mode of transport. These initiatives require support from infrastructure investments, in the form of efficient, strategically located transfer points and adapted, supportive infrastructure. Infrastructure decisions are also linked to technological development. Before certain modes of transport or energy carriers can be implemented, we need a reliable infrastructure.

3. CO_2 EMISSIONS FROM THE TRANSPORTATION OF GOODS OVER THE PAST TWO DECADES

To develop and implement efficient policy instruments for reducing CO_2 emissions, we must understand the mechanisms that control emissions. To have an informed and concrete discussion we focus on one country, i.e. Sweden, but similar patterns are likely to appear in most advanced economies/countries as the increasing CO_2 development trend for goods transportation is a global phenomenon. This chapter expands previous research in the field by specifically spotlighting the dynamics in observed changes, in our case for Sweden in the years 1990–2008. It has been shown that growth in goods transportation work as well as in GDP appears to follow cyclical patterns, longer than business cycles, in which transportation work grows faster than GDP during high-growth periods and slower than GDP during low growth periods (Eng-Larsson et al., 2012). In other words, although GDP affects emissions from the transportation of goods, it appears that other factors are also in play, with different effects during periods of low and high growth. The growth-cycle theory can help explain these observations. In this chapter, we discuss the conceptual basis of this theory and how it can explain observations regarding transportation work and emissions. Based on this discussion, we then present a calculation model. Next, we apply empirical data regarding emissions from the transportation of goods in Sweden between 1990 and 2008. Finally, we discuss the significance of the results of the analysis.

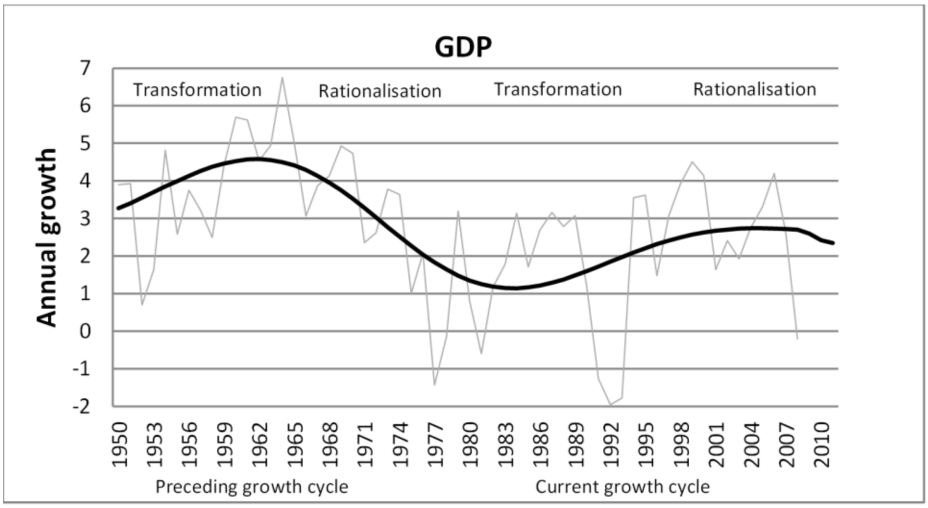
3.1 Growth and change

The growth cycle in the modern era

When you look at the GDP over time, it is easy to get the impression that long-term economic development is linear – that growth climbs steadily, only interrupted by temporary disruptions such as financial crises or oil price shocks. However, variations in annual growth figures show something quite different: recurring cyclical patterns lasting about 40 years and ending with serious structural crises.

The current and the preceding growth cycles in the Swedish economy are illustrated in Figure 2. The preceding cycle started in the 1930s, was interrupted by the war, and then accelerated rapidly during the 1950s and 1960s. Growth subsequently declined, reaching its lowest point in the structural crisis of the late 1970s. The current growth cycle is largely based on ICT. In an initial stage, it led to rapid growth in productivity, which culminated in the mid-1990s. Since then, productivity growth has declined, while ICT has spread throughout the economy. The current cycle is in its latter phase, and if the progression follows the previous pattern, growth will decline more and more, to bottom out within a few years. It is worth mentioning that annual growth figures are not the only way to describe these cycles. Productivity, salaries, profits and investments follow similar cyclical patterns. A growth cycle consists of two periods: a transformation period and a rationalisation period (Schön 1994, 2010 and Lundquist & Olander 2007, 2011). Table 1 shows the characteristics of these periods. The transformation brings about a clear change in the direction of growth, caused by radical technological shifts under genuine uncertainty. The rationalisation is a kind of harvest period, when most industries are using the new, radical technology in combination with other innovations and technologies. Gradually, the renewal decreases, competition increases, overcapacity arises and many companies begin to struggle for survival in an increasing number of industries. The economic behaviour of companies and consumers changes between the periods. The same applies to growth properties in the economy. The spread of GPT and macro innovations[2] leads to investments in new production areas during the *transformation* (20–25 years). Growth increases rapidly in new industries and later spreads to older industries. Thus, economic resources are reallocated between businesses. During this period, productivity increases primarily through the transfer of resources from low-productive to high-productive industries, not through productivity-enhancing measures in individual industries. Production increases faster than productivity in the beginning of the transformation, because of extended learning periods and limited availability of skills in the new technology. This relationship only changes later in the transformation. The renewal and growth during the period are primarily visible in the increased activity on the supply side of the economy. The new technology leads to falling relative prices and rising relative volumes in new and updated technology-intensive production.

Figure 2. **Annual GDP growth in Sweden, 1950–2010***



* The wavelet method was used to eliminate short fluctuations in the economy and to calculate the long-term cyclical trend. The forecast for the last two years is based on the cyclical trend in the period 1830–2008. Source: The Maddison Project database.

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[2] A macro innovation is a radical idea that leads to completely new production technologies, products and industries.

Table 1. **Characteristics of the two periods:**
Schön (1994, 2010)and Lundquist & Olander (2007, 2011)

Transformation	Rationalisation
• GPT initiation	• Diffusion of competence
• New industries	• Technological standardisation
• GPT diffusion	• Decomposition
• Supply-driven industries	• Demand-driven industries
• Development blocks	• Consumption growth
• Slow productivity growth	• Rapid productivity growth
• Bottlenecks	• Credit market expansion
• Building investments	• Machinery investments

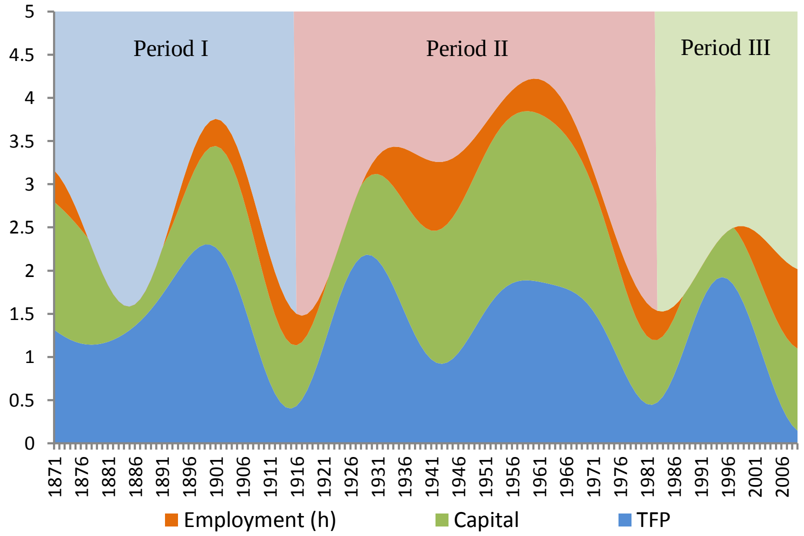
In the beginning of the *rationalisation* (15–20 years), services and demand-driven industry expand, while the previous supply-driven industry slows down. During this period, resources are increasingly concentrated to the most productive units in the industries (Lundquist et al. 2008a, 2008b). The new technology that emerged in the preceding period is standardised, expands into other fields of application and spreads efficiently to older parts of the economy. Investments are primarily focused on cutting costs in production and distribution. Large-scale production increases and demand from new, globally growing economies becomes more important to countries with advanced economies than the ever-slower growth of the domestic market. Gradually, the supply from these new economies expands, creating increasingly keen competition. To deal with the competition, companies rationalise production, which reduces employment. Eventually, an international overcapacity develops. In combination with previous credit-financed overconsumption, debt crises arise, which conclude in a more or less serious structural crisis that embraces many countries. Slow growth, recurring recessions and falling profits will eventually lead communities and economies to prepare for opportunities for new paths of growth.

Brief history

The growth cycle is not just a recent phenomenon. To date we have had three industrial revolutions. Each one consists of two growth cycles and is characterised by a certain number of dominant key technologies, company structures, institutions, economic geography and lifestyle patterns, which in turn give rise to new trends, including energy demand. Each industrial revolution thus introduces a new techno-economic paradigm (Freeman & Perez 1988, Freeman & Louçã, 2001). For related points of departure regarding the role of radical macro-innovations in creating long, wave-like growth progression, see also e.g. Kondratieff (1926), Schumpeter (1939), van Duijn (1983) Bresnahan & Trajtenberg (1995), Schön (2000) and Lipsey et al (2005). The techno-economic paradigm that evolved during the first industrial revolution was closely related to the development of the steam engine and its relationship to railways/transports, while the second revolution was largely characterised by new opportunities created by electrotechnology, the use of electricity and the development of combustion engines. The technological impetus of the third industrial revolution is microelectronics and the opportunities this has created in ICT.

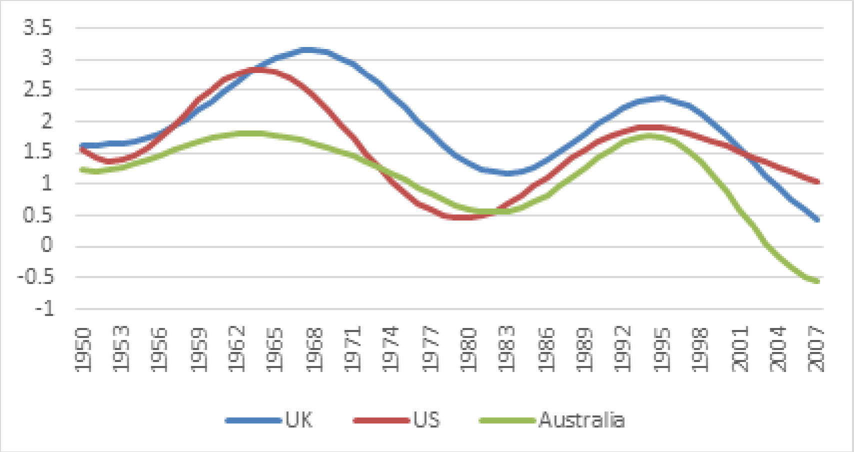
These industrial revolutions and their growth or productivity cycles can now be observed in GDP data. Figure 3 illustrates a trend assessment of the GDP growth in Sweden from 1852 to 2010, from which short-term fluctuations (economic cycles) have been removed. Periods I, II and III are industrial revolutions. As mentioned previously, each such revolution consists of two growth or productivity cycles. We are currently in the first cycle of the third revolution, which is starting to come to an end. This development pattern is not unique for Sweden; it is also found in other developed countries (Figure 4). Since the end of the Second World War, most other developed nations have followed the same growth pattern as Sweden, with a structural crisis in the 1970s, followed by an upswing in growth that culminated in the mid/late 1990s, and then an expansion of ICT capital stock. Extensive studies of the latest growth or productivity cycle show that the Swedish economy is heading towards declining growth in coming years, up until about 2020 (Lundquist & Olander 2011). The economic development of the coming 10 years will in all likelihood be dramatically weaker than the record years of the 1990s and early 2000s and will end with a structural crisis. This trend will be global, based on structural levelling, price competition, industrial overcapacity and market integration. Financial and debt crises, which are currently ongoing around the world, are crises in their own right, but they are also early warning signs of coming structural crises. Such crises are not only negative, however; they also open the door to reorientation, new paths of development and new technology. This means that, in all likelihood, new growth will take place after 2020, with characteristics we do not yet know of in detail. As a rule, such long-term development is fuelled by large, extensive technological shifts in production, infrastructure and energy systems. The peak is estimated to be reached around 2050, after which growth will again slow down. New business models, changed logistics, vehicle development, alternative energy sources and other technological solutions will be a part of this development. Therefore, policy, regulations and measures may need to be adjusted along the way, depending on what specific paths the economic and technological development will take. They will also need to be adapted to trending changes in the economy. Emissions from the transportation of goods over the past decades must therefore be seen in the light of the consideration that macroeconomic development is not linear over time, but follows the patterns outlined above.

Figure 3. **GDP growth trends (%) with underlying factors in Sweden***
(Nilsson et al., 2013)



* Employment = hours worked, Capital = real capital in the form of buildings and machines, TFP = productivity for a weighted index of production factors.

Figure 4. **Long-term employment growth (hours worked), 1950–2009 in the UK, US and Australia**
(Nilsson et al., 2013)



Cycles, goods transports and CO_2 emissions

Each growth cycle encompasses major changes in production, its organisation and its location. These changes differ between the transformation and rationalisation periods. Based on the presented literature regarding growth cycles, this is a good starting point for a hypothetical discussion about the characteristics of growth and its effect on CO_2 emissions over time. The focus will be on the current growth cycle, primarily on when the transformation will culminate and the rationalisation will take over.

Transformation. The annual GDP growth is generally lower in the transformation period than in the rationalisation period. Above all, growth comes from completely new manufacturing industries and new services provided for these industries, while the mature industry grows slowly. The conception and establishment of new industries and new services increase the gap between weight of total manufacturing and value-added. The new industries that arise during the transformation period are entrepreneurial and more focused on growth than efficiency. Their supply chains are less efficient and more focused on purchasing components than on purchasing complete system solutions. Components are often bought where they happen to be available at the time. This often leads to a risk of supply chains becoming geographically spread out, both nationally and internationally. In addition, flexible solutions are often required during the transformation period, using more road and air transports. This leads to greater tonne-kilometres and higher emissions per GDP in new industries. Thus, emissions growth during the transformation period is driven by greater transportation intensity and a shift to faster vehicles, while value density has a moderating effect.

Rationalisation. Economic growth during the rationalisation is powered by several forces. The new manufacturing industries are rationalised, which leads to lower relative prices and greater relative volumes. Older industries increase their markets and services through improved technology, reduced costs, generally increasing real salaries and expanding credit markets. The service sector is dominated by relatively “heavier” industries such as wholesale and retailing. The importance of customer service increases, which generates time-controlled distribution systems and direct deliveries, which in turn boost the frequency of transports and lead to a greater number of vehicle kilometres. Various types of raw materials gain in importance because many countries, including technology laggards, are a part of the economic development. Rail and sea transports become increasingly important in these circumstances, which slows the rate of growth of emissions. While developments in vehicle design and energy carriers follow their own courses, it becomes easier to implement energy-saving technology during the rationalisation because costs become a priority, while at the same time the expansion of credit markets makes it easier for companies to invest in vehicle technology. This means that the growth of emissions during the rationalisation period is fuelled above all by increased economic growth, while increased operational efficiency and a switch to more rail and sea transports slow down the overall increase in emissions. In the following sections, we test these assumptions empirically.

3.2 Basic concepts and correlations

To test our assumptions, we start from a conceptual model that breaks down the measured CO_2 emissions from the goods transportation system into a number of ratios. Each ratio represents a factor which, if it changes, contributes to a change in CO_2 emissions from the transportation of goods. These factors are affected by macroeconomic changes and also by decisions made by players in the small and large systems. It is difficult to assess in detail how various changes will interact, but based on the discussion above, we can present a theoretically informed projection of how various changes in the small and large systems have affected the contribution of the various factors, and therefore the total emissions from the transport of goods in Sweden.

- *Economic activity (the sum of the value added of all workplaces)* and *value density* depend on the macroeconomic and industrial-structural development during the coming growth cycle. While it is true that the general shift towards more service-driven growth is expected to continue, some of the transportation tonne-kilometres come from heavy basic industry originating in, for instance, mines and forests, which drastically limits opportunities to significantly reduce the value density.

- *Transportation intensity* is a measure of how far each tonne of goods travels in the economy. This depends on the number of nodes (factories and warehouses) in the supply chain and their location (which determines the distance between the nodes).

- *Traffic intensity* is a measure of how much traffic work, vehicle kilometres, it takes to meet a given transportation need. A vehicle/vessel's CO_2 emissions decrease with the proportion of empty transports on the return trip, with the tare weight and increase with the deviation from the most direct route. The effect of these factors on the CO_2 emissions differs significantly between modes of transport and can also be affected by route planning, groupage, balancing of transports in both directions and the choice of vehicle and load carrier best suited to the infrastructure, the traffic and the cargo.

- *Energy intensity* is a measure of the energy consumption for specific traffic work. It differs significantly between modes of transport. Sea transport has the lowest value, followed by rail, road and air. The value also depends on air resistance and rolling friction, speed, traffic rhythm, driving style and energy recovery during deceleration.

- *Emission intensity* is the result of emissions of CO_2 from the conversion of energy in a vehicle and the transportation and production of energy carriers. The industries that currently manufacture vehicles, engines and fuel for various modes of transport are the primary change factors for emission intensity, but the electro-technical industry and the energy industry are becoming increasingly important players.

The conceptual model describes an absolute value (CO_2 from the transportation of goods) as a product of several ratios. However, it is important to understand *change* in this value, and how the different factors contribute to the change. This can be illustrated through a Shapley decomposition, which is a method of explaining change in aggregated data through contributions from the different factors at different points in time. To make such an analysis possible, we need to adapt the conceptual model to one that can be used for data analysis. This requires two small adjustments. The first is in modes of transport. Since the available data differ between modes of transport, we measure the variance between them, called the "modal split". We analysed three domestic modes of transport: road, sea and rail, disregarding air transports since they make up a very small part of the domestic transportation of goods. The other change is in the last two factors. It is of interest to distinguish between these factors when discussing measures and policy instruments, but in initial analysis of available data it becomes clear that both are based on the same input data: fuel consumption. Therefore, in this data analysis we have chosen to combine these ratios into one emission factor, expressed as emission per vehicle kilometre.

The final analysis model is illustrated in the form of an equation (1) below. The Shapley decomposition shows the change in emissions as a sum of the contribution of the factors, in which each contribution is an approximation of how much the change in the factor affects the change in emissions per period. The Delta sign is used to clarify where the value from the Shapley decomposition is used. When actual change is indicated, the ratios are used instead. In the final analysis model (1), changes in the emissions from the transportation of goods are broken down into six elements: changes in *economic activity* (measured in GDP), *inverted value density* (transported tonnes per GDP), *transportation intensity* (tonne-kilometres per transported tonne), *modal split*, *traffic intensity* (vehicle kilometres per tonne-kilometre), and finally *emission factor* (CO_2 emissions per vehicle kilometre) (Table **2**). This type of breakdown is compatible with several earlier studies, but due to a lack of reliable data for other modes of transport than trucks, several modifications have been made. The handling factor, which is often used for truck studies (see, for example, REDEFINE, 1999), is included as a part of our greater value density measurement, while the transport distance (which is used by e.g. McKinnon & Woodburn, 1996) is included as a part of our transportation intensity measure. For the same reason, no disaggregation into industries and product groups has been performed. Table 2 gives a summary of the factors.

Table 2. **Factors in the decomposition**

Factor	Description	Unit	Designation in chart
$\Delta C_{emissions}$	CO_2 emissions from the transportation of goods	Kg CO_2	CO_2
ΔC_{GDP}	Economic activity (GDP)	SEK	GDP
$\Delta C_{Val\ dens}$	Inverted value density	tons/SEK	tons/GDP
ΔC_{Tsp_int}	Transportation intensity	ton-kms/ton	ton-kms/ton
ΔC_{Mode_sp}	Modal split	fraction	–
ΔC_{Tfc_int}	Traffic intensity	Vehicle km/ton-km	vkm/ton-km
ΔC_{Emf}	Emission factor	Kg CO_2/vehicle km	CO_2/vkm

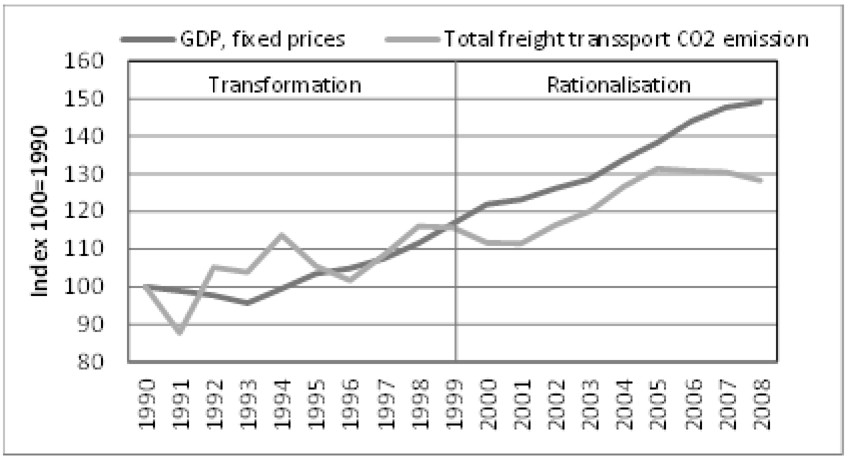
$$\Delta C_{emissions} = \Delta C_{GDP} + \Delta C_{Val\_Dens} + \Delta C_{Tsp\_Int} + \Delta C_{Mode\_Sp} + \Delta C_{Tfc\_Int} + \Delta C_{Emf}, \ (1)$$

3.3 Decomposition of CO_2 development 1990–2008

During the 1990 to 2008 period, CO_2 emissions from transportation of goods in Sweden increased by 28%. Figure 5 illustrates this development along with the GDP growth during the same period. As shown, GDP increased significantly more than emissions. Particularly in the most recent years, growth has increasingly been "decoupled" from CO_2 emissions. Although the financial turbulence has been substantial during individual years, which explains some of the drop in emissions, there is a clear structural trend to this decoupling, which also has other explanations.

There is a certain correlation between GDP and CO_2 emissions, which we can see in Figure 5**Error! Reference source not found.**, but the relation is not the same in both periods of the growth cycle. The annual GDP growth is low during the transformation period, while emissions are fairly high. During the rationalisation period, the reverse is true. The correlation is not linear over a longer period, so growth is not a straight forward indicator of the level of emissions over time. Several other factors – both macro factors (GDP, value density and transportation intensity) and micro factors (modal split, traffic intensity and emission factor) – play key roles in this context. To define the driving forces behind emissions, we can decompose the course of events. Table 3 shows the results of such a decomposition. In the following sections, we compare this result with what was previously expected in consideration of the characteristics and progression of the growth cycle.

Figure 5. **GDP in fixed prices and CO_2 emissions from the goods transportation system in the period 1990–2008**



The period as a whole

Seen over the course of the whole period, the three macro factors had the greatest significance for total emissions. GDP growth has the greatest effect (+47%), followed by transportation intensity (+38%). The combined effect of these two factors is partially counteracted by the structural change, measured as an increase in value added per tonne or as a reduction of tonnes per value added (–50%). This structural change, which includes both increased knowledge intensity in industrial products and a greater element of services in the economy, is the most important inhibiting factor for emissions from the transportation of goods in Sweden.

Micro factors that can be related to new organisational and technological solutions in the fields of transportation and logistics are subordinate to the macro factors seen over the whole period. The total effect of the choice of mode of transport, primarily through an increase in road transports, contributed to a moderate increase in emissions (+7%), while factors related to traffic intensity (vehicle capacity and fill rate) had a slight counteracting effect (–8%). The results are consistent with previous studies (Sorrell et al., 2009; Kveiborg & Fosgerau, 2007; Åhman, 2004).

Table 3. **The contribution (%)***

Factor	Transformation 1990–1999	Rationalisation 1999–2008	Period 1990–2008
ΔC_{GDP}	17	26	47
$\Delta C_{Val\ dens}$	–34	–14	–50
ΔC_{Tsp_int}	31	6	38
ΔC_{Mode_sp}	11	–4	7
ΔC_{Tfc_int}	–15	6	–8
ΔC_{Emf}	5	–9	–6
$\Delta C_{emissions}$	16	11	28

* (Shapley values) of six factors to the change in CO_2 emissions from the goods transportation system relative to the base year in three periods: transformation (1990–1999), rationalisation (1999–2008) and the period as a whole.

In this context, we are primarily interested in the dynamic changes over time, not the changes between two fixed points in time. Table 3 indicates that different factors have different significance during the two phases of the growth cycle. Their relative effects on emissions change over time. In general, we see that micro factors have the greatest effect during rationalisation, while macro factors have the greatest influence in the transformation. These observations are consistent with what was previously said about the characteristics and progression of the growth cycle. We will analyse these connections more closely by studying the transformation and rationalisation separately.

Transformation

As we see in Table 3, the changes in value density and transportation intensity have a much stronger effect in the transformation than during rationalisation. From the perspective of the growth cycle, this is to be expected. During the 1990s, the transformation of the Swedish economy was primarily fuelled by a significant restructuring of the manufacturing industry (Lundquist et al. 2008a). A strong growth of new, knowledge-intensive industries, technological renewal of traditional industrial sectors and the phasing out of outdated and stagnated industrial industries resulted in a dramatic increase in value added per produced tonne in the Swedish economy. This manufacturing-related restructuring of the Swedish economy was the single most important factor that restrained the increase in CO_2 emissions from the transportation sector. However, as Figure 6 shows, this restructuring had the knock-on effect of greatly heightened transportation intensity. This increase is most likely due to the fact that the newly evolving industries began to use unproven supply chains in the attempt to find suppliers of new components, even if their location was less desirable from the perspective of transportation costs. Unexpected bottlenecks in production and deliveries forced companies in new industries to change suppliers repeatedly, with little consideration of transportation costs or logistical efficiency. This continuously increasing transportation intensity thus counteracted the advantages created by the massive structural change.

The increase in emissions from modal split (+11%) is entirely due to increased road transports during the transformation period. This development is expected, since the advent of new supply chains and changed methods of organising production also led to greater demand for flexible transportation and logistics solutions.

While changes in transportation intensity and increased road transports contributed to greater emissions during the transformation period, the development of traffic intensity had a lessening effect (-15%). This was somewhat unexpected, because it indicates a more efficient use of transportation resources during a period in which we otherwise expect companies to be more interested in volume growth and market expansion than cost efficiency. However, several exogenous events during the period can explain this development. In the mid-1990s, new ordinances and regulations were implemented in Sweden that allowed the use of heavier trucks. This led to an increase in both vehicle capacity and average payload, which in turn boosted efficiency in road transports (Åhman, 2004, REDEFINE, 1999). Another explanation is related to changes in the freight transport market. When Sweden entered the EU, the Swedish trucking market was consolidated into a handful of dominant companies, which came to represent about 85% of the market. These major players optimised their traffic networks by reducing the number of terminals and using fewer and larger vehicles with greater fill rates than previously (Transport Group 2010, Berglund et al, 1999). Studies in other countries during the same period show similar results (Kveiborg & Fosgerau, 2007).

Finally, the emission factor had an increasing effect on emissions (+5%). This is also expected, because the period is characterised more by growth than by cost-effectiveness measures; it is also a result of the introduction of larger vehicles during the period. The strong economic growth is probably one reason why the vehicle fleet was not updated fast enough with new innovations in aerodynamics, tyre pressure, fuels and engines to slow down the increase in emissions. Larger vehicles and heavier loads consumed more energy and therefore generated higher emissions. The improvements in vehicle usage that occurred during the transformation were counteracted by the increase in emissions per kilometre.

Figure 6. **Development of underlying factors during the transformation period, 1990–1999**

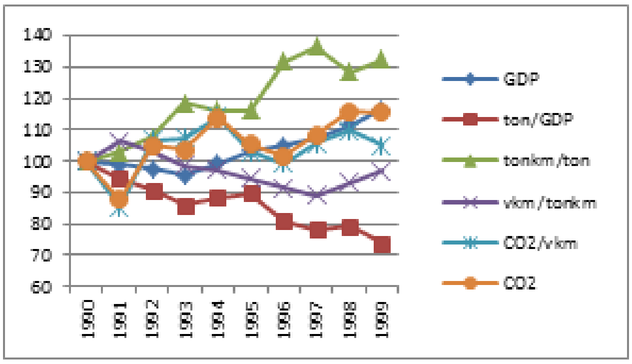
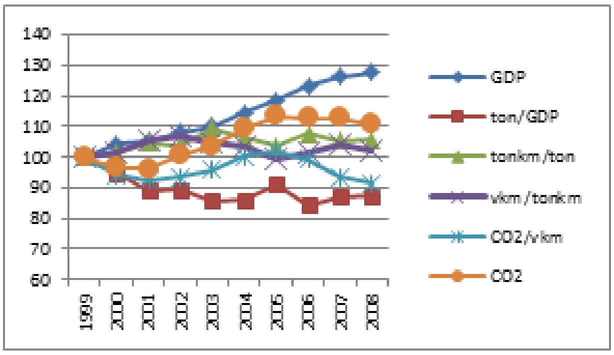


Figure 7. **Development of underlying factors during the rationalisation period, 1999–2008**



Rationalisation

As Table 3 shows, macro and micro factors have different effects during the rationalisation and transformation periods. Figure 7 shows the progression of the rationalisation period. The most important observation is that the total interaction between macro and micro factors results in a clear decoupling of economic growth and emissions. This occurs despite the high GDP growth that characterises the rationalisation period right up until the global banking and finance crisis.

The higher rate of GDP growth during the rationalisation period contributed to an increase in total CO_2 emissions from freight traffic as compared with the transformation, i.e. 26% compared to 17%. However, it is not the rate of growth in itself that is most significant for the end result, but the forces behind the growth and their effects on other macro and micro factors.

Growth during the period is characterised by consolidation and rationalisation in industry. This process leads to enhanced productivity in general, and to strong growth for many services. The emergence of the "weightless economy" in Sweden is primarily the result of the extensive restructuring of the manufacturing industry that occurred during the transformation. This industrial transformation, however, was more or less complete by the turn of the millennium, which is a key reason why the mitigating effect of value density on emissions dropped precipitously and then stabilised at a low level during the rationalisation (Figure 7). An additional factor was a dramatic increase in global demand for natural resources and raw materials during the rationalisation period, particularly from the new growth economies, which grow strongly in the latter half of a growth cycle. This resulted in an upswing for traditional Swedish industries such as mining, steel and forestry. Development is not only reflected in an intense increase in value added, but also in rising transportation costs for these industries. This expansion of raw materials dampens the effect of the general trend of increased services, which would otherwise have led to a further increase in value density in the Swedish economy. As Table 3 shows, the restricting effect of value density on emissions diminished drastically from −34% in the transformation to −14% in the rationalisation. It should be pointed out that the remaining inhibiting effect on emissions is almost entirely due to the general increase in services of the Swedish economy and not to further weight losses within the manufacturing production.

Table 3 also indicates that the change in transportation intensity during the rationalisation period tends to increase emissions (+6%), but to a significantly lesser degree than during the transformation, when this factor was the single most important driving factor behind increasing emissions. This development is consistent with previous hypotheses. During the rationalisation, economies of scale and greater productivity become increasingly important in more and more parts of the economy, which also heightens the demands on rationalisation and efficiency in companies' supply chains. Lundquist & Olander's (2009) results support this, showing that logistics and transportation costs for Swedish companies, particularly in the manufacturing industry, gradually decreased from the late 1990s to the middle of the past decade. This process resulted in a redistribution of Sweden's total transportation costs, from the manufacturing industry towards the service sector, particularly retail and wholesale trade. The total effect was a slower increase in tonne-kilometres per tonne of transported goods during the rationalisation period, and therefore a drop in the rate of growth of CO_2 emissions during the period 1999–2008.

In addition, we can see in Table 3 that, consistent with the above development, the effect of the distribution of modes of transport (modal split factor) has changed, from being a significant factor in increasing emissions during the transformation period to a factor in reducing them during the rationalisation period. This means that a greater proportion of tonne-kilometres were transported by rail and sea, and a smaller proportion by road. This development was expected for two reasons: firstly, as the new production is streamlined and logistics and supply chains become increasingly structured and effective, the need for flexible road-based transportation solutions decreases. Secondly, the revitalisation of traditional manufacturing industry and the "return" of production based on raw materials both contribute to creating a greater demand for rail and sea transportation solutions, because heavy industry can make use of the economies of scale offered by these modes of transport (Transport Group, 2010). Thus, the net effect of modal shifts is to help limit the emissions from transportation of goods during the period.

The effect of traffic intensity on the CO_2 emissions from goods transportation changes over the growth cycle, from reducing emissions to increasing them. This indicates that the rationalisation period is characterised by falling vehicle capacities and/or lower fill rates and poorer usage of capacity. This effect can in part be explained by the increased importance of customer service, as discussed above. The Transport Group (2010) supports this interpretation, showing that smaller vans took over a larger proportion of total road transports during the period. This development is most likely due to more frequent deliveries because of just-in-time and other time controlled production systems. Thus, from the perspective of the supply chain, we can note that during the rationalisation period, while transports become increasingly well organised and consolidated in businesses that upstream in the supply chain, a different set of motivators leads to increased transportation work closer to the consumer. However, it is important to emphasise that traffic intensity throughout the period has proven to have a significant restricting effect on the growth of emissions. The level has been more or less constant since the beginning of the millennium.

Finally, the emission factor that increased the goods transportation sector's CO_2 emissions during the transformation period demonstrates a restricting effect during the rationalisation period (–9%). As in the previous period, explanations linked to changes in vehicle loading capacity cannot be ruled out. However, it is significantly more likely that the reduction in the emission factor is related to technological breakthroughs (for examples, see the previous section) in the transportation sector. Many of these innovations were known and introduced into the market as early as in the late 1980s and early 1990s, but did not start to demonstrate a restricting effect on emissions until much later, when the technology had matured and the absorption capacity in the industry had reached the right level. New ways of organising transports also contributed to the restricting effect on emissions at this time. The impact of these efforts also coincides with strong economic incentives for companies and industries to cut costs in general, which characterises the economic behaviour during the rationalisation period of the growth cycle. From this perspective, the curbing of emissions from this factor is more like a side effect of cost-cutting strategies than constituting conscious attempts to reduce emissions.

Main findings

As we have shown, the figures the model generated for the period 1990–2008 supported our assumptions. The expected differences between the two periods of the growth cycle in terms of the relationship between GDP and emissions from the transportation of goods were indicated. We also saw expected differences between how macro factors (GDP, value density and transportation intensity) and micro factors (modal split, traffic intensity and emission factor) contributed to emissions in the two periods. In total, the results show that the differences and the changed relationships between GDP growth and growth in emissions from the transportation of goods over the course of the growth cycle are not linear and therefore cannot be explained solely through economic growth. The growth rate itself is not the determining factor; rather, it is the factors and mechanisms that propel development. The effect of each factor and the relationships between them change over time, resulting in varying degrees of “decoupling” between emissions and growth. The general trend is that macro factors are most important to emissions during the transformation period, while micro factors related to companies’ logistics and transportation decisions and technological development are most important during the rationalisation period and the subsequent structural crisis. In the short term, the micro factors can most easily be influenced through changing standards and business models at companies and through policy instruments in the public sphere. This means that the opportunities for companies to reduce emissions through various measures and for society to influence developments through policy instruments will increase dramatically in coming years as the rationalisation period turns into a structural crisis. Effective collaboration between regulation and economic development is greatest at the end of a growth cycle. It should be possible to take advantage of this to rapidly decrease emissions from the transportation of goods. The remainder of this paper is based on these historical results and experiences.

4. CHALLENGES AND REGULATION UP UNTIL 2020

In the following chapter, we discuss the challenges and opportunities in the medium term – the period that is relatively foreseeable from both a macroeconomic perspective and a company perspective. Since the long-term targets for reducing emissions apply to 2050, the target for 2020 may differ depending on the direction that the reduction of emissions takes. As described in chapter 3, the discussion is exemplified by Sweden. This chapter is structured as follows: First we present the target for 2020. Then we present the expected *trending development* (the trend as it looks today), based on the dynamics of the large system discussed in the previous chapter. Next, we investigate what measures are required for a *possible faster development*, and what such a development could at most lead to in terms of reduced CO_2 emissions. We then investigate the *expected development* up until 2020, as stated by companies in the small system. The *possible faster development* and the companies' *expected development* differ. The reason for this is that an aggregated CO_2 potential at macro level sometimes cannot be achieved while simultaneously observing restrictions at micro level, such as vehicle compatibility with specific goods, the capacity of individual vehicles or time limitations. Since there is a gap in the courses of development between these alternatives, we discuss policy instruments that could conceivably be used to close the gaps. The chapter then concludes with a few reflections. The focus of this discussion is the "small" system in Figure 1.

4.1 Targets for 2020

The planning of national transportation systems has hitherto been primarily based on projections of existing trends. This has led to investments and measures that have often conflicted with other goals, such as climate targets. As an example, the Swedish Transport Administration posits that projections about increased truck transports have motivated greater investments in roads, which the administration thinks would have been better spent on enabling more freight transportation by rail and sea (Swedish Transport Administration, 2012). Increased investments in the road network in turn boost demand, which leads to even higher projections.

The formulation of the targets for 2020 indicates a modest rate for achieving the long-term targets: by 2020, the Swedish reduction target is 40% compared with 1990 (Swedish administration, 2008). The target for the EU is 20% by 2020 and 40% by 2030 (EU, 2011). As described in chapter 1, projections, increases, and estimated effects of regulatory measures that have already been implemented or are planned contrast sharply with the targets, regardless of which targets we consider. Thus, with the current trend, CO_2 levels are expected to increase.

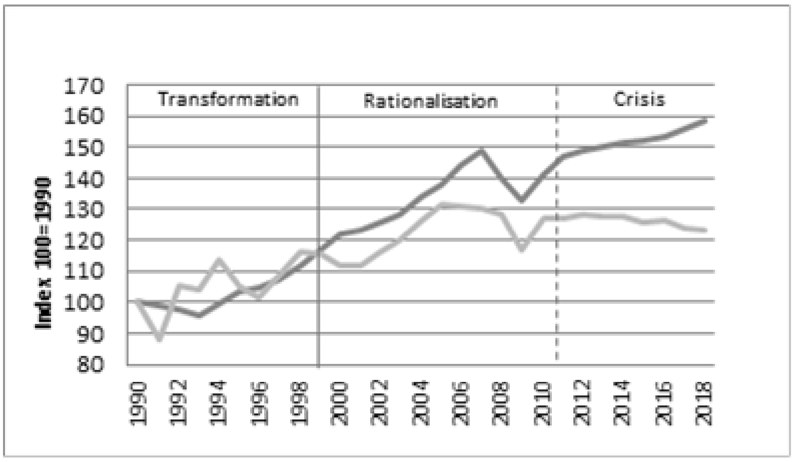
4.2 Trending development: "Business as expected"

None of the projections, analyses and targets that are used include the reasoning that we develop above, in chapter 3. The link between GDP and CO_2 emissions differs in different parts of the growth cycle. The transformation and rationalisation periods involve major changes in production, its organisation and location, and thus alter the effect of various policy instruments and measures. The practically linear projections used in forecasts do not consider the variations in growth cycles that we have seen in the past, nor are they consistent with the challenge of steering towards specific emissions targets, such as the climate target.

With the decomposition model we described in chapter 3, we analysed the actual development of CO_2 emissions from the transportation of goods up until 2008. According to growth cycle theory, after this point the Swedish economy will have a few years of stagnating growth, continued rationalisation and increased competitive pressure from external sources. This final phase of the growth cycle is called the structural crisis period. It usually lasts a few years before the new growth direction stabilises the economy and eventually gets it rolling again.

In Figure 8, we attempt to estimate the significance of this crisis period for the CO_2 development from Swedish goods transports. Figure 8 is identical to Figure **Error! Reference source not found.**5 for the years 1990–2008. Between 1998 and 2008, a clear "decoupling" occurred: GDP increased faster than CO_2, and in the final years the absolute CO_2 levels decreased. The model and the figure have been updated with actual values for dependent and independent variables for the years 2008–2011. As shown, GDP has nearly recovered from the bank and financial crisis of 2008/2009 and is close to the 2006/2007 levels. CO_2 development has also "recovered", but not to the same extent; rather, it has flattened out. The gap between GDP and CO_2 has thus increased during these years that have been updated with new, actual data. For the years 2012–2018, the figure shows a "business as expected" projection, which can also be described as a theoretically informed crisis projection. It is based on the assumption that GDP, given its actual level in 2011, will develop relatively similarly to the GDP in the previous structural crisis in the late 1970s, i.e. we will see growth figures decreasing and stagnating in the future. This is based on the assumption that the European, Japanese and American debt crises and the cost increase in China will dampen international demand for goods and services and intensify global competition for several years to come.

Figure 8. **GDP in fixed prices (darker line) and CO_2 emissions from goods transports (lighter line), 1990-2018***



* Projection based on *trending development* during the structural crisis, 2012-2018

Overcapacity and increased international competition will lead to continued stringent rationalisation. Companies will close, unemployment will increase, profits will drop and demand will decline even more. The new technology-driven and supply-driven parts of the economies will not be able to create their new development paths in such a short time. This projection is also based on the assumption that value density, transportation intensity, traffic intensity, modal split, energy intensity and emission intensity will continue to develop according to the current trend in relation to how they have developed so far during the rationalisation years of 1998–2011 (Table 4). These assumptions are based on the idea that the crisis period is a continuation of the rationalisation period. It is possible that the stringent rationalisation that will occur during the crisis period is underestimated (see below).

Table 4. **Contribution (%) of various factors by 2018 if CO_2 develops according to the current trend, as compared with 2011**

Factor	Contribution, in per cent, of various CO_2 change factors by 2018 as compared with 2011
GDP	+12
Inverse value density	–9
Transportation intensity	–4
Traffic intensity	–1
Emission factor	0
Potential total CO_2 change	**–2**

The result of this crisis projection indicates that development will spontaneously double the relative "decoupling" during the crisis period. Absolute CO_2 levels will also decrease, but not very much. The reduction will result in a CO_2 level corresponding to that of the early 2000s. This means that we still have a long way to go to the Swedish 40% reduction of the 1990 levels of climate gases by 2020 that the two-degree target requires. Apart from the assumption about the coming GDP development being non-linear, this projection contains only assumptions that other factors will continue to develop according to the trend they have followed 1998-2008. Such assumptions may be far too conservative and unrealistic considering the new opportunities to streamline logistics and increase technical development in the coming years. Competition and cost-cutting imperatives will also become tougher during the crisis than during the rationalisation period, which will most likely make companies even more willing to take advantage of new opportunities. If these new assumptions and realistic opportunities are added to the projection, CO_2 development may well be more favourable. The following section discusses and tests such opportunities.

4.3 Possible faster development: overall perspective on possible measures by 2020

It is obvious that without active changes, CO_2 emissions from the goods transportation system in Sweden will be far from achieving the target for 2020. Several measures could be implemented to prevent this. As it is ultimately the companies in the small system that influence emissions in this short a term, this is where changes must primarily occur.

In this section we discuss the measures that have been proposed in earlier reports to reduce emissions from the goods transportation system. This will give an idea of what is considered possible in terms of reduction potential with the current economic structure. In turn, this will give us an idea of what appears to be the maximum possible CO_2 reduction in Sweden by 2020, given the projected economic growth as set out in the previous chapters.

Three overall opportunities to reduce emissions

In an overall perspective on emissions from the transportation of goods, emissions can in principle be reduced by reducing one of the factors in the decomposition model in Chapter 4. Thus, measures can roughly be sorted into three primary approaches:

1. Reducing demand for goods transports
2. Streamlining logistics or
3. Implementing new technology

Demand for goods transports in the small system can be influenced by reducing consumption of new products or increasing the proportion of the service sector. *Streamlining logistics* means changing the structures and processes in logistics to allow shorter transport distances, fewer vehicle kilometres within given distribution structures, or a larger proportion of transports with more energy-efficient vehicles. *Implementing new technology* can occur in both the transportation sector and in infrastructures in the large system. Both current and future technological development in the large system can be implemented in the long run. However, there is already extensive technology that could be used to drastically reduce emissions, but it is currently not being implemented by companies for various reasons (see section 4.4 on the companies' perspective).

Aggregated reduction potential

Let us illuminate the potential for CO_2 reductions in the three overall approaches listed above by analysing related company measures. Over the past few years, authorities, organisations and researchers have produced several reports analysing, at the aggregate level, the potential for CO_2 reduction of various measures. This section presents some of those reports.

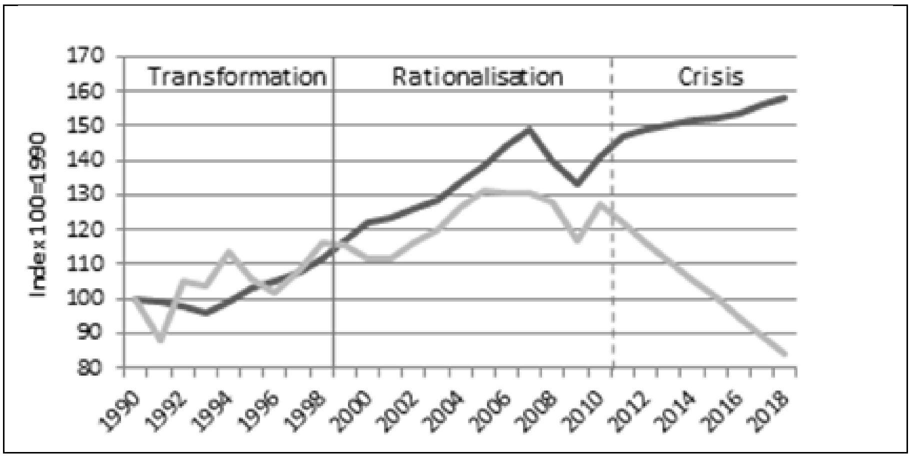
In our further analyses, we base our calculations on a report by the World Economic Forum (WEF). This report is selected as it presents and analyses a range of measures for globally reducing CO_2 emissions from the supply chains of goods-owning companies within current available technologies and supply chain setups (Doherty and Hoyle, 2009). Through various calculations, the WEF report analyses both the potential and the feasibility of each measure, illustrated here in Table 5. Those measures deemed to have both the highest potential and the greatest feasibility are the implementation of cleaner transport technologies and reducing speed in logistics networks.

Table 5. **Measures for carbon-efficient supply chains**
(Doherty and Hoyle, 2009)

Measure	Reduction potential (Mt CO_2)	Estimated feasibility
Cleaner vehicle technology	175	High
Reduced speeds in supply chains	171	High
Enable carbon-efficient purchasing: agriculture	178	Medium
Optimised networks	124	High
Make buildings more energy-efficient	93	High
Packaging design	132	High
Enable carbon-efficient manufacturing	152	Medium
Training and communication	117	Medium
Modal shift	115	Medium
Recycling	84	Medium
Local purchasing	5	Medium
Increased proportion of home deliveries	17	Medium
Reduced traffic congestion	26	Low

Other publications on this topic analyse scenarios for reducing CO_2 emissions from transport until 2050 internationally (for instance, IEA, 2009; ITF, 2012) and current trends and measures for reducing transportation emissions on national levels (for instance, the UK (Piecyk and McKinnon, 2010); Sweden (Elforsk, 2012; Swedish Transport Administration, 2012)).

Figure 9. **GDP in fixed prices (darker line) and CO_2 emissions from goods transports (lighter line), 1990–2018***



* Forecast based on *potential opportunities* during the structural crisis of 2012–2018.

Our next forecast is based on the assumption that the coming GDP development will not be linear during the crisis. Once again, the assumption is based on the actual level in 2011 and the belief that GDP will thereafter develop relatively similarly as it did during the previous structural crisis in the late 1970s. The assumptions about the development of the other factors, however, have changed compared with the previous projection. We no longer assume that development will continue according to the trend. Instead, we base our assumptions on the WEF report, which analyses various measures to reduce CO_2 emissions from companies' supply chains (see Table 5). Working from this report while maintaining the assumption that the coming GDP development will not be linear during the crisis, we can generate a new projection of maximum potential. The measures in this projection are more far-reaching than those previously assumed according to the trend. The measures in the WEF report do not have a specific timeframe, but all are believed to be possible to implement within the existing cost structure, infrastructure and technology. Using the WEF's assumptions, our calculations show a potential to reduce CO_2 emissions from the transportation of goods in Sweden by about 33% compared with the 2011 level by 2018. This means a reduction to 15% below the 1990 level of CO_2 emissions from goods transports. The target is 40% below the 1990 level. Compared with Piecyk and McKinnon (2010), our projection falls somewhere in between their cautious, realistic projection and their most optimistic one. Our calculations are based on the assumption that GDP will not grow linearly during the period. Annual growth is assumed to decline and at times stagnate, as has been seen in previous structural crises. This is consistent with the theoretical models presented earlier, and predicts relatively modest overall economic growth during the period. If growth turns out to be greater, this will require greater changes in the areas that are expected to decrease, for example traffic intensity and emission factors, if total emissions are to decrease by 33%. It is difficult to conduct a sensitivity analysis for this. Streamlining in transportation and logistics will be a part of the driving force of an increase in GDP, particularly in periods of low growth. This means that we cannot decouple these changes from each other. What we can say is that the economic growth phase we are currently enmeshed in has a stronger correlation between streamlining measures and GDP compared with other periods of the growth cycle: if GDP were to grow at a faster rate, streamlining would probably be more extensive as well, and vice versa. However, our models cannot currently predict to what degree one will grow faster than the other.

Table 6. **Relative contribution of various factors to a potential decrease in CO_2 emissions by 2018 compared with 2011**

Factor	Relative contribution to a change in CO_2 emissions
GDP	+12
Inverse value density	–5
Transportation intensity	–18
Modal split	–4
Traffic intensity	–11
Emission factor	–7
Potential total CO_2 change	**–33**

Table 6 shows quantifications of possible measures and their effects, which have been used in the projection. The primary contribution comes from the sharply declining emissions from transportation intensity and traffic intensity, while modal split and the emission factor only make limited contributions to to reducing emissions. In the next sections, we will discuss whether this potential can really be used in the years up until 2020, and to what degree various policy instruments are required in order to achieve this. Above all, we will discuss the need for regulating the various factors at the end of the section on *Companies' expected measures* later in this chapter.

4.4 Companies' perspective: Expected development without increased regulation

The previous discussion focused on the maximum theoretically possible reduction in emissions through changes in the small system. In this part of the paper we instead investigate *probable* development, i.e. the measures that the companies in the small system believe are possible and profitable to implement until 2020. We initially describe the overall challenges that companies face in order to reduce emissions in supply chains. We then compare our model calculations with Swedish companies' expectations of the development, based on an empirical survey of these companies' motives and driving forces as well as their estimated measures for reducing CO_2 emissions from goods transportation until 2020.

Motives and driving forces

Awareness of the motives and driving forces of goods owners and transportation companies to reduce emissions from the transportation of goods can help us to understand how regulation can contribute to reducing such emissions. Motives can be found in companies' business strategies, while driving forces stem from external requirements set by various stakeholders. Applying the resource-based view to the reduction of emissions from goods transportation lets us identify various internally based motives: 1) Short-term profitability, 2) Long-term competitiveness, 3) Market-related advantage, 4) Being perceived as an employer with environmental credentials, and 5) Taking social responsibility. We can identify various externally based driving forces in a similar way by applying the stakeholder model to the reduction of emissions from goods transportation: 1) Customer requirements, 2) Authority requirements, and 3) Owner requirements. By seeing these two strategies and models as complementing each other, we can combine them to evaluate what motivates and drives companies to reduce emissions from the transportation of goods.

A survey of 172 companies (corresponding to a response rate of 40.3%) in nine industries in Sweden with a high volume of goods transportation analysed motives and driving forces (Pålsson and Kovács, 2014). The analysis shows that in the issue of whether or not to make their transports greener, company strategy seems to be more significant than requirements from stakeholders. The prospects of reducing emissions are greatest for companies that have motives for improving their economic situation as well as their image. Driving forces based on external requirements do not differ between companies. Requirements from external stakeholders seem to reduce the level of emissions at industry or national level, but do not differentiate between companies. Therefore, to steer development towards an effective reduction in emissions, external requirements in the form of laws and regulations should be complemented by incentives that increase companies' motivation to reduce emissions.

Companies' expected measures

In sections 0–0 we discuss the trending reduction in emissions from transportation by 2020 and a possible more rapid reduction. The conclusion we arrived at through the discussion is that none of the scenarios would lead to the target in Sweden: a 40% reduction of the 1990 level, but that the latter option would make good progress towards the target. However, emissions are primarily determined at micro level in this short perspective, i.e. goods owner companies, transportation companies and other organisations (such as public sector operations) are the players that affect emission levels within the given rules. It is therefore useful to study expected measures for CO_2 reduction among these companies. They can reduce CO_2 emissions from goods transports by implementing various measures, such as changing logistics structures, improving packaging design or using non-fossil fuels (see Table 7 for additional options).

To estimate the development of CO_2 emissions until 2020 we must consider the companies' expected measures. The survey of 172 companies in transport-intensive industries in Sweden analysed the prospects of companies reducing their transport emissions until 2020 by introducing the measures described in Table 7 (Pålsson and Johansson, 2013). The survey shows that goods owner companies and transportation companies in Sweden will probably reduce their CO_2 emissions from the transportation of goods in the coming decade. The estimated reduction will come from a combination of measures. Table 7 shows the proportion of companies that estimate the likelihood of them implementing various emission-reducing measures as moderately high to extremely high. Because the survey reveals a clear link between the estimated potential for CO_2 reduction from a specific measure and the probability of its implementation, the table indicates which measures will have the greatest total impact. For example, the table shows that 77% of the companies estimate that they, with moderately high to extremely high probability, will improve the way in which they plan their transportation (e.g. through groupage and better route planning) to reduce CO_2 emissions. As the probability is positively correlated to the effect of the measure (the latter being slightly higher) we can also conclude that the potential CO_2 reduction for these companies is estimated to be moderately high to extremely high. It is notable that the companies perceive that operational changes, such as improved transportation planning, increased load capacity and eco-driving, will have a greater impact on the reduction than structural changes (relocation of facilities and selecting nearby suppliers) will have.

It is also notable that the main obstacles to many measures are moderately significant or minor, indicating that they should be manageable. Costs are highlighted as an obstacle to 7 in 12 measures, but are only perceived as a significant obstacle in one case. Costs

therefore appear to be a significant obstacle, but their extent should not be exaggerated – in 5 of 12 measures cost is not given as an obstacle at all, and in most cases it is only rated as a moderately significant obstacle.

Table 7. **Companies that estimate they have a moderately high to extremely high probability of implementing CO_2 reduction measures**

Measure	Moderate – Very high probability (proportion of companies in %)	Main obstacles and their extent*
Improved transport planning	77	**Moderate**: *Flexibility, delivery time*
Cleaner vehicle technologies	61	**Moderate:** *Costs, lack of commercial solutions, lack of technical know-how*
Eco-driving	59	**Minor:** *Lack of motivation, lack of competence*
Increased load capacity in vehicles	52	**Minor:** *Infrastructure, laws and regulations*
Non-fossil fuels	46	**Significant:** *Lack of commercial solutions* **Moderate:** *Costs, lack of technical know-how*
Replacing trucks with other mode of transport	46	**Significant:** *Flexibility, delivery time, infrastructure* **Moderate**: *Costs*
Introducing traffic control technologies	45	**Moderate**: *Lack of IT*
Using nearby suppliers	36	**Moderate**: *Costs*
Packaging design	39	**Moderate:** *Costs*
Load carrier design	36	**Moderate**: *Costs*
Relocation of production facilities and warehouses	34	**Significant:** *Costs*
Replacing transport by air with other mode of transport	28	**Moderate:** *Delivery time, flexibility*

* The obstacles can be extremely minor, minor, moderate, significant or extremely significant. The largest are included in the table.

In the discussion of the model in chapter 3 showing the development of emissions from transportation over time, we used emission factors (Table 2). The companies' expected reduction must be related to these emission factors and then compared to the current trending reduction and the possible result of the model calculation. From a company perspective (focusing on logistics and transportation) the factors economic activity and value density cannot be influenced. Transportation intensity can be reduced through shorter transport distances, i.e. by changing the logistics structure through increased use of nearby suppliers or relocation of production facilities and warehouses. Traffic intensity involves driving fewer vehicle kilometres within a given logistics structure. This can be achieved through improved transportation planning, better design of packaging and load carriers or increased load capacity. Energy intensity addresses energy consumption per vehicle kilometre, which can be reduced by a shift from transport by air to a different mode of transport, a shift from trucks to an alternative mode of transport, the introduction of traffic control technologies or eco-driving. Finally, emission intensity – emissions per produced quantity of energy – can be reduced by using non-fossil fuels or switching to cleaner vehicle technologies. These relationships between company measures and emission factors are shown in Figure 10 further on in the paper.

To assess previously presented model calculations of CO_2 reduction in until 2020, the aggregated trending model calculation in Table 4 and the possible more rapid development in Table 6 are compared to the companies' own views of measures and effects on emission factors according to Table 7. We present our interpretation of this comparison below. In connection with this interpretation we also present possible policy instruments to influence the factor. A more complete list of policy instruments that influence each factor (intensity) is shown in Figure 10.

Transportation intensity. The calculation model showed that this factor will have the largest individual impact in both a development based on the current trend (–4%) and in the case of more rapid development (–18%). The companies' valuation of this factor in the small system is closest to the trending development because, on average, they rank potential effect as moderately high, but the probability of changing logistics structures as quite low. This may be related to the fact that when logistics structures are changed it is quite difficult to forecast effects on CO_2 emissions, because the implementation of various company measures may influence each other. For example, centralisation may lead to a shift from road to rail transport, which can consequently reduce emissions even if transport distances increase (Aronsson and Brodin, 2006). Seeing as companies' expectations are closer to the trending development than the possible development, greater regulation of transportation intensity may form part of the solution. The policy instruments that affect transportation intensity are shown in Figure 10 and include demonstration projects and good examples, research and development, emissions trading schemes and infrastructure investments.

Traffic intensity. In the trending development, this factor contributes a –1% reduction, but it is the second most significant factor in a more rapid development (–11%). The latter is closest to companies' own valuations of measures linked to traffic intensity. The immediate interpretation of the Swedish companies' valuations is that the market mechanisms along with existing policy instruments are sufficiently strong to achieve a substantial reduction of CO_2 emissions related to traffic intensity. Similar potential for improved transportation planning was confirmed in a study in the UK (Piecyk and McKinnon, 2010). The potential is related to a greater load factor and fewer transport runs with empty vehicles. The most important obstacles are the lack of flexibility and increased delivery time. Another company measure related to fewer vehicle kilometres is the use of vehicles with a larger load capacity, which was judged to have relatively high impact. This may, however, be a somewhat conservative assessment, because experiences from both the UK (McKinnon, 2005) and Sweden (Berndtsson, 2011; Vierth et al., 2008) of increased maximum vehicle weight have resulted in major economic and environmental benefits. Many policy instruments can be related to traffic intensity (Figure 10), such as vehicle control, capacity control, congestion charging and road toll charges.

Energy intensity. For technical reasons, the calculations only produced one value for a more rapid development and that was for a fraction of the energy intensity; a modal split (–4%). However, the companies estimated that measures related to a modal shift (replacing road transport with transport by rail or sea) will have a relatively high potential impact and there is a moderately high probability that such measures will be introduced. Due to limitations in railway infrastructure, we should point out that intermodal transportation by rail cannot be the main solution with which to achieve carbon-free goods transportation in the next decade. The companies' responses clearly show that there are good reasons to increase the opportunities for intermodal solutions via proactive investments in infrastructure, even if such solutions cannot be fully realised in the shorter timeframe. With the above outcome and reasoning, we can see that the modal shift factor is of relatively equal importance, but is perhaps somewhat undervalued in the model calculations compared to the companies' estimates. For the energy intensity factor as a whole, other measures for reduced energy consumption should also be considered. Eco-driving is estimated to have moderately high to high potential and is expected to be introduced during the next ten-year period. However, the potential effect and probability of implementing traffic control technologies is given quite a low ranking. Overall, we note that the companies value measures related to energy intensity slightly higher than the result of the calculation model for modal shift. The thinking about energy intensity as a whole indicates that the need for policy instruments is greatest to support intermodal solutions and traffic control technologies. Examples include infrastructure investments in rail, research and development, and demonstration projects and good examples. This reasoning is supported by the fact that the survey above showed that intermodal users are more positive to increasing their use of intermodal solutions than those not using such solutions.

Emission intensity. The contribution of this factor in the calculation models was 0% in the trending development and the second lowest (–7%) in a more rapid development. The companies' estimates are in line with the more rapid development. There is a relatively high level of confidence that technical development will contribute to decreased CO_2 emissions. Such solutions are convenient, because they do not affect logistics structures or logistics decisions. Our survey shows particularly great confidence in the potential effect of using non-fossil fuels. Due to a lack of confidence that commercial solutions will be available during the next decade, the respondents are somewhat sceptical to non-fossil fuels making a major breakthrough during the ten-year period. Considering the companies' valuations, the effect of emission intensity on emissions from the transportation of goods in Sweden should increase somewhat in the next decade compared to the calculations for the possible rapid development. The technical solutions that the surveyed small-system companies plan to implement, however, are developed in the large system. To enable the companies (in the small system) to implement what they expect, policy instruments may be necessary to achieve technical developments – for example in the form of fuel classification, environmental classification of vehicles, tax relief for biofuels, and research and development.

Overall, there is agreement between the calculations presented in Table 6 and the companies' valuations. Our interpretation is that the total calculated potential reduction (-33%) lies within the same range as the companies' total estimates. However, the companies' estimates show a slightly different distribution between the factors. Taking the company perspective into consideration, the potential of transportation intensity should be reduced and the remaining three should be increased somewhat.

Besides the gap between expected development and a possible more rapid development as described in the above factors, there is also a gap between the companies' estimated potential and their intention to implement a measure. In the case of all company measures, the estimated potential is higher than the intention to implement the measure. Regulation can be introduced to reduce this gap; there are thus two reasons why regulation is necessary:

1. Regulation to reduce the gap between the companies' expected development and a possible more rapid development. This varies between the different factors as discussed above.

2. Regulation to increase the level of implementation among companies so that the potential they believe to exist is actually achieved.

As a whole, the companies' estimates of expected development are in the range between the trending development and a possible more rapid development (section 4.3) for all factors. Their positions within the range vary – the further the companies' estimates are from the more rapid development, the greater is the need for regulation in order to achieve full potential. Regulation linked to point 2 above is relevant to all the factors. We gauge that greater regulation is required in these areas:

- Transportation intensity: Regulation can potentially increase the reduction level.
- Traffic intensity: It appears that many companies in the small system will achieve the more rapid development, which indicates that regulation is above all required to close the gap between the companies' valuation of potential for and probability of implementation.
- Energy intensity/Modal shift: For technical calculation-related reasons, the estimate of energy intensity is incomplete, but the potential for a modal shift seems to be achievable for many companies. Greater regulation should primarily focus on intermodal solutions and traffic control technologies. In other respects, regulation is mainly required for the gap in point 2.
- Emission factor: As the companies' estimates are in line with the more rapid development, regulation must primarily close the gap in point 2. To ensure that technical development makes sufficient progress among the companies in the large system so that implementation can take place in the small system, policy instruments are probably also required for technical development.

4.5 Regulation until 2020: closing the gap between companies' expected development and a possible faster development

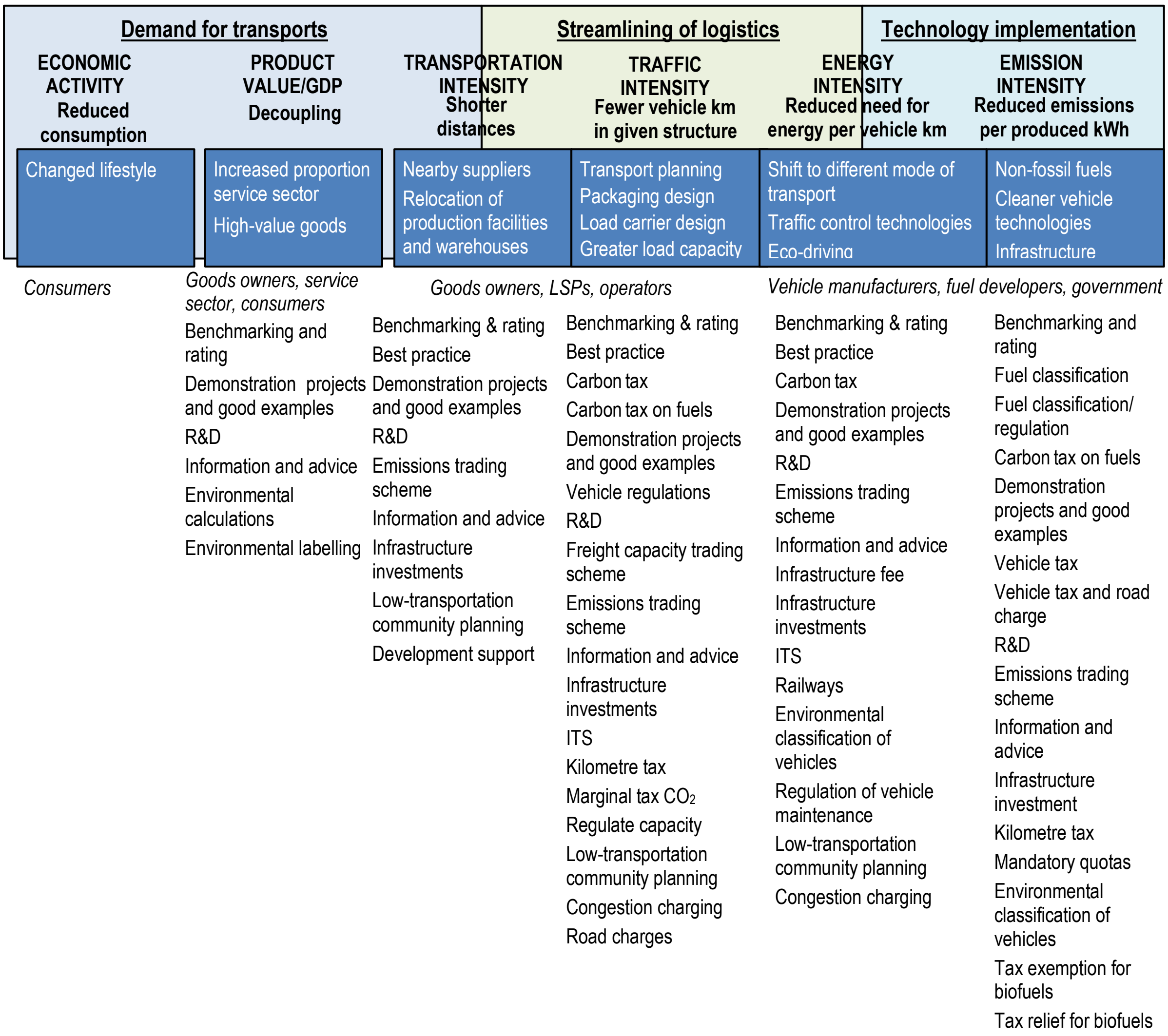
The descriptions in this chapter so far have shown that there is a gap between companies' expected CO_2 development regarding the transportation of goods and a possible faster reduction within the framework of existing industrial structure, cost structure, infrastructure and technology. Part of the reason for the gap is that companies estimate a somewhat lower reduction potential than the model calculation, but above all that companies believe that certain measures will not be fully implemented.

As previously discussed, there are good opportunities of closing the gap between companies' expected development and a possible faster development. We have demonstrated that the companies have cost-related and image-related motives for CO_2 reduction and we are also in a rationalisation phase, heading towards a structural crisis in which there is generally a high level of acceptance for streamlining measures. Some emissions can even be reduced at a negative marginal cost, i.e. the measure costs less than other costs will drop with the reduction. The years up until 2020 are thus a highly suitable period in which to introduce policy instruments that boost rationalisation trends in industry and commerce and lead to larger reductions in emissions than would otherwise take place. As discussed earlier in this chapter (under *Motives and driving forces)* this can be achieved by designing policy instruments that address the companies' internal motives for further cutting emissions. Although part of the reduction can be achieved with small means, this does not mean that it is easy to close the gap. Some policy instruments are less accepted than others and certain measures are more costly than others. The results in this chapter show that reductions of about 30% are possible by 2020 if a number of policy instruments are introduced. These results are in line with several other studies (cf. Piecyk and McKinnon, 2010; Swedish Transport Administration (2012)).

Policy instruments to reduce emissions from the goods transportation system

Regulation is required to achieve the possible potential of reducing CO_2 emissions by about 30% by 2020. A review of existing and proposed future policy instruments for the transportation of goods described in scientific literature and authority reports showed four categories of such policy instruments (Stelling, 2011). *Economic policy instruments* can be used for lower-carbon transports by increasing the cost of the transport, which may result in a higher price to customers, a shift to a different mode of transport or streamlining by improving the fill rate, for example. However, the transport cost often constitutes a small proportion of the value of the goods, which reduces the effectiveness of economic policy instruments. *Knowledge-based policy instruments* (information and advice, research and development, demonstration projects and good examples, benchmarking and rating, environmental calculations and environmental labelling) can be used to influence companies' logistics decisions and logistics structures, which in turn affect transportation. *Legal policy instruments* can be used to expedite technological development by gradually increasing restrictive limit values, such as requirements based on the Euro classification of truck engines. Legal policy instruments can also be used to legislate on matters such as vehicle regulation and longer, lighter or larger vehicles and load carriers. *Social policy instruments* have long lead times and will therefore be discussed in chapter 5. They comprise infrastructure investments, intelligent transport systems (ITS) and low-transportation community planning. The review also showed that the scope of policy instruments is limited and that those addressed mainly concern road transports – and above all kilometre tax and emission trading schemes in the transportation sector. Figure 10 below compiles the policy instruments addressed in the literature, links them to company measures, which players are affected and the main approaches to CO_2 reduction. The framework can be used to identity suitable policy instruments for different purposes.

Figure 10. **Framework that links policy instruments to company measures, players, macro factors and main approaches for CO_2 reduction**



Reflections on policy instrument implementation

Up until 2020 Sweden's challenge is to achieve a high degree of implementation of the company measures discussed in section 4.4. Regulation is required in part to reduce the gap between the companies' expected development and a possible faster development according to section 4.3 and in part to increase the implementation level among companies in order to achieve the companies' estimated potential. Reducing the gap between companies' expected development and a possible faster development involves making companies in the small system reduce more than they at present believe they can due to their perceptions of the available potential. The gap can be closed by using regulation to force the creation of the potential revealed in the analysis of the possible faster development. Lessons learnt from other areas and countries can be used to achieve this (Pålsson et al., 2013). To reduce the other gap, i.e. between perceived potential and degree of implementation, the companies need incentives. In this context is it important to understand and address the companies' motives and driving forces. The two gaps and thereby the needs for regulation vary between the different factors in Table 2.

Regulation of transportation intensity is above all required to reduce the gap between the companies' expected development and a possible faster development. Conceivable policy instruments are demonstration projects and good examples, research and development, an emissions trading scheme and infrastructure investments, as well as other alternatives shown in Figure 10. In terms of traffic intensity the first gap is small. This factor instead requires regulation to close the gap between implementation level and companies' estimated potential. Examples of policy instruments include vehicle regulations, capacity regulation, congestion charging and road charges. Intermodal solutions and traffic control technologies for reduced energy intensity are measures that require more regulation, which can take place through infrastructure investments in rail, research and development, demonstration projects and good examples. For other measures in energy intensity, regulation is mainly required for the gap between implementation level and companies' estimated potential. Increased use of intermodal solutions is one measure that can be highlighted. As current intermodal users are more likely to increase their use of intermodal solutions than those not already using such solutions, decision makers can focus on policy instruments that lead to companies testing such solutions. Here there are probably also threshold values that lead to a rise in the propensity to increase intermodality the more widely it is used. The same gap (implementation level and potential) needs to be considered for emission intensity among companies in the small system. However, regulation targeted at companies in the large system is probably also required for the development of vehicle and fuel technologies.

Lessons learnt from other areas and countries (Pålsson et al., 2013)) can primarily be used to create policy instruments to reduce the gap between companies' expected development and a possible faster development. These lessons can complement the existing policy instruments described earlier under *Policy instruments.* By illuminating new angles, the lessons can contribute to creating innovative policy instruments. At the same time, they have already been tested, either in a different context or different country, which means that advantages, disadvantages and conceivable effects should be possible to predict more accurately than for untested policy instruments.

Incentives for companies to reduce the gap between estimated potential and degree of implementation can be addressed through regulation by taking motives and driving forces among companies in the small system into consideration. Based on current development, price mechanisms do not appear sufficient and need to be bolstered with other policy instruments. These should consider the discussion of the motives and driving forces of companies in the small system for reducing CO_2 emissions from the transportation of goods. One insight gained is that, while both internal motives based on the companies' strategies and external requirements from laws and regulations are highly significant to CO_2 reduction, the internal motives have the greatest effect. To address these motives we need new policy instruments. They will indirectly reduce CO_2 emissions, but will primarily affect company culture and consumers' expectations of low-carbon behaviour among companies in the small system. For example, they may consist of information that makes it even more important to companies to be seen as a green employer. Decision makers should also harness the knowledge of how important internal motives and external driving forces are to companies' CO_2 reduction. By taking account of the fact that many companies in the small system regard motives for improving their image as being of equal importance to economic incentives, policy instruments that enable communication of image can gain a high level of acceptance. One such policy instrument is to communicate good examples with Best Available Technology (BAT) applied to every industry.

4.6 Closing the gap between possible CO_2 development and government targets

Even if the combination of policy instruments turns out to be successful, we have discussed that the targets for emission reduction in Sweden will not be fully attained by 2020, because this potential is lacking in the small system and it takes longer to change the slow structures of the large system. The Swedish case indicates similar challenges in other advanced countries. The gap between the Swedish government's targets for 2020 and the possible maximum reduction of about 30% that we discussed in section 4.3 means that a further reduction of 25% is required to reach the desired 40% of the 1990 level of emissions.[3] Our calculations point in the same direction as several other studies with a similar focus: the greatest potential CO_2 reduction with the economic structure, infrastructure and technology we can thus far foresee is insufficient to attain the targets set by the government. There are principally three options for tackling this gap:

1. Reduce growth
2. Lower the targets
3. Implement the remaining reduction after 2020

The first option is difficult to pursue politically during a period that will most likely in all circumstances be dominated by weak growth, competition and structural problems. In addition, even zero growth for several years would not make a notable contribution to reducing emissions according to our model. Further weakened growth during the period would also make it more difficult for companies to implement the measures that would otherwise be possible in terms of costs, logistics and technology. The second option above directly counteracts the task and is therefore not considered. This leaves us with the third option, in which part of the reduction in emissions by 2020 must be postponed, even if some of the decisions must be made before then. In the next chapter we will look ahead and attempt to see how different types of structures at different times may conceivably help to limit future emissions for target achievement by 2050.

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[3] See the discussion under *Aggregated reduction potential* (page 32).

5. PROBLEM SCENARIO 2020-2050

Earlier discussions revealed the difficulties involved in attaining the emission targets set for 2020. Even in the most optimistic scenarios where many measures are introduced, the maximum potential from measures in what we call the small system, appear to fall short of the targets set for the period. Despite the failure to achieve the targets for 2020, there is an opportunity to reach the emission targets for the goods transportation system in the longer term. Measures in the small system do not suffice to reach the targets, so the systems that surround the goods transportation system must be changed in the right direction, which will enable logistics and transportation decisions in the small system to lead to lower emissions. In this chapter we therefore look beyond the small system and discuss what structural changes are necessary in the subsystems that surround and affect the goods transportation system to reduce emissions in the longer term. We also consider the changes that should *not* take place, i.e. changes that lead to behaviour that takes us in the wrong direction in relation to the targets. The “large” system in Figure 1 illustrates the focus of the discussion.

5.1 Growth scenario until 2050

When the current structural crisis has passed in a few years’ time, a new growth cycle will most likely start with an initial transformation phase of about 20–25 years, followed by stabilisation, a rationalisation phase of some 10–15 years. The first years of a new growth cycle generally consist of a recovery based on the economic structure of the preceding cycle. Demand will have been restrained and production capacity will have fallen during the crisis, leading to the release of old growth forces at the beginning of the next cycle. The direction and nature of the first growth from about 2020 onwards will therefore probably resemble those of the “old” economy.

The reduction of tonnes per GDP (inverse value density) that characterised the growth cycle that we are now leaving, arose from the transformation of industry, teamed with strong service development. This transformation took place at a late stage in the previous cycle and can also be expected to occur at a relatively late stage in the next one. This means that initially around 2020 and for a few years afterwards we cannot expect any “automatic” boost from the structure factor to reduce CO_2 emissions. The service part of the economy had already reached its peak at the start of the current structural crisis and has subsequently declined, leading to falling value density and increased transportation. This is due to the dynamic interaction between industry and services declining when the markets become saturated. Fewer genuinely new products lead to fewer new services, which in turn generate fewer new products/services. At the same time, purchasing power, employment and the credit expansion do not grow as much as before. Households’ consumption of goods and services decreases, which affects the retail trade and other household-related industries that grew most just before the current crisis. We will probably have to wait until we are a long way into the next growth cycle before the dynamic interaction between industry and services gets under way and the structural transformation again becomes a factor that restrains CO_2 emissions.

There is therefore a tangible risk that growth will be dominated by traditional production until the mid-2020s, which will increase transportation and possibly emissions again after the crisis. Growth in the new economy develops slowly from the ground up and does not give the transformation its new essence and effects until a few years later. The new growth will eventually take over while the old economy contributes less and less to GDP development. The new economy will be based on GPTs or macro innovations that consist of innovation clusters with strong technical and commercial complementarity. Historically, these technologies have arisen spontaneously and comprised transportation and communication, energy and infrastructure. It is not possible to know for certain what technologies will propel the next growth cycle, but there are strong indications that, for the first time, mankind will have to step in and actively influence the choice of growth direction and technology to solve the resource, energy and climate crises. New macro innovations within this field will create new services and new industries and are already transforming existing economic operations. Company structures, institutions and lifestyles will be affected. This will all take place relatively slowly, often with bottlenecks, dead-ends and lock-in effects that will take time to resolve. Innovations must be built up and markets created, and their application must reach a critical mass to become self-supporting driving forces for development in society.

Even if the new growth, once it begins to impact the economy, will focus on energy-saving products and processes, improvements in energy efficiency, fuel-economical transportation systems and new energy sources, the transformation period will need to include extensive material processing and transportation in its structure establishment phase. It is therefore possible that the period until about 2040 could be a balancing act between the energy efficiency and carbon efficiency of the new production, and the structural transformation that may initially create effects leading in the opposite direction. Private consumption is generally held back during the transformation phase due to the need for comprehensive private and collective investments in machinery, equipment and facilities, which may help to balance the transformation’s advantages and disadvantages.

It is possible that the full effect of the transformation will not become noticeable until after 2040 through a significant reduction of CO_2 emissions and progress towards zero emissions. Not until after 2040, in the rationalisation phase, will the new economy’s structure, production and energy supply be able to have a full effect on CO_2 emissions. Private consumption usually expands strongly during the rationalisation period. Consumption will hopefully have changed, causing less emissions, by about 2040/2050. By that time transportation should also be possible using modes of transport in an infrastructure that contributes very little CO_2 to the atmosphere.

5.2 Regulation, measures and structures

In this section we use the theory of the growth cycle, its different parts and characteristics in order to divide up the description of these years into various periods up to 2050. We examine the scenario above in more detail and illuminate the problems for the transportation of goods. As described previously, changes must take place in the various subsystems in the large system to enable more CO_2 reductions than the small system’s estimated maximum reduction potential (33%). As changes subsequently take place in the subsystems, new measures can be implemented in the small system, i.e. the large and small systems interact. Below we discuss and illustrate using examples of changes how each subsystem could in principle affect the small system in the long term and what direction their development should take. It should be noted that the structures in the various subsystems may alter at different paces and have varying durations. The following division into periods focuses on what decisions should or must be made during the periods, regardless of whether the effect becomes apparent relatively immediately or much later on.

The end of the current structural crisis and start of the transformation

People's consumption, norms and awareness of climate problems may change drastically up to the mid-2020s (Klintman, 2012), which may help to curb private consumption and transportation or at least force them to be adapted towards reducing energy and emissions, given the currently foreseeable opportunities. In addition, private purchasing power may also decrease as a result of government needs to finance society's investments via taxes. Together, such adaptations and measures may spontaneously counteract the increase of traditional goods transportation and emissions that we assume will occur during the period.

Regulations or institutions are one subsystem that affects these issues. Institutional theory differentiates between formal (e.g. legislation) and informal institutions (e.g. norms). It can be difficult and time-consuming to change systems of rules and norms. Political visions and ambitious targets often take a long time to achieve due to the sluggishness of the change process. For example, lobbying organisations, stakeholder organisations and authorities have their own, sometimes opposing, targets. It is also time-consuming, with inquiries and circulation of proposals for comment, to draft legislation or draw up documentation for decisions regarding infrastructure investments or policy instruments for transportation. If people's norms and climate awareness change, this may also create acceptance of a faster adaptation using policy instruments that may reduce demand in the short term, but can streamline companies' material flows and transportation flows and fuel society's investments in climate-smart technologies and energy sources in the long term.

The urbanisation structure of our urban regions, the distributions of the population and the business community, the structure of the national region hierarchy, and the infrastructure (roads, terminals, ports, railways and airports) also belong to the large system, but these structures are more stable and slow to change. Their common denominator is that the decisions made today about their alteration and development will set future frameworks for action for generations of structures that can change rapidly. Up to 2025 it should be important to carefully consider which doors to keep open and which to shut in terms of these slow-changing structures that are significant for capacity and climate issues. The design and urbanisation of urban regions, inter-regional development and the expansion and coordination of core transportation systems must be studied in depth to gain better understanding of their significance for transportation and emissions. The greatest need for innovation is probably the future supply of goods to major urban regions and their importance to transit transportation and transportation to ports, terminals and industries.

Infrastructure investments and decisions concerning them are major challenges to carbon-efficient goods transportation as it is time-consuming and costly to build, rebuild and equip infrastructure. However, changes may have long-term effects on the reconstruction of supply chains. There are also uncertainties related to future progress and investments in logistic infrastructure. A major challenge is to change infrastructure in urban areas, because there are several limitations such as the height of bridges, width of carriageways, dimensions of market squares and risks of damage to objects and areas with cultural heritage. By applying a marginal change principle like in Sweden today the recommendation is minor infrastructure measures combined with measures for better use of existing infrastructure, because this utilises today's resources more efficiently. This planning principle risks contributing to preservation of today's infrastructure, as building new infrastructure is a last resort.

The short-term changes to passenger transportation that affect goods transportation mainly comprise changed utilisation of the infrastructure and the vehicles. One short-term possibility is to allow public transport by road to accommodate the increase in passenger transportation, while free railway capacity can be used for higher volumes of goods. There are also sound opportunities for transferring energy-efficient transportation of people for home delivery of goods to more energy-efficient transportation of goods, and to use public passenger transport for goods transport as well.

The short-term changes in the energy system apply particularly to production and distribution. Within a given structure, the planning of electricity production can be regulated to affect electricity consumption, while for example the distribution of diesel can be planned to reduce the impact of transportation to filling stations. In the medium term, the distribution infrastructure in particular can be changed. We can relocate transformers, build and/or close filling stations, and construct charging points for electric vehicles. Small-scale production can also be initiated, such as the recent soaring increase in solar cells among private consumers in Germany.

ICT is developing robustly and affects efficiency in the small system through the sharing of information and greater integration within and between organisations. Available ICT in the large system can be applied relatively quickly at various levels from product labelling to vehicle identification and regulation of the whole transportation system in the small system. ICT is also closely linked to other subsystems in the large system. For example, ICT can increase the use of existing infrastructure capacity and can create conditions for consolidation of goods, combination of passengers and goods transportation, use and distribution of loading zones and carriageways, and joint parking areas. Present development will help to increase transportation efficiency, for example through greater opportunities for groupage, improved route planning and smarter and more flexible regulation of transportation. ICT can also help to integrate intelligent agents (such as vehicles, unit loads, products and players) and infrastructure for the goods transportation system. This improves visibility in the transportation system and contributes to better traffic control, increased traceability and higher utilisation of resources. In the next and coming decades, we can expect ICT to continue being a facilitator for rationalisation and productivity enhancements in actual transportation production, in the integration between transportation production and the processes in society that demand transportation, and within and between the other subprocesses in the large system. There are, however, also potential problems and breaks in the trend for ICT, such as cyber attacks that shut down the internet, GPS disruptions or natural disasters that lead to chaos in transportation and traffic systems. A lack of confidence and shortcomings in laws and agreements concerning safety and integrity entail that data are not collected or distributed between those who need them.

Changes in transportation and traffic technology will make progress until the mid-2020s, improving the situation. The same applies to the development of fuel and coordination of transportation; their structures often have short transition times and short life spans, but they are beyond the reach of goods owners and transportation companies. We present a few examples of short and possible changes: many parts of the world (e.g. Brazil, New Zealand, Australia, the US, Canada, Mexico and South Africa) permit much longer and heavier vehicles than those allowed in Europe on parts of the road networks. These are classified with the load capacity 4 TEU of 30 m and 60–86 tonnes or 6 TEU of up to 53.5 m and 62–126 tonnes. Several of these countries require the vehicle combinations to hold certification complying with strict PBS, which has made them safer and less physically damaging to the infrastructure in terms of wear. Finland has recently decided to increase the maximum weight to 76 tonnes, yet staying within the length limit of 25.25 m. Finland is considering allowing this heavier weight with existing vehicle combinations for a transitional period – without reinforcing bridges in advance. This would increase axle weights and thereby wear on roads. This is a concrete example of how rapid structures can be changed before the slow ones have been adapted.

Future transformation and early rationalisation

At present we know virtually nothing about which rapidly changing structures will be developed between 2020 and 2040, apart from the fact that consumption, production, business models, supply chains and logistics will change as a result of the transformation period. The only thing we know with greater certainty is that these fast structures must be allowed to change within relatively familiar frameworks, in harmony with the visions that determine the change of the slow structures. However, it is not possible for us to know a great deal about the exact composition of these structures. Even if urbanisation, transport flows, roads and public transport systems follow clear visions, we do not know for certain how the technology of traffic systems will develop, which energy sources will be used and how energy will be generated. Communication, step-by-step implementation and demonstration of research findings are important to technical solutions. This may be applicable for electrified roads, distributed electricity production, installation of fuel cells, collective distribution of goods via virtual shops, intermodal terminals and underground distribution of goods in cities. We can also expect that vehicles, load carriers and packaging will get lighter through the use of new materials such as high-strength steel, aluminium, sandwich constructions, fibre composites and graphene. This means that more goods can be transported at the same gross weight, and with increasing gross weights the ratio of payload/gross weight will increase even more.

Most vehicles run on internal combustion engines, except for train locomotives. The energy efficiency of these engines can be expected to rise, at most to double (e.g. diesel engines from 30% to 60%), but that is the upper limit due to the laws of thermodynamics. Powertrains may also become more energy-efficient, especially if the braking energy is stored or returned to the power supply. Energy can be stored temporarily in the vehicle in various ways, such as using batteries, supercapacitors, compressed air and flywheels. We do not yet know what technology will dominate in the future. By switching from fossil oil or natural gas to biofuels or synthetic fuels, such as hydrogen gas, vehicles can largely become free of fossil CO_2 emissions.

The availability of biofuels is likely to be limited, so they should be reserved for vehicles that are difficult to electrify (planes and ships). Cars, buses, trucks and work machinery should switch to electric motors. They can obtain electricity from a battery or supercapacitor in the vehicle, from fuel cells as stored hydrogen gas, or directly from the road through conductive, inductive or capacitive transmission. We do not yet know what combination of technologies will dominate in 40 years' time, but we must nonetheless start the electrification process now. As the uncertainties regarding primarily technological development are considerable, major deviations from the development described above may occur. One risk is that we decide to electrify motorways, and just as that is completed there is a radical breakthrough in the storage of electrical energy that will make all those investments in electric roads obsolete. Another risk is that an inexpensive and climate-neutral energy source for vehicles will be invented (as promised by cold fusion) rendering all the investments in making energy more efficient, replacing energy carriers and changing modes of transport obsolete.

The slow structures in the energy system are ultimately related to electricity production and infrastructure. For instance, new power stations take a long time to plan, decide on, build and finally commission – even with the technology now available. When such power stations have been built, they have a long lifespan. The same applies to refineries and their infrastructure. It is not until these structures are in place that quick decisions can be made optimally in terms of the given structure. Many visions, for example regarding biodiesel or electrified roads, involve major investments in the slow structures of the energy system. Infrastructure and distribution as well as filling stations and charging points must be in place before goods transportation producers can venture to invest in vehicles to produce transportation with new technology. Being locked in slow structures is not all bad – they signal a vision and minimise the risk of the players who have the opportunity to affect emissions by establishing a long-term framework. This will all come about as part of the economic transformation, and as a result of investments in society and commercial adaptations.

5.3 Investing in slow structures to open doors

We cannot really expect any major effect of the expansion of slow structures by the mid-2020s, but political visions must be allowed to rapidly take shape in the meantime so that decisions can be implemented and coordinated. It is probable that certain development paths, or doors, in the subsystems in the large system must be closed, while others should be opened to facilitate and become part of the structural transformation that will occur up until 2040. To conclude this chapter we discuss the approach of opening and closing doors and present examples of their implications.

Managing slow and fast structures sequentially and in parallel

The starting point is that changes in the slow structures take a long time and their effects take even longer. From the discussion above we deduced that it is unlikely that emission-reducing effects of the large system will be attained before 2025. It is therefore necessary to implement CO_2-reducing changes in fast structures, but in this transition it is important that fast and slow structural changes are synchronised to prevent changes in fast structures from counteracting changes in slow structures. One example of such synchronisation is Finland’s switch to heavier vehicles, where transportation companies in the small system must work together with infrastructure and transport technology in the large system. Vehicles need to be developed with additional axles to avoid increased road wear. But to up the pace of the change, heavier vehicles have been permitted on the roads, despite greater wear, during the wait for new trucks to be produced. Changing fast structures can also give input to the slow structural changes, because there is a learning curve – which is often exponential rather than linear. This means that new investments in fast structures can generate lessons for slow structures. For example, an investment in new logistic infrastructure, such as groupage terminals, can enable a shift from road to rail. This generates lessons for intermodal transportation solutions, which in turn provide input to infrastructure investments.

It is also crucial that changes in slow structures are planned in the right context in terms of time, i.e. implementation time and conditions from other systems must be taken into account. For example, a vehicle fleet that runs on non-fossil fuels in 2030 needs access to biofuels, which in turn requires infrastructure for biofuel distribution. It is essential to invest in long-term structures, even if they do not generate short-term gains, because there is a risk of not achieving long-term changes if too much focus is placed on short-term benefits. In this restructuring process the transportation sector can learn from transitions in other sectors, such as the energy sector, where a successful transition from heavy dependence on fossil energy sources to a virtually fossil-free energy supply has taken place. Investing in carbon-efficient development of long-term structures does not just comprise identifying opportunities, but also closing doors to fossil-dependent alternatives. Examples in other areas include the ecodesign directive's ban on the sale of incandescent light bulbs within the EU and the fact that certain types of cars (such as SUVs) pay a penalty tax in cities.

Political challenges

Political visions and their implementation form a key factor in changing slow structures. Goods transportation will not become carbon-neutral with individual measures alone; it will require a package of decisions and measures in the small and large systems. These decisions and measures must utilise the innovative power among players in both systems.

Working within and between business community players, authorities and decision makers, various forms of support and extensive scope for action all benefit innovative sustainable ideas. This will be politically challenging but necessary for a transition. Integration of modes of transport in infrastructure investments is one example of such cooperation. A current development in Sweden is the construction of extensive railway lines from ports to dry ports[4] that link shipping and railways. This involves transferring goods from road to rail and enabling ports to be specialised based on their functions. Similar measures should be possible to and from airports. In general, different modes of transport should be integrated, making it easier to link them in parallel and sequentially. Another example is the changing of behaviours; this requires altering mindsets and cultures among citizens, companies and organisations. Investing in research and training about sustainability is one possibility of steering development in this direction. Another example of cooperation is to deal with market failures that lead to CO_2 potential becoming unusable due to incorrect pricing. Similar examples are correcting institutional failures, such as subsidies to the oil industry.

All in all, a detailed structure is required to regulate energy and transport infrastructures. This includes performing environmental impact assessments for all investments in slow structures based on today's transportation and transportation systems and on a broad spectrum of possible future options for these.

5.4 Main messages for 2050

We have chosen to base our discussion of the future on the division of the growth cycle into periods, because the preparedness for change of people, companies and society varies substantially during the course of the cycle and thereby sets frameworks for norms, investments, politics and technology. Our approach has only generated a conceptual framework, within which further research must specify how future development should be regulated through various actual measures.

The transformation period in the growth cycle involves tension between the old and the new. There is no reason to believe that a new growth cycle with a new growth direction will immediately meet our needs and quickly lead to solutions to our problems concerning traffic development, energy consumption and CO_2 emissions. Not even a development optimist can be naive in this context. It will take many years before the technology that will propel future development dominates consumption, production and economic structure. If we assume that the new technology will focus on energy efficiency and non-fossil energy sources, it will encounter many problems along the way. For instance, service development in the economy will not dominate the start of the transformation period, which would slow down the increase in goods transportation. Instead the transformation will be dominated

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[4] Facility with a port-like construction but lacking a direct connection to shipping.

for a long time by the production of goods and building of infrastructure – first through investments in traditional and then new infrastructures. There is therefore a very high risk of substantially increasing CO_2 emissions and increasing goods transportation during the first 10 years of the transformation. It is during these years that consumers and companies in the small system will need to take major responsibility for curbing emissions from the transportation of goods, while the rest of society invests in and plans long-term solutions that will produce effects beyond 2040/2050. At the same time, policy instruments must be established to force and encourage consumers and companies to take this short-term responsibility for the reductions.

Consumption will probably slow down at the beginning of the transformation period as a result of increased tax pressure and a restrictive credit market, which will contribute to redirecting production and thus lessen some of the demand for transportation and CO_2 emissions. The tax pressure and credit restrictions are necessary, due to the need to finance both short-term and long-term investments without making the total debt burden of society skyrocket uncontrollably. In addition, transportation must be streamlined much faster than before, and this must be achieved with the support of regulations and restrictions. For instance, city logistics must be regulated and planned, traffic flows optimised and goods transportation electrified in cities and other urban areas, while more efficient vehicles and alternative fuels are continuously permitted to increase their proportion of the entire transport system. Companies' desire for goodwill, a green image and reduced costs will not be enough impetus; a visible hand must control community building efforts and the development of transportation until at least 2040. Higher carbon tax may have to be imposed on transportation to increase the pressure on consumers, companies and society to transform. However, it is important that the CO_2 reduction does not rely too heavily on cutbacks in the transportation of goods, because transportation plays an important role in enabling the transformation. Building the new systems that will hopefully have an effect in the long term will require extensive, probably even increased, transportation. Paradoxically, increasing transportation may be a part of the solution to the total long-term CO_2 problem. Implementing excessively harsh policy instruments targeting the transportation sector in order to achieve short-term CO_2 improvements may turn out to be counterproductive if this reduces the efficiency of transportation and logistics in society, which in turn would reduce opportunities to build the long-term sustainable structures necessary for a low-carbon society. All this means that we must walk a fine line, trying to reduce the sector's CO_2 emissions in the short term without jeopardising its ability to contribute to the long-term solution. This may mean that other sectors of society must initially be prepared to take on a greater proportion of CO_2 reductions than the transportation of goods.

Many of the policy instruments discussed in this paper will be able to streamline transportation work over a limited time and give us some respite from the pressures that the transformation will bring, but they cannot resolve the entire problem. The majority of the solution must come from the transformation itself, with the right focus. But even if we achieved the full effect of our initiatives towards energy efficiency and CO_2 reduction by 2040/2050 we would not eliminate all environmental problems. Traffic intensity, congestion, shortages of resources and the liveability of cities are at least equally important problems to resolve as the CO_2 issue. Resolving the CO_2 issue does not necessarily mean that these problems will automatically be solved; indeed, perhaps the contrary will be true.

6. FURTHER RESEARCH

In the paper we have used a theoretical framework to show that the growth cycle theory offers a dynamic approach to CO_2 emissions from the transportation of goods, which generates different scope for action in different periods of time. In our theoretical framework we have also built up and discussed a frame of reference that has contributed to analysing the problem scenario through a structured description of the direct and indirect impact on emissions from goods transportation by players in the goods transportation system and external subsystems. The approach is new and its application leads to revaluation of the principles for assessment of and approaches to CO_2 reduction. However, a new understanding that can be reflected in how decision makers and authorities assess situations and opportunities will not suffice. Additional research is required into how changed assessment principles can be implemented. Also, future research into how society can be steered towards CO_2 reductions from the transportation of goods needs to consider synergies with factors, such as resource-efficient use of land, availability, effects on public health, safety, noise and congestion.

As discussed in this paper the development of transportation and emissions is driven both by structures that can change rapidly and more stable structures that are slow to change. Most of the rapidly changing structures are selected in a step-by-step process, in which planning can act as a "door opener" or "door closer", i.e. enable or prevent different development paths. As we cannot estimate or foresee which doors will be opened or closed, there is a need to heighten our understanding of fast structures and decision models for them.

The common denominator of the stable structures is that the decisions made today about their development will set future frameworks for action for generations of structures that can change rapidly. We propose that the design of urban regions and urbanisation, the speed of urbanisation, inter-regional development and the expansion and coordination of core transportation systems must be studied in depth as a whole to understand their current significance for transportation and emissions. These in-depth studies should also aim to explain how this overall development of society should be regulated and designed to be sustainable, while creating maximum opportunities in the future to open and close doors to the selection of the fast structures.

Another research area is the urban environment where the need for new, more sustainable solutions grows. Here research needs to be carried out identifying the utilisation of the dynamics of the growth cycles. From a regulatory perspective, the roles of public-sector operations in new concepts need to be studied, as well as how policy instruments should be designed to manage goods transportation in systems alongside the transportation of people in urbanisation. Specific areas that require increased knowledge through research are logistics solutions for the urban environment, alternative solutions for locations of warehouses, collective goods transportation, and the role of packaging in urban transportation systems.

A goods owner’s or transportation company’s logistics and transportation decisions are affected by the company’s strategy and by demands from external stakeholders. To maximise the CO_2 reduction, further research should examine how external driving forces can be turned into internal motives. We also require more detailed understanding of how goods owners and transportation companies react to different incentives for developing knowledge of how authorities, through policy instruments, can affect the will to change.

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