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Under-utilisation of road freight vehicle capacity

A case for eco-efficiency through collaboration

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To my wives

Abstract

The road haulage sector experiences a considerable amount of inefficiency, characterised by sub-optimal utilisation of an individual vehicle's cubic load fill and weight hauling capacity. This study firstly aims to understand why – despite its evident economic and environmental cost – this phenomenon has existed over the years. Next, an overview of initiatives and opportunities for improving freight vehicle capacity utilisation will be given. This paper by no means attempts to suggest that part-loaded or empty trucking can be fully eliminated. What is argued however is that there is theoretical scope for reducing the socio-environmental externalities of these activities while sustaining – if not increasing – the benefits that road haulage offers to the economy. Alongside direct mitigation of energy efficiency (by vehicle technology and/or modal shifts), maximizing existing vehicle capacity utilization must also form an integral part of efforts to green modern road freight logistics.

It is suggested that horizontal collaboration and multi-actor co-loading of freight vehicles holds the greatest potential for improving vehicle fill rates. This requires little capital investment and would mean that the same degree of utility is delivered with fewer individual vehicles on the road. However, it is also argued that a collaborative road freight model may come in conflict with modern customer demands and production patterns, which typically involve rapid just-in-time deliveries of ever smaller consignments. Subsequently the widespread outsourcing of road freight operations to external third-party operators has not resulted in pronounced gains in vehicle capacity utilisation. It appears that a transport operator has very limited ability to better consolidate goods within its vehicles, unless its contractors offer an operational environment where this is possible.

This paper suggests that a platform be established that will enable transport purchasers (contractors) to identify synergies in their logistical flows. This should help to move away from one-vehicle-to-one-customer arrangements, and develop an approach where a single moving vehicle's available capacity is viewed as a service that is available for the benefit of several actors at the same time.

Keywords: Road freight transport, empty running, consolidation, back-hauling, eco-efficiency, horizontal collaboration.

Table of Contents

Figures

Abbreviations

HGV – Heavy goods vehicle (also referred to as "truck" and "freight vehicle")

LTL – Less-than-truckload

FTL – Full truck-load

3PL – Third party logistics operator (used interchangeably with "haulier")

ICT – Information and communications technology

JIT – Just-in-time deliveries

(the terms "transport purchaser", "shipper", and "contractor" are used interchangeably)

1 Introduction

1.1 The pressures of a growing road freight sector

Road freight activity has historically been strongly correlated to overall national economic output (Eom *et al.* 2012; McKinnon & Woodburn 1996) and today it continues to play a crucial role in servicing wealth-generating activities such as industry, trade and retail. Although exact future road freight volumes are highly dependent on oil prices (ITF 2012), global road freight volume and total haulage distance are expected to triple by the year 2050 (relative to 2000 levels) (World Energy Council 2007), and its energy usage will grow unchecked as technical improvements are largely outpaced by increments in transport demand (Mattila & Antikainen 2011; Helmreich & Keller 2011). For example, in the European Union, transport is the only major sector whose greenhouse gas emissions have risen continually despite the recent economic downturn (EC 2012).

The latest IPCC report estimated that transportation accounted for over 13% of global anthropogenic green-house gas emissions (IPCC 2007), and although passenger transport accounts for the largest share of this figure, on an individual vehicle basis road-going heavy goods vehicles (hereafter HGV's) are responsible for considerably higher amounts of air pollution. Currently HGV's alone account for up to a quarter of all transport-derived CO_2 emissions in the EU, or 6% of EU's total CO_2 emissions – and that despite their comparatively low quantities (EC 2012, 2013). What is more, the high combustion temperatures and excess air intake of their diesel engines result in elevated levels of nitrogen oxides (NO_x) and particulate matter (PM) emissions (Alvarsson & Andersson 1995; Cullinane & Edwards 2010). Coupled with noise, vibration, visual intrusion, high risk of fatal accidents and intimidation of other road users (Delle Site & Salucci 2009; Vilkelis 2011), road freight vehicles present a myriad of short and long-term physiological and psychological nuisances to the public (see eg. Pope *et al.* 2002; den Boer 2007). The sector's dynamism concomitantly presents unforeseen levels of these socio-environmental externalities, resulting in continual deterioration of the large freight vehicle's overall public image (PwHC 2008). It is clear that the picture painted by Peake (1994) several decades ago has largely persisted to this day; the price of transport continues to poorly reflect its full social cost, and we are not seeing rapid returns on infrastructural investments destined to alleviate this sector's externalities.

1.2 Problem definition: Partly- and un-loaded trucking remains rife

In the modern era of climate change regimes, environmental group pressures and increasing public environmental awareness, the road freight transportation sector is facing the challenge of ensuring for economic prosperity while simultaneously adapting to changes in customer demands and minimising the broader socio-environmental externalities of its services (TRIP 2012; Delle Site & Salucci 2009).

It may thus be somewhat surprising that vehicles across Europe are frequently travelling un- or under-loaded. Cruijssen (2012) estimated that the average loading rate of travelling freight vehicles is only about 56% of their total weight haulage capacity. Similarly, the latest available figures outline that in 2011 roughly 84% of all road transport in the EU-27 was performed by vehicles with a maximum permissible laden weight of over 30 tonnes, and yet the average weight carried per road vehicle was a mere 13.6 tonnes (12.7 nationally and 16.1 internationally) (Eurostat 2012). It is also known that in the United Kingdom 44-tonne trucks with a maximum payload of 29 tonnes actually carry an average of 17.6 tonnes when laden on the road (Knight *et al.* 2008). Interestingly, as result of regulations allowing national transport of heavier loads, the average load weights carried within Sweden were around 30% above the EU average (Eurostat 2012). However, while some of this under-loading is the result of "cubing-out" by voluminous goods with low weight and density, Arvidsson *et al.* (2013) outline that average HGV load factors have historically declined, and estimate that there is still room (even in Sweden) to cut the environmental impacts of road transport by as much as a half should loads be better grouped within fewer trucks.

Much of the blame can be assigned to modern production and consumption patterns [see section 2.7.5] that are creating situations where businesses are unable to fill an entire truckload prior to its dispatch. Part loaded or "less-than-truckload" (hereafter LTL) shipments are thus common operations among major European road freight logistics operators (such as DB Schenker, DSV, Trans-Net and TransImperial) and particularly express carriers (such as DHL, FedEx and TNT) (Dekker *et al.* 2012).

The number of trucks running completely empty is even more alarming. In 2010 the European Commission estimated that almost a quarter (23.9%) of all HGV kilometres run in the EU were made by a completely empty freight vehicle (EC 2011b). Empty running may well be unavoidable in situations of asymmetric demand and where materials need to be distributed across a wide area from a single source (eg. building materials from a quarry), however even a large, land locked, well-performing economy such as Germany observes national HGV empty running rates of over 20% of the total domestic road freight kilometres covered per annum (Eurostat 2011a). These figures are typically higher for domestic operations compared to international hauls where there is a stronger financial incentive to find a backload for the return journey (Vilkalis 2011; McKinnon & Edwards 2010). Most importantly, because the ratio of empty running vehicle kilometres fell by a mere 1% (from 25% to 24%) between 2007 and 2010 (Eurostat 2011b), it would appear that this phenomenon is to remain well into the future. Cruijssen (2012, 3) provides a rather bleak outlook, stating that:

> *"In the period of 2001-2010 between 18.0% and 20.4% of freight kilometres driven in the European Union (27 countries) were conducted by empty vehicles.* [Combined with low average loading rates] ... *these two observations result in an overall efficiency score of European road transport of around 45%. The total cost burden of road freight transport inefficiency is enormous. It increases from around €120 billion in 2001 to around € 160 billion in 2010, having a peak of € 170 billion in 2008."*

Hence the strongest case for better utilising travelling HGV capacity comes not from increasing degree of under-utilisation, but the growing economic cost that this inefficiency is accruing. It is indeed becoming ever more expensive to transport freight by road in the EU, primarily a result of rising oil prices, road tolls and various environmental taxes. This in turn means that the cost of operating at sub-optimal levels is ever greater. *Figure 1* outlines how vehicle utilisation rates have remained relatively unaltered over the last decade, but the cost of this inefficiency – with the exception of the 2008/09 recession – has risen unchecked.

Sweden has been among the most successful countries to minimize these inefficiencies. The share of empty runs among Swedish registered trucks has fallen by some 29% between 2009 and 2011 as a result of reduced haulage assignments and fewer kilometres driven. Some have even argued that with so few haulage assignments of over 300 kilometres, Swedish road transport operations are no longer worth the efforts of consolidation, and they are out of the competitive reach of other traffic modes (Stefansson & Woxenius 2007). However this paper takes the position that further potential or theoretical opportunity still remains, especially as 17% of the total amount of kilometres driven on Swedish roads in 2011 continued to be performed by empty vehicles (Sveriges Officiela Statistic 2012).

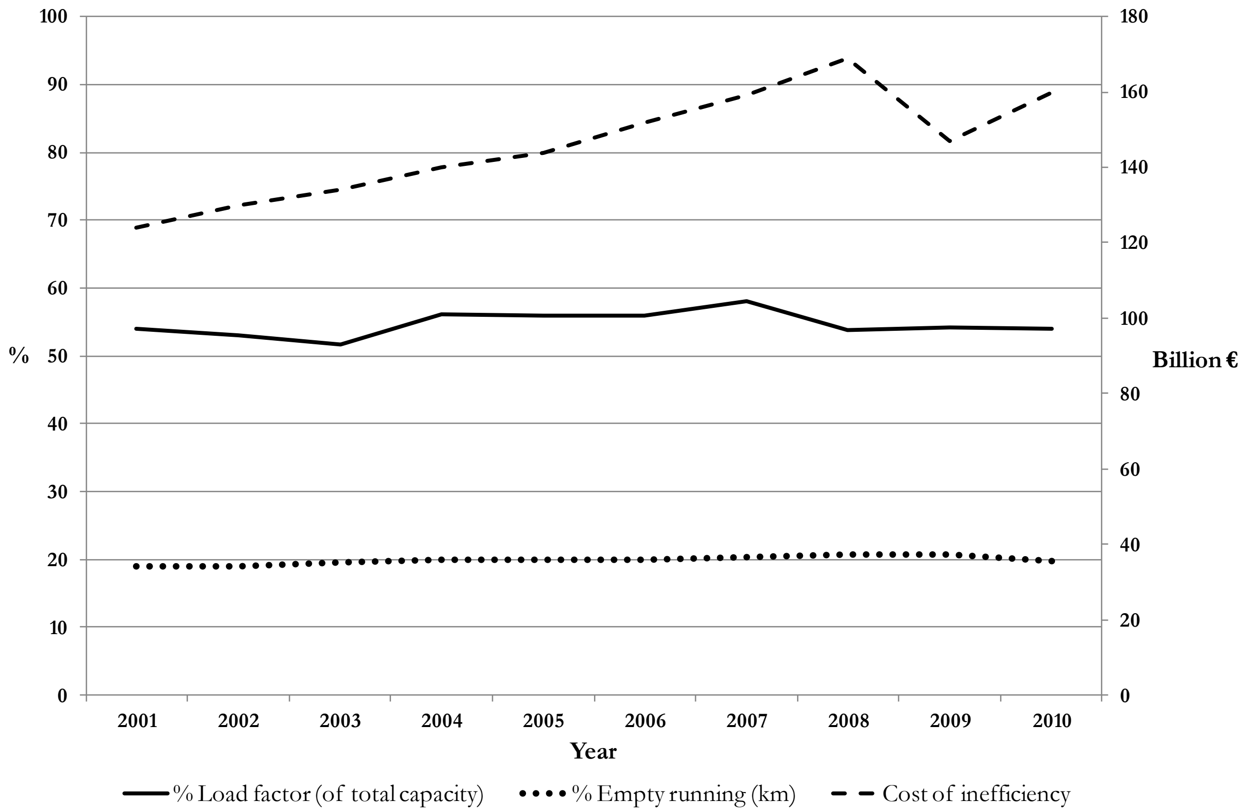

Figure 1. EU temporal trend of heavy goods vehicle utilisation rates and the cost accrued from this inefficiency. Data source: Cruijssen 2012[1].

1.3 Research questions

In the light of the above mentioned inefficiencies, and therefore what are believed to be unnecessarily high socio-environmental externalities of road haulage operations in the EU, this paper will address the following questions;

- What factors are currently driving down the levels of vehicle-utilisation, and are there any foreseeable changes therein?
- To what extent is HGV capacity being shared among several actors, and what opportunitites exist for transport buyers and logistics operators to maximise vehicle utilisation even further?

1.4 Methodology

The findings, discussions and general thought process of this paper are founded upon an in-depth literature review as well as semi-structured interviews with relevant persons in the logistics industry and academia. The approach of the research has been exploratory in nature.

First and foremost the Lund University search engine "LUBsearch" was queried. In essence the search strings were gradually examined from the most basic to the most complex. The search criteria always included the search terms: "road freight OR road haulage OR road

[1] Although every effort was made to access to original Eurostat and EU Environment agency data, these data sets were not available at the time of writing.

transport", "logistics" and "vehicle". Further terms were added interchangeably: "load", "fill", "truckload", "environment OR environmental performance", "freight vehicle utilisation", "load fill", "haulage capacity", "freight consolidation", "co-delivery", "empty running", "backload OR backhaul" and "logistical optimisation". Further cross-referenced search terms that emerged out of this literature included "tonnage", "cube OR cubic" "less than truckload", "groupage", "co-operation", "partnership", "alliance", "cabotage", "horizontal collaboration", "eco- AND/OR efficiency", "outsource OR -ing", "own-account". In some instances to make an emphasis on trends that are more local to the author's host institution, the terms "Sweden", "Swedish", "Sverige" were added to refine results. A maximum of seven search terms were used at any one time. The search results were further refined so that their publication date was no older than the year 2000 (although in some instances references to older literature were made to outline well-established trends as well as theories); the subjects as well as publication names were refined to all those including the words "transport(ation)", "road", "freight", "truck" and "logistics"; and all literature considered was in English (with the exception of personal vehicle manufacturer sustainability reports, and Swedish official statistics documents). A Google search was often used to locate literature outside the immediate realms of road freight vehicle utilisation, such as for EU road freight policies, statistics, vehicle components and technology, information communication technology as well as product service systems. It must finally be mentioned that a considerable amount of literature was consulted at later stages of the research; upon recommendation by interviewees.

Next numerous potential interviewees were contacted, generally to accumulate qualitative information and to support some of the trends mentioned in the literature. The selection of persons was by and large a growing networking process that began with staff in the author's host department and then broadened onto logistics researchers in other faculties of Lund University and its outbranching projects. These contacts were either queried face-to-face or via email exchange. Researchers at the University of Cambridge's Centre for Sustainable Road Freight Transport were also queried, if not directly for interviews then for suggested literature. Additionally some 19 European freight operators were contacted by email, but if their website offered a phone contact that was the preferred choice of communication. Nine automotive manufacturers were also contacted via a standardised drafted email (see Appendix), and phone interviews were carried out if a positive response was given. The interviews were then carried out in a semi-structured way, with a drafted set of questions in mind (see Appendix), but enabling the interviewee to elaborate on the subject as they wished. Typically interviews did not exceed one hour in duration. As a result of very low response rates, it is not possible to give a structured interviewee selection method or to aggregate their responses in any way other than to supplement information gathered from the literature review.

1.5 Limitations and Scope

First and foremost this study attempted to derive information from the most recent available literature. Publications with a publishing date prior to 2000 were considered relevant for the identification of historical trends only.

The study is further delimited geographically to trends within the European Union. This applied to the selection of analysed and/or contacted road freight operators, research projects, institutions, statistics as well as web-based services. Although there will be some mention of external trends, the study's main applicability is intended to be within the EU. Additionally, as often as information availability permitted, the study has singled out trends relevant specifically to Sweden, so as to improve its relevance to the host institution.

Every effort was made to ensure that the reported trends are predominantly applicable to the long-distance (over 300km) haulage in heavy vehicles exceeding 17 tonnes. After all, this is the largest category of road freight vehicles in Sweden (excluding light vans of under 1.5 tonnes) in terms of both vehicle number (13,000) and collective distance travelled within the country (86 million miles) in 2012, of which flatbed trucks and towing tractor units comprise the two largest categories (Sveriges officiela statistic 2013). Trends and findings are considered to be poorly applicable to smaller consignment deliveries, specifically in urban environments.

Logistics is a large and highly diverse field, and thus several criteria have had to be defined in order to narrow down the research and associated discussions. The research invariably revealed considerable amounts of information regarding the modal shift away from road freight. While the environmental benefits of these shifts are considerable, this review takes the position that road freight will remain an irreplaceable component of supply chains. It thus deals with the internal efficiency of road freight operations and makes no attempt to stray into the modal shift discussion. In addition, this paper is focussed around vehicle-level efficiency and will not engage in significant discussion surrounding vehicle routing techniques as well as freight consolidation infrastructure (consolidation hubs), although these too invariably have a strong role in promoting logistical eco-efficiency.

Finally, the analysis of available information communications technology (ICT) was limited by the fact that the specifics of software packages are only available to customers upon their purchase. This also applies to software development projects, the access to which is frequently reserved to member companies. This has meant that analysis is limited only to the content of the associated web pages, and interviewee experiences.

1.6 Audience

First and foremost it must be mentioned that this study has been a learning process for the author. It can thus well be intended for non-experts in the field who seek to gain an appreciation for the reasons behind various trends in the industry. This report could thus also be consulted by concerned members of the public so as to gain a better understanding of why freight vehicle operators are unable to reduce their socio-environmental externalities to the degree that some would like to see them do.

Most importantly however it is hoped that this study will be of relevance to purchasers of road freight logistics services (shippers) so that these can appreciate existing inefficiencies, their drivers, as well as the economic and environmental case for making efforts in the direction of higher vehicle-utilisation. This should enable shippers to make necessary alignments in their interactions amongst other transport purchasers as well as with regards to their relationship with transport operators.

2 Literature review

2.1 The business case for greener logistics

Corporate interest in greening road freight traffic began already in the 1970's (particularly in the UK) as a result of incentives such as tighter fuel efficiency and exhaust emission regulations. By the 1990's this trend was supported by an expanding academic research base focusing on decoupling economic growth from road freight traffic levels via greener transport technologies, and improved vehicle utilization rates (McKinnon 2010a). Historically the business case for environmentally responsible logistics has grown not only because economic and environmental objectives are often aligned (eg. utilizing returning trucks for waste product retrieval and re-cycling), but also as a result of the competitive edge and corporate image boost that environmentally conscious transport activities had to offer (Srivastava 2007). There is indeed a strong link between environmentally preferable purchasing within a firm's supply chain and its overall performance on the market (Craig *et al.* 2000). Several authors reported that greening logistics forms an integral part of any enterprises efforts to 1) improve operational efficiency and resource conservation and 2) preserve long-term public image or avoid negative publicity (Björklund 2005; Goldsby & Stank 2000; Berglund 1999).

Goldsby and Stank (2000) outline how there is a strong link between the environmental performance of a firm's logistical operations and the overall degree to which the firm can be considered as environmentally pro-active (also see van Hoek 1999). Today transportation remains the single most environmentally damaging aspect of a logistics system, meaning that transport issues are closely connected to corporate environmental policy as a whole. When purchasing external transport services, companies have started viewing environmental performance as important added-value. A high level of internal environmental management also means that a company is less price-sensitive when it comes to purchasing environmentally preferable transport services (Lammgård 2007; McKinnon 2010a). This is because they place high priority on how their operations will perform in the face of environmental regulation, as well as if they are seeking to advertise their products and services as being green (Wolf and Seuring 2010). Various industry sectors are subsequently being highly pro-active in collaborating with freight service providers so as to decarbonise their logistics activities (CEFIC 2011) and in the haulage sector it is well recognized that aside from cutting fuel expenses and improving internal efficiency, green initiatives often enable haulers to gain credentials that solidify customer relationships and overall business appeal (Carter & Jennings 2002; Commercial Motor 2007, 2008).

2.2 An opportunity for eco-efficiency

The literature reveals that there is considerable inefficiency in the road haulage sector, which makes itself particularly apparent through the common under-utilisation of individual vehicle's weight and volume haulage capacity. The author takes the position that the numbers of on-the-road vehicles and their associated socio-environmental externalities are therefore unnecessarily high, and that given the correct, innovative operational environment, these aspects can be reduced at minimal cost to the already struggling road haulage sector. This is the idea of "something for nothing"; greener transport without the loss of convenience for all involved stakeholders (industry, third-party logistics operators, end-customers, society and environment) (Peake 1994, 14). After all, it is not uncommon for transportation cost, competitiveness and environmental impact to point in the same direction, and better emphasis thereof should influence the mind-set of managers for the greater benefit to the environment (Aronsson & Huge Brodin 2006).

The above mentioned patterns of freight vehicle under-loading clearly provide an opportunity for improved eco-efficiency, defined as "the delivery of competitively-priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity" (DeSimone & Popoff 1997, 47). These should in theory be very welcome to supply chain executives, especially as surveys have revealed that cost-savings via improved efficiency are perceived as their primary responsibility in the entire business (IBM 2010).

2.3 The case for utilizing existing vehicles to their full potential

An HGV is an inherently wasteful and energy demanding means of transport. While most road-going heavy duty vehicles are powered by diesel engines – which due to high combustion temperature and high air intake are the most efficient transportation power plants – their size, weight and aerodynamics result in very high fuel consumption. Typically as much as 60% of the energy contained in the utilized fuel is lost as heat and sound, and of the 40% that remains for mechanical work, up to 21% can be lost to aerodynamic drag and 13% to road rolling resistance (Leduc 2009). Depending on zone of operation and vehicle specifications, these loses could account for as much as 94% of the energy used to sustain an HGV at a speed of 105 kmh^{-1} (US Department of Energy 2006).

First and foremost, this is of course a case for shifting as much freight as possible to more energy-efficient transport modes such as rail or sea. Nonetheless, a strong case for road freight usage remains. Direct trucking provides the rapid services needed over shorter distances and can accommodate for short-term demand fluctuations to a much better extent than other freight modes (Groothedde *et al.* 2005). Its responsiveness and flexibility mean that road freight haulage will invariably remain a crucial component of virtually any distribution network. What this also means is that when road vehicles do have to be resorted to, there is a strong case for making the best use out of every individual vehicle; that is getting the maximum possible service out of the available haulage capacity potential. Eliminating empty runs and consolidating different shipments to maximise vehicle fill rates essentially means that the positive offerings of road freight movements are better balanced against the negative externalities of this transportation. Partial load operations typically result in more trucks per any given shipment weight, and thus higher emissions per tonne-kilometre (transport of one tonne of goods over a distance of one kilometre) (Hedenus 2008).

Further drivers for vehicle-level utilisation improvements include:

- Reduced congestion as fewer trucks are needed to deliver the same level of service (Vilkalis 2011).
- Fuel and operational cost savings, meaning higher margins for haulers and a widening of their customer base as they can offer cheaper services to transport purchasers (JW Suckling Transport 2008).
- Driver salaries often comprise the highest individual cost for road haulers (Stefansson & Woxelius 2007). Loading vehicles to maximum capacity would ensure that the number of hours that a driver is paid for are spent delivering the highest possible utility.
- Within a typical distribution network, it is largely the last and relatively short leg of the journey that is run empty (McKinnon 1996), meaning that there is potential for cost and environmental savings (via back-loading) without the need for fundamental distribution network restructuring.
- Finding back-hauls can open up opportunities for reverse logistics. The flow of products and/or materials up the supply chain from the consumer to the manufacturer

supports closed-loop material recycling or refurbishment (Engel 2008), which is beneficial to both industry and environment.

The following sections will demonstrate that on the other hand there are strong reasons justifying the apparent market failure of sub-optimal vehicle-utilisation. Among these is the over-reliance on technological fixes and the inability of policy measures to drive eco-efficiency.

2.4 Why direct mitigation will not save the day

The environmental benefits of improved vehicle utilisation have often been overshadowed by the would-be offerings of increased green technology penetration. Considerable research and investment has been dedicated to addressing HGVs' externalities through direct mitigation via technological fixes. Manufacturers are continually placing emphasis upon incremental developments in vehicle components and the concomitant benefits of fuel-economy and lowered emissions. Unlike the "emotionally-driven" passenger vehicle market, commercial freight vehicles are primarily differentiated according to their life-cycle costs – a large proportion of which is determined by running costs (PwHC 2008). In the UK, fuel costs typically account for as much as 40% of the total costs of operating a heavy truck (DFF International LTD 2012; Cook 2012). There is thus strong customer demand and European HGV manufacturers are driven to be at the forefront of fuel efficiency (EC 2011b; PwHC 2008). Research and development into transmissions, drive-trains, engine efficiency enhancements and/or fuel-hybridization, aerodynamics and light-weighting has been so substantial that truck manufacturers who are lagging behind on clean and fuel-efficient propulsion technology are faced with considerable market entry barriers (PwHC 2008).

Over the past decades, as much as two-thirds of the gains in the fuel efficiency of the heaviest category goods vehicles have stemmed from improvements in engine performance alone (Commercial Motor 2010a). Transport emissions – particularly in the OECD – are set to grow at slower rates than transport volumes as a result of combustion engines becoming more efficient and less CO_2-intensive (ITF 2012). The European Commission estimates that – if widely implemented – such technologies could save between 30 and 52% of freight vehicle-level greenhouse gas emissions by the end of the decade (EC 2012; EC 2011a; EC 2011b).

In their review of developing green vehicle technologies, McKinnon *et al.* (2010) report that considerable further HGV energy efficiency potential lies in engine downsizing (and turbo-charging so to achieve the same power with lower fuel consumption), application of hybrid technologies such as battery power, installation of separate power systems for auxiliary equipment, roll resistant tires, and driver aids such as anti-idling devices and automatic gearboxes. It is however extremely difficult to accurately estimate the environmental gains arising from these technologies as their benefits depend hugely upon how and where the vehicle is used. In addition, direct mitigation does not always reduce all environmental externalities. For example, innovative engine re-designs such as *exhaust gas recirculation* (EGR) and *selective catalytic reduction* (SCR) have been developed to meet current (2013) Euro 6 emission standards. Yet neither is without its downfalls; SCR requires the addition of an expensive and not-environmentally benign urea-based AdBlue chemical, while the EGR system involves lowered combustion temperatures and thus leads to higher particulate matter emissions (McKinnon *et al.* 2010).

The above points to a more general trend across the entire industry; the benefits offered by technological fixes are rapidly saturating. In Sweden, the steady rate of reductions in average carbon dioxide emissions per tonne-km experienced in the 1990's has since not been matched, and although Volvo Trucks claims that further fuel efficiency gains are still to be made, improvements appear to be stagnating (Hedenus 2008). In addition, the potential for alternative fuels to truly revolutionize the road freight sector is low under current levels of technology and infrastructure. Although an in-depth discussion of these technologies is beyond the scope of this analysis, it appears that alternative fuels are a rather distant solution especially in terms of their price-competitiveness relative to conventional diesel. For example, in a Swedish study of future prospects for alternative fuels in the road freight sector, Hedenus (2008) reported that:

- While biofuel engine technology is well developed, ensuring for climate neutrality of these fuels as well as for sufficient future supply is questionable.
- Hybrid technology could offer substantial savings in urban driving environments, but the gains for highway operations are quite marginal (7% savings compared to conventional engines).
- Similarly, fuel cells could potentially be used to power delivery trucks for short distances, but the range demands for long-haul transports would require substantial amounts of on-vehicle liquid hydrogen storage, entailing very large costs and comparatively small efficiency gains over the diesel engine.
- The number and weight of batteries required for electric-only driving in heavy, long-distance trucks would be unreasonable and cancel out efficiency gains.

What is more, as such improvements mainly address new vehicles, efficiency and environmental gains are limited to vehicle stock turnover (Nordic Energy 2013). European HGV fleets are already relatively modern with almost half (46%) of all vehicle kilometres driven in the EU15 in 2011 having been made in vehicles less than four years old (EC 2011c). Road haulers – who already typically experience very low profit margins (Stefansson & Woxelius 2007) – are also less likely to be incentivized into new vehicle purchases as significant cost-savings will not be immediately visible. Vehicle replacement has also fallen substantially since the 2008 economic crisis (Eurostat 2011), and the recession continues to make operators wary of investing in new vehicles under uncertain business prospects and general lack of investment funds – both of which outweigh any positive reasons to invest (FTA 2012). When it does come to fleet renewal, haulers tend to purchase overly powerful tractor units as these keep their cost and maintain higher residual values (McKinnon 2010a).

Overall the incremental improvements from refining existing technologies are diminishing while marginal (financial and environmental) return on fuel-efficient technology investments is saturating. It is reported that improving fuel economy will be unable to offset future increments in Europe and the OECD's overall emissions (ITF 2012; McKinnon 2010a). The models of Matilla and Antikainen (2011), also suggest that while vehicle efficiencies will still have the greatest individual impact on future emissions, the best strategy cannot rely on a single technological measure. Improvements in loading factors as well as modal shifts are thus integral to a sustainable European road freight future. Truck manufacturers are indeed already heavily invested in fuel economy R&D, and there is no radical technological break-through that would be a cost-effective environmental investment. What is more, regardless of how green the truck market may be, haulers will remain hesitant to take on the acquisition costs of new trucks, and the "low hanging fruit" savings made through optimizations in route planning and internal operations will be paramount for their profitability (PwHC 2008). A study by the World Economic Forum (2009) outlined a series of prioritized strategies for alleviating the environmental impact of freight transport operations. While clean vehicle technology was estimated to have a worldwide abatement potential of 175 Mt CO_2, reduced transport speed [see section 2.7.5] and increased vehicle load filling were estimated to have the potential of saving an almost equal 171 Mt CO_2, and were considered to be measures of equally high feasibility as introductions of clean technologies.

Aside from vehicle fleet modernisation, considerable attention has been dedicated to driver training programmes. While a discussion thereof is beyond the realms of this research, it will be said that it is still difficult to derive long-term benefits from such eco-driving partially because drivers tend to alter their behaviours, regularly switch vehicles (that are often maintained to different degrees) and operate over varying haul distances (McKinnon 2010a). Even if it has been shown that fuel consumption can be reduced by up to 30%, long term savings appear to be orders of magnitude lower (3-6%), especially as additional incentives such as financial prizes for efficient driving are required (Hedenus 2008). Similarly, programmes often have to be tailored to the skills and experience of individual drivers (PwHC 2008), meaning that industry-wide standards have yet to be developed. Ultimately the time spent in driver training is that which is directly lost from profitable work, and to maintain long-term benefits this has to be accompanied by sophisticated driver-specific monitoring technology investments and bonus schemes. Both of these are poorly applicable to many of EU's companies that operate a mere handful of trucks and drivers (Liimatainen *et al.* 2012).

2.5 The current policy climate

The political discourse surrounding freight movement continues to focus on the penetration of greener technologies and alternative fuels. Modal shifts to less energy intensive means of transport are also high on the agenda, with the 2011 EU transport white paper stating that "30% of road freight over 300 km should shift to other modes such as rail or waterborne transport by 2030, and more than 50 % by 2050" (EC 2011d, 9). Although equally important, this discussion is beyond the realms of this review, and herein the author takes the assumption that the developed road networks and the subsequent flexibility of road freight, will ensure for its future popularity and relevance of efforts to make it less environmentally damaging.

Direct regulation of HGV technology is lacking as the diversity of vehicles and auxiliary equipment makes clear-cut, component-specific regulations difficult to draft. Technology policy must also be highly comprehensive and balanced. If for example only small gains are reaped from engine efficiency regulations, these would have to be tied to policies that encourage remarkable improvements in other variables such as vehicle aerodynamics (Matilla & Antikainen 2011).

In addition, compared to the personal vehicle sector, HGV manufacturers have relatively little control over the on-the-road fuel efficiency of their vehicles, due to the fact that it varies significantly according to operational environment (Commercial Motor 2010a). Thus a new HGV's on-the-paper emission standard compliance is likely to misrepresent the emissions that it will create during its operational life. Due to all this, strong incentive-based measures for fleet modernisation are limited predominantly to urban environments, where a number of European cities have introduced low emission zones that help to accelerate the introduction of cleaner delivery vehicles (Arvidsson *et al.* 2013).

Furthermore, all EU (and EEA) member states are currently striving for a target of 10% renewable energy in the transport sector by 2020. The Nordic countries have set even more ambitious national targets. At the forefront is the Swedish government that is aiming for a 14% renewable energy share by 2020, and a completely fossil-fuel independent vehicle fleet by 2030 (although precisely what this "vehicle fleet" entails remains to be elucidated) (Nordic Energy 2013). Energy fuel taxation, carbon fuel taxation as well as "green ownership" awards are the main fiscal incentives to greening the transport sector across the Nordic regions, yet these policies have so far made little headway to meeting the ambitious goals that have been set (Nordic Energy 2013).

This may be the result of the above-mentioned limitations in current technology, or the fact that manufactures are finding the current policy climate quite restrictive if a radical shift to new designs is to be seen (Commercial Motor 2010a). There is for example a trade-off between tighter emission controls and fuel efficiency, meaning that had NOx controls not been imposed, average truck fuel efficiency could be considerably higher than it is today (Arvidsson *et al.* 2013; McKinnon *et al.* 2010). Similarly, while the use of front and rear downward sloping "teardrop" trailers has indeed shown motorway travel fuel efficiency gains as high as 10%, a true shift to a new generation of low-drag vehicles will require the legal length limit of HGV's will to be considerably extended if they are to retain their current sizes and volume carrying capacities (Commercial Motor 2010b).

With HGV manufacturers rapidly approaching the ceiling of what policy and technology allow them to achieve, it would appear that haulers will have little to resort to in the light of increasing fuel taxes and prices. Although it is not uncommon for virtually any industry to claim that compliance with environmental regulations is crippling their business, it may be somewhat alarming that out of 400 surveyed European road freight operators as many as 15% believed that – as a result of fuel prices, carbon taxation and the technological cost of carbon regulation compliance – they will be out of business by the end of the decade (Commercial Motor 2012). Indeed, given the high oil intensity of the road freight sector, oil price increments will affect the kilometre cost of trucking far more than that of other freight modes (ITF 2012). Naturally it will be the road haulers rather than HGV manufacturers that will be the most immediate cost-bearers if additional policy instruments such as toll CO_2 payments or emission trading schemes (that have recently been introduced for the aviation industry) are put in place. Furthermore, the extent to which logistics operators can shift added costs to their customers is largely dependent on their fleet size (PwHC 2008), meaning that EU road logisticians will continue to find operations increasingly expensive given that 85% of these businesses operate no more than ten vehicles (EC 2011a), and frequently even less than five (Cruijssen 2012).

2.6 Policy for operational efficiency

While existing fuel and emission taxation does encourage more environmentally-efficient technologies, it is also a signal for more efficient logistics on a purely operational level. Road logistics operators are clearly in need of rapid cost-savings that do not require the initial capital investments that fleet modernization entails. It has thus been argued that the maximization of asset utilization may well be the key solution for the industry to resume its post-recession growth (Cook 2012; Waller n.d.). In theory if an operator gains a commercial benefit from improved vehicle utilisation, then additional governmental fiscal incentives to maximise vehicle utilisation will be unnecessary.

Accordingly, the EU transport white paper states that "more resource-efficient vehicles and cleaner fuels are unlikely to achieve on their own the necessary cuts in emissions", nor would they address the problem of congestion (EC 2011d, 7). This vision does not outline specific goals or strategies in this area, but does state that "[resource-efficient vehicles and cleaner fuels] need to be accompanied by the consolidation of large volumes for transfers over long distances" (EC 2011d, 7). Similarly – aside from vehicle and engine efficiency – one of the goals of the 2050 Freight Vision European Strategy for Sustainable Freight Transport is to improve the efficiency of vehicle *usage*, thereby covering aspects such as loading factors, and empty running vehicles (Helmreich & Keller 2011). Formal regulation in favour of vehicle utilisation is however yet to be seen. Existing legislative incentives such as road use, congestion and carbon taxation should in theory be already pushing haulers to better utilise the full load capacity of each of their vehicles. In fact, given the virtually non-existent governmental financial assistance for reducing fleet carbon emissions, the minimisation of empty running appears to be the single win-win strategy that can reduce socio-environmental externalities of road freight at little extra cost to transport operators (Commercial Motor 2010a; Browne & Allen 1998). Nonetheless, McKinnon (2010c) outlines that there are further regulatory schemes that could be beneficial in furthering this cause:

- Taxation on ownership and operation of trucks could incentivise operators to use them more efficiently. For example the Swiss heavy vehicles fee (HVF) has – in its first years – achieved exactly that. Trucks travelling through the country were documented to be carrying larger loads, especially on backhauls. Waller (n.d.) has also argued that the introduction of road taxes could concentrate traffic flows on selected routes, thereby strongly encouraging goods consolidation. However it is unclear how the industry would react to such disruptive legislation.
- In urban environments there have been several incentive-based schemes where haulers fulfilling a certain load factor requirement were given access to preferred un/loading points and dedicated bus lanes. These have demonstrated some – albeit short-term – changes in trucking operations and planning behaviour (Arvidsson *et al*. 2013).
- Relaxing the maximum size and/or weight limits of trucks could potentially enable shippers to better utilise this additional capacity and transport more with less trucks. However despite evident economic and environmental benefits, the safety and social acceptance aspects have to be considered alongside the fact that this will undermine the goal of shifting more freight off the road altogether.
- Further liberalisation of non-resident haulers access to domestic road freight haulage [see section 2.7.2] to relieve from operational constraints on back-loading.
- Government advisory schemes to better inform shippers of how to optimise their operational practices. For example, UK Freight best practice, US SmartWay and Canadian Fleetsmart accreditation programmes have been quite successful in reducing the emissions from road freight (Liimatainen *et al*. 2012). Thus vehicle utilisation should also form part of these agendas.

Although we have seen that the policy sphere leaves much to be desired, there is a good case for why actors throughout the supply chain should take a pro-active approach towards maximising asset utilisation, even in the absence of top-down legislative pressure.

2.7 What drives poor vehicle utilisation?

The task of increasing vehicle loads (via better load consolidation) and reducing the number of empty running trucks is very difficult. Freight demand is subject to major geographical and operational imbalances. In their review of vehicle utilisation trends, McKinnon and Edwards (2010) outline that there are good reasons – often involving rational trade-offs between efficiency and other corporate goals – for why trucks are run empty or part-full. These range from unforeseen incidents such as breakdowns and staff absenteeism impeding the necessary scheduling, to the constraints presented by incompatibilities between the packaging and handling equipment available at the source, the specifications of the vehicle in question, and ultimately the infrastructure at the actual delivery point. An overview of the barriers for truck fill improvements will be provided next.

2.7.1 A highly heterogeneous logistical environment

Typically the information flow that follows a product from its production to consumption is highly product-specific (Johnsson 1998), and ensuring that an HGV is filled to its maximum capacity with a multitude of goods is problematic, not least as a result of the strong product specialization on the European market and poor standardization of the associated transport requirements (Delle Site & Salucci 2010; Helmreich & Keller 2011). As opposed to transport of homogenous products from a single supplier, more complex networks involve collection of smaller shipments from different sources or locations (as in the case of reserve logistics), limiting the feasibility and time available for their consolidation (Meade & Sarkis 2002; Dekker *et al*. 2012).

It is also all-too-commonly overseen that in articulated vehicles tractor units can be decoupled from their trailers. This means that the utilisation of the more expensive tractor asset can be maximised without having to lose time waiting to load/unload a single trailer and trailer can be pre-loaded to be immediately picked up by an incoming tractor. Distribution centres indeed often have over two trailers available for every tractor unit (McKinnon & Ge 2006).

A large proportion of loads are also be limited by volume rather than weight. Under-utilisation of weight carrying capacity is frequently observed when transporting low density products that occupy the entire available floor area of the vehicle. Unused potential thus lies in the volumetric space above the goods transported. While there is considerable attention being devoted to standardizing EU loading units and swap bodies to facilitate co-modal shipments (Helmreich & Keller 2011), the growing demand for rapid transport and guaranteed delivery times [see section 2.7.5] creates smaller consignments and limits amounts of containerised shipments (Dekker *et al*. 2012).

The matter is only further complicated by the fact that HGV's themselves are often manufactured according to specific customer requirements and operational cycles (this is also true for trailers and auxiliary equipment) (EC 2011b), meaning that specialization among trucks and the handling characteristics of products (eg. Refrigeration requirements) can impair load consolidation as well as back-loading opportunities (McKinnon & Ge 2006). For these reasons, better standardisation of vehicles, trailers and other logistics resources can indirectly alleviate environmental externalities of the industry (Aronsson & Huge Brodin 2006). Companies involved in back-loading operations thus have to work with their hauliers to ensure for greater vehicle/trailer versatility and thereby maximise vehicle fills (Freight Best Practice 2010). The monitoring of vehicle specification for load matching undoubtedly places a considerable burden on logistics operators, but could potentially be simplified by the wide adoption of vehicle telematics (Piecyk & McKinnon 2009).

2.7.2 Asymmetric freight movements

Most freight is destined to move in one direction. Transport purchasers therefore tend to favour outbound deliveries, fearing that the time required to find a backhaul or better consolidate the available orders on fewer trucks will essentially delay the next outbound delivery (McKinnon & Ge 2006). Further supply chain restrictions result from customer demands for precise delivery times as well as daily and often diverse pickup and delivery operations. Such network imbalances deteriorate fill-rates and result in high emissions and other environmental externalities (Abbasi & Nilsson 2012).

Traffic demand imbalances can be overcome through triangulation of delivery destinations (i.e. not simply A-B-A but via A-B-C-A) (McKinnon & Edwards 2010). This however still does not ensure for maximal capacity utilisation as distributing vehicles are successively emptied along a given route, and their content is dependent on delivery time constraints, number of stops and available loading times. This is particularly true in urban environments, where load rates are typically low (a quarter of those seen in rural distribution networks), and with high per kilometre emissions resulting from lower speeds and motor idling at delivery points (Gebresenbet *et al*. 2011), fuel saving is predominantly achieved via vehicle technology rather than route optimisation (Arvidsson *et al*. 2013). More complex networks where journey legs are added specifically for backhaul operations often suffer from delays. This restricts back-loading operations to supply chains with a slack schedule that can accommodate a degree of unreliability (Stefansson & Woxelius 2007).

Additionally, all road freight movements are subject to EU law. These regulations are effectively aimed at preventing a vehicle "roaming" throughout Europe and exploiting the haulage market while undermining the work possibilities for local haulers (Bernadet 2009). In the past many haulers would rely upon agricultural commodities – that were exempt from such regulations – for securing back-hauls (Flood 1961). Over the 1990's access of non-resident haulers to domestic road freight haulage (known as cabotage) has been greatly liberalised, and the 2009 cabotage licensing (Article 8 of EU Regulation 1072/2009) still only allows a foreign vehicle to remain abroad for at most seven days and complete a maximum of three laden trips (in addition to the initial delivery to that country) before it has to return laden or unladen to its country of registration. In several countries it is actually forbidden for one company's trucks to pick up a return load from another company (McKinnon 2010b; Vilkelis 2011). Greater liberalisation of hauler activities is however anticipated in the coming decade (Helreich & Keller 2011), and as such regulations inadvertently contribute to the amount of empty laden trips (Bernadet 2009), one can anticipate some reductions in its contribution to current empty running levels.

2.7.3 Poorly monitored optimisation potential

One of the largest barriers to improving road freight operational efficiency is the fact that vehicle utilization is very poorly monitored. Conventionally emissions per average transport mode and distance travelled are the most basic ways of describing transport in an environmental context. Freight usage is commonly described in tonne-kilometres (tonnes of goods multiplied by total distance carried in a given transport mode). This metric however excludes empty transports and fails to differentiate between heavily loaded short-distance and lightly loaded long-distance routes (Björklund 2005).

The literature also presents few examples of how vehicle utilisation efficiency can be computed, and these elaborate indicators appear to be restricted to the realms of research and academia. Simons *et al.* (2004) have for example suggested an overall vehicle effectiveness (OVE) composite indicator that incorporates vehicle fills as well as general performance along a delivery route (speed, driver breaks, loading times, delays etc.). Load metrics are however easily manipulated by vehicle size, consignment characteristics, as well as the actual stage during a vehicle's route that these are monitored at (eg. what is the utilisation, after its first delivery, of a vehicle that is set for several destinations?). Additionally a vehicle fill metric can paint a picture that counteracts existing route optimisations. It would for example be highest when the heaviest load remains on the vehicle for the longest time, while it is evidently best to drop the heaviest load first (Arvidsson *et al.* 2013; Simons *et al.* 2004).

Given the already considerable difficulty in obtaining accurate data on empty running (eg. as criteria for what is actually considered as empty running and how much of that is reported varies between companies) (Vilkelis 2011), we are still very far from a situation where vehicle-specific volumetric data can be collected in a standardized way, let alone openly communicated for load matching. One potential facilitator is the fact loads are often carried in standardised pallets/containers. The number of these units could potentially give a rough indication of the volume required to carry a particular load and thus could inform whether back-loading is feasible or not (McKinnon 2010a). This however would still be more indicative of deck-area occupation rather than 3-dimensional cubic capacity utilisation, and widespread exchange of such information across haulers is yet to be observed.

There is thus a dire need to encourage suppliers and operators to gather information about these inefficiencies so they can better identify opportunities and the business case for logistical optimisation (Cmilt 2008). In the UK the government's Transport Energy Best Practice Programme (EEBPP), had been supporting different freight sectors (food, automotive, pallet-load etc) in their collection of energy efficiency indicators – aiming to (among other things) assess the potential economic and environmental benefits of increasing truck backloads and load consolidation (McKinnon *et al.* 2004). Vehicle fill and frequency of back-loading operations have also been suggested as key performance indicators by the UK's department for transport (DfT 2010). Nonetheless the general trend among the haulage industry is that while ideas for improvements are rife, the persistence in carrying out tests as well as mechanisms for analyses, learning and implementation are lacking, and few concrete actions are observed at the operational level (Arvidsson *et al.* 2013). While the sector experiences more information collection than ever before, it is true that proportionally less is being effectively captured, managed and analysed (IBM 2010).

2.7.4 Competitive dynamics

Ultimately it is not the physical filling of trucks that is most difficult to overcome, but the poor internal business practice alignment which presents barriers for external collaboration (McKinnon & Edwards 2010). As we shall see later, the elimination of under-capacity operations often involves inter-company partnerships [see section 3.3] – a practice that is controversial as it involves disclosure of vehicle routing and capacity data that could potentially violate competition laws and/or weaken a hauler's competitive position. The general lack of transparency in the road haulage market hinders the backhaul capacity matching and the majority of backhauls are generated internally from the same company. The few backhauls that do stem from other supply chains are predominantly identified via informal "word of mouth" communication (McKinnon & Ge 2006). Further complications arise from tax accounting and invoicing when sharing resources (Clements 2008; McKinnon & Edwards 2010). These tensions exist among shippers too, who may not allow their logistics operators to consolidate their goods with those from their direct competitors (Arvidsson *et al.* 2013).

2.7.5 Just-in-time deliveries

In recent decades, patterns of industrial production have undergone considerable changes that are seemingly driving the sector's expansion much further than the historical increments seen during the development of motorway networks. The field of logistics has experienced explosive growth as a result of the revolution in computer and communication technology and the associated consumer demand for just-in-time deliveries (hereafter JIT) (Marasco 2008). In essence JIT involves a continuous flow of materials while minimizing static inventories. Products are delivered rapidly and only in the required amounts (Clements 2008) – a phenomenon which already decades ago was anticipated to reduce consignment sizes while acting antagonistically to the operational efficiency gains from deregulation and vehicle routing technique development (Vanek & Morlok 2000; Sarkis 1995; McKinnon & Allan 1996).

Modern shipper demand for shorter lead-times, narrower delivery time windows, and the shipping of small quantities of goods at any one time, have all resulted in low load factors and increased incidences of empty running vehicles. This is ultimately contributing to the worsened profitability and increased bankruptcies seen across the entire sector (Cruijssen 2012). Not surprisingly, growth is seen predominantly in the small, palletized unit loads and the partially loaded less-than-truckload (hereafter LTL) sector (with average load rates of no more than 50% of the HGV's maximum capacity). Full load operators are increasingly marginalized even though shipment groupage is more competitive in terms of cost of transport per unit weight (Cook 2012; Gebresenbet *et al.* 2011; Abbasi & Johnsson 2012; Arvidsson *et al.* 2013).

What is more, the growing demand for rapid transport and guaranteed delivery times means that operators have to operate on fixed timetables, thereby effectively creating a disconnect between transport volumes and transport demand (Dekker *et al.* 2012). In such conditions it is not uncommon for vehicle capacity to be planned to accommodate demand peaks arising from monthly re-stacking, sales or promotions (McKinnon & Edwards 2010). Hence the total available on-the-road capacity will far exceed an average day's load requirements. Shipment aggregation is on the other hand becoming increasingly synonymous with longer lead times, delays and overall detriment of customer service (Kohn & Brodin 2008). All in all, JIT inadvertently reduces average load factors and vehicle utilization rates and is partially the reason for why transport work (in terms of vehicles required to move a given load) is continually outpacing economic growth (Gebresenbet *et al.* 2011). It is thus clear that in the modern road haulage environment it is not uncommon to deliberately operate at sub-optimal efficacies.

Alongside globally expanding supply chains and centralized inventories (reducing warehouse numbers to a situation where all demands are met from a single location), JIT has undoubtedly added to the environmental externalities of global logistics operations (McKinnon & Edwards 2010; McKinnon 2010)[2]. Several studies have indeed suggested that the increased traffic work that JIT entails is very likely to increase the sector's emissions should this strategy propagate further (see Arvidsson *et al.* 2013 and references within). On the other hand, the reduced inventory levels may well lead to lowered emissions associated with warehousing, or environmental benefits may be observed as a result of improved supplier operation efficacy stemming from shorter set-up times and more successful pollution prevention adoption at the manufacturing stage itself (Abukhader & Jönson 2004a; Tracey *et al.* 1995). Additionally it can be argued that JIT home deliveries are indeed environmentally friendlier than situations where end-consumers have to commute to a given store or service provider, although these benefits are of course primarily dependent on the distances between the shopping/warehousing facility and the customer (Abukhader & Jönson 2003). What is clear is that delivery time windows are getting increasingly stricter, which commonly means that more vehicle trips are required to deliver the same amount of goods, thus incurring a detriment to haulers' overall environmental sustainability. Some haulers have actually begun to advertise operations with longer lead times as added-value environmental services, though strong interest in such offerings has yet to become apparent (Arvidsson *et al.* 2013). The bottom line is that customer service quality and resource efficiency are all-too-often opposing forces within the road haulage industry.

2.7.6 Insufficient backing from ICT systems

There in considerable application of information and communications technology (ICT) in the road freight transport sector. According to Abbasi & Johnsson (2012, 29) such technologies are the key to "integrated, connected, visible, adaptive, and intelligent supply chains" and can subsequently contribute to improved environmental performance of freight distributions. Not surprisingly, road haulers are continually pressured by the government, vehicle manufacturers, transport buyers and other supply chain stakeholders to incorporate new ICT systems into their operations (Arvidsson *et al.* 2013; Stefansson & Woxenius 2007). ICT's are most

[2]The interested reader is also referred to an opposing view offered by Kohn and Brodin (2008) who argue that centralized systems enable for greater opportunities in consolidating goods, changing modes and reducing emergency deliveries.

appealing to operators transporting high value, hazardous or refrigerated goods and especially to those seeking to offer JIT services (Perego *et al.* 2013).

2.7.6.1 Real-time vehicle monitoring

The literature presents a multitude of applications, with a strong emphasis on ICT's trials and tribulations in representing real-life phenomena (travel times, congestion, accidents, crime etc.) and communicating these to the driver and general management (see eg. van Woensel *et al.* 2011 and references within). The vehicle telematics industry is indeed rapidly expanding and has been able to offer considerable internal savings to road haulers. For instance, the Volvo Dynafleet software that the HGV manufacturer has been selling alongside its vehicles since 1996, has been able to offer fuel and cost savings and general internal efficiency gains to its customers (primarily long-haul operators and sub-contractors). Invariably this has also involved improved routing techniques that reduce rates of empty running vehicles. The environmental benefits accrued optimised and reduced travel distances and subsequent fuel savings are however only a secondary motivation for the purchase of Dynafleet systems (Selvén pers. comm. 2013).

What is more, the emphasis remains on collecting data about the vehicle and the driver's behaviour, while less is monitored about the carried goods. Hence, although technologically it would be possible to export the collected data to external brokers or consolidators, the overall IT structure of the sector remains extremely diverse and offers little in terms of harmonization for the purposes of horizontal collaboration in freight movements. Many operators are actually demanding further customization for better integration of vehicle telematics systems with their internal working processes. The virtualization of HGV fleets is driven by offerings of internal savings, risk management and legislative compliance rather than opportunity for capacity sharing (Selvén pers. comm. 2013; Perego *et al.* 2011). The utilization of real-time information is yet to develop into a planning process that optimizes not just intra- but also inter-organizational processes. It can indeed optimise relationships between shippers and logistics providers (Langley 2012) but the literature has revealed little about ICT's role in developing horizontal partnerships.

With strong specialisation among traffic management software, and operators are at an increasing risk of investing into systems with functional overlap, while resources for such non-mandatory investments remain scarce (Arvidsson *et al.* 2013; Stefannson and Woxenius 2007). The EU is indeed invested in several projects (FREIGHTWISE, EURIDICE, e-Freight, iCargo) that are seeking to create inter-operability between the systems employed by different stakeholders within a supply chain, and combine ICT platforms for services at different levels of cargo interaction (intermodal shifts, vehicle positioning, vehicle loading, shipment tagging). These young projects however have yet to demonstrate clear deliverables which are specific to the road haulage sector.

All in all, the potential asset utilization and operational efficiency benefits are all too commonly blocked at the very initial stages of ICT implementation. The biggest barrier to ICT-derived operational efficiency is the fact that road haulers are not unanimously willing to dwell into adopting these systems altogether.

2.7.6.2 Back-load identification

Alongside communication with remote workforce, real-time vehicle telematics and driver monitoring, Perego *et al.* (2011) classify ICT applications into management of information exchange and the tracking, scheduling and optimization of vehicle loads. ICT has indeed facilitated some forms of multi-actor collaboration to reduce the number of empty running vehicles. For example, the Teleroute [www.teleroute.co.uk] online freight exchange is a Europe-wide platform that connects a community of registered transport companies to identify back-loading opportunities for trucks that would otherwise run empty across international borders. Other web-based information sharing platforms in Europe include [www.loadup.co.uk], [www.return-loads-from.com/trucks] and [www.truckspace.co.uk]. Alongside the growth of reverse logistics, lengthening of freight journeys, and overall corporate initiatives, such internet freight exchanges do play a role in the decline of empty running HGVs (Arvidsson *et al.* 2013). These platforms are however still rather crude as they only operate on a load or no-load basis. In other words they only identify completely empty running vehicles rather than collect load weight and volumetric fill data that is required for true shipment consolidation. Interestingly, members of a similar platform in New Zealand [http://www.backload4u.co.nz/backload-empty-trucks.php] do occasionally advertise unfilled cubic space on partially loaded trucks, although empty vehicles still make up most of the posted opportunities. Most importantly, these platforms work on a case-by-case basis, meaning that they offer little encouragement for long-term collaborative transportation partnerships.

2.7.6.3 Shipment consolidation

In theory however, ICT can do a lot more. IBM's transport management software for example can be used as a transport buyer's tool to directly manage shipping services. It is common for manufacturers and wholesalers to want to clear their docks overnight, meaning that if all is left to them they will probably choose to purchase more expensive LTL services. This means that the final buyer of the goods is then seeing higher transport costs and sub-optimal vehicle fills. IBM's Software as-a-Service model (SaaS) should enable the end buyer to take a lead role in the supply chain, and exert pressure for more eco-efficient operations (IBM 2011).

Similarly, in cases where haulers can take the initiative themselves, ICT can aid them in identifying cargo availability, assessing the consolidation process within available containers (see eg. Hellström 2011) or trailers considering the cargo's characteristics, and finally making informed decisions regarding the costs and benefits of concomitant route and schedule alterations. There is particularly strong demand for software with such functionality among rapid door-to-door delivery operators (Lin *et al.* 2012). Lin *et al.* (2012) have developed a web-based collaborative logistics management decision support system (ICLMDS) aimed at exactly that. The information-sharing platform allows shippers and haulers to "virtualize" their cargo dimensions and vehicle capacities in three-dimensions, thereby identifying optimal consolidation opportunities and routes. It consists of distinct modules: cargo-to-container and -vehicle matching advisor as well as a pick-up and delivery routing planner. The benefit of the system is that it is entirely web-based thus avoiding software acquisition costs and minimizing the cost of communication. It also provides a bridge between warehousing and distribution operations which are traditionally managed independently from each other.

One of the most ambitious freight exchange platforms is known as Tailgate and is anticipated to be launched by the European Logistics Users Providers & Enablers Group (ELUPEG) in 2014. Tailgate will essentially become "an Expedia for freight" (Bolam pers. comm. 2013) that matches shipment demand to available capacity via a series of algorithms that incorporate a myriad of factors including price, consignment logistical behaviour, route and associated CO_2 emissions as well as contribution to congestion. Operators will upload information about their fleet (size, weight, trailer dimensions, Euro emissions standards), and must ensure for its tracking capability. In turn, shippers will be able to co-ordinate their loads either internally among their selected haulers, in a wider sector-specific marketplace or in a completely open marketplace that will essentially enable for the consolidation of goods between very distinct industries. This will also be a multi-modal solution that will incorporate rail and eventually short-sea and inland waterways operations. It is anticipated that the platform will have some 1500 members within 5 years of its launch in 2014. With some 10 searches for each load query, and with an anticipated volume of 400,000 loads per day, the platform will essentially be making some 4 million load matching operations every 24 hours. Other than just finding a hauler for any given load in real time, Tailgate will also aim to find the least CO_2 and transport intensive solution for each load. It will be built off an existing business-to-business integration hub known as Omprompt (Bolam pers. comm. 2013).

In the current marketplace, such solutions are still lacking. What is true is that if a member of the public is seeking to make a large shipment (eg. furniture, boats and other vehicles, or just general packaged items) that does not require rapid delivery, and is relatively flexible in terms of shipment timing, they can turn to so-called "going there anyway" couriers advertised on [www.shiply.com], [www.anyvan.com] or [www.deliveryquotecompare.com]. These websites consider the characteristics, weight and dimensions of a shipment and advertise it among member haulers who may have spare capacity to offer on their existing routes. In a form on an on-line shipping auction the customer can then choose between several offers made by different haulers. Such offerings are nonetheless still a long way off from an official platform for regular business-to-business information exchange for large-scale consolidation of goods between contracted shipments. Tailgate will certainly be a pioneer in this area, but its deliverables and environmental savings will only become apparent in the future.

2.7.6.4 Lack of affordable web-based software

In their comprehensive literature review, Perego *et al.* (2011) report that while electronic data interchange, scheduling and routing software is well-established, web-based systems have generally had quite poor penetration into the industry. This means that software acquisition costs (licenses, servers and IT staff) are still a strong barrier to any potential benefits that ICT is to offer. Not surprisingly, there is an evident disconnect between the IT capabilities of logistics operators and the level of IT penetration that their customers are demanding (Langley 2012). Company size remains a crucial variable in ICT adoption, with small operators preferring to stick to more traditional communication and operations management systems. There is nonetheless some reason to be optimistic, as research has already developed a tool that can connect small transport companies in a "virtual fleet" so as to achieve greater communal operational efficiency (through economies of scale) (Delle Site & Salucci 2010). Similarly, more complex logistics management systems are set to become available as web-based services that offer regular updates and whose accessibility to multiple external stakeholders (customers, suppliers) is easier to set-up and manage. Open web-portals mean that new members can integrate easily and cheaply, and all members receive the same benefits, support, upgrades and infrastructure. In this way such systems will also pave the way for improved information sharing, the lack of which is currently most prohibitive to collaborative logistics (Tesseras 2011). Cloud computing platforms such as Deltion's CarrierNET [www.deltion.co.uk/sol_carriernet.asp] can indeed optimise asset utilisation, load fills and minimise empty runs without the hassle of additional equipment or software (Cook 2012).

2.7.7 Customer pressure for greener haulage is still lacking

Environmental requirements – unless directly aligned with cost savings – often remain merely a minimum requirement for the establishment of 3PL relations. This is very applicable to the EU where there are virtually no associated regulations to dictate transport buyers' decision-making process or logistics providers' service design. Additionally the road and congestion charges have had the effect of increasing the sensitivity of transport purchasers to road freight costs, rather than encouraging any widespread environmental adaptation in their purchasing decisions (Wolf & Seuring 2010). Environmental transport purchasing, it seems, is largely reserved to the realms of large companies, while smaller businesses decisions are predominantly driven by price signals (Lammgård 2007). This argument however is – at least in theory – not applicable to the environmental benefits offered by goods consolidation, as the very nature of such eco-efficiency should offer customer cost savings.

What is true is that there is no clear guideline for how the relationship between a focal company and a 3PL should be managed to maximize environmental considerations and efforts. Whether transport purchasers can impose strong environmental demands, let alone see their deliverables is arguable. As outlined by Björklund (2005), companies are often very limited in the number of carriers that can handle the large number of transports and volumes required by the company's production rates, and similarly they cannot possibly apply the same environmental requisites across all the international hauliers that they co-operate with. For example, given their modern fleets and widespread ICT capabilities, requirements placed on Swedish hauliers will exclude all possible hauliers in other markets. Hence from the transport buyer's side, there is a considerable administrative burden involved in the tailoring of 3PL requirements to the operational geographic area.

Accordingly, Lieb and Lieb (2010) showed that even if sustainability dialogue between companies and 3PL's is on the rise, out of 39 interviewed transport purchaser CEO's only three said that sustainability issues were frequently used when securing or extending 3PL contracts. IBM's survey of over 400 executives also showed that only some 25% of them would actively choose their outsourced transportation operators based on emissions or energy consumption evaluations (IBM 2010). Further yet, logistics is a multi-actor field, and given the degree of outsourced services, accurately monitoring and maintaining required levels of environmental performance (be it truck fuel efficiency, emissions standards, or capacity utilisation) in different intermediary actors across the supply chain is exceedingly difficult (Vilkelis 2011; Abbasi & Nilsson 2012). In fact, all this may well be driving down the stringency of transport buyer's environmental criteria. Overall this means that the precipitation of any environmental criteria (let alone one which is not even monitored; as seen in section 2.7.3) from mere customer aspirations, to concrete purchasing requirements, and finally 3PL operationalisation is an inherently slow process. As outlined by Liimatainen *et al.* (2012) customer expectations for energy efficiency are often directed at large 3PLs but are not transferred further down to the smaller sub-contracted hauliers.

Concomitantly, 3PL interviewee's in Abbasi & Nilsson's (2012) study declared that their customers generally had low interest in prioritising environmental transport solutions, either as a result of the customer's own poor competencies in this field, or because they are primarily demanding the lowest time and price for their transport services [see section 2.7.5]. Even if an eco-friendly solution exists, and is operationally cheaper (which is exactly what freight consolidation offers), the extra time needed to plan the transports was reported to discourage demand (Abbasi & Nilsson 2012). This corresponds with older findings suggesting that transport buying decisions are primarily hinged upon cost and service quality, timely delivery, reliability, technical capacity, financial stability and overall 3PL performance history (Björklund 2005; Selviaridis & Spring 2007). Environmental performance is – or is at least perceived to be – in conflict with service quality. As result of contractual terms, risk mitigation strategies, lacking data collection and their general "resource provider" status, transport providers appear to be badly positioned to encourage and implement innovative solutions (Langley 2012; Fabbe-Costes *et al.* 2009).

The above suggests that the signal for eco-efficient vehicle utilisation should be coming from transport purchasers rather than transport providers. In Sweden, Björklund's (2005) study showed that out of 50 Swedish shippers some 92% considered their environmental expectations as exceeding those required by law, and 90% felt capable of influencing the environmental status of their transport suppliers. Haulage contractors (transport buyers) can thus play a considerable role in incentivizing a transition to greener road freight operations. The demand for consolidation and better vehicle utilisation has to be in place, before freight operators can start adapting their operations. As there is a disconnect between the environmental purchasing that transport buyers claim to have in place and what 3PL's are actually experiencing from their customer base (Wolf & Seuring 2010), it is evident that the potential for customer's to encourage greener haulage remains largely untapped.

2.7.8 Vehicle utilisation is not a criterion for supplier-3PL partnerships

Operationalisation of the notion of green logistics has also proven difficult. The literature outlines that strategies for a holistic consideration of transport's energy efficiency and associated environmental externalities in the broader context of corporate supply chains have been vague or altogether neglected in both theory and in practice (Halldórsson and Kovács 2010; Abbasi & Nilsson 2012; Wolf and Seuring 2010). The notion of sustainability is already exceedingly difficult to operationalise internally, thereby often limiting interpretation and prioritization of transport-related issues in what are often inert, money-driven business environments (Abbasi & Nilsson 2012).

Nonetheless, in a business environment where ever more supply chain functionality is external to a company, transport purchasers have started to impose some forms of environmental qualifiers on their external logistics operators. Typically, they will use questionnaires or perform audits to gather environmental performance data for selecting transport mode and differentiating between logistics providers prior and during contractual partnerships (Simongati 2010; Sink & Langley 1997). For instance, out of a global study of over 2000 shippers, 52% have revealed that fuel efficiency and carbon emissions have become part of their 3PL service provider selection criteria (Langley 2012). However, these evaluation methods often have little else to go by other than 3PL's official average values for emissions and energy consumption (eg. NOx, HC, PM emissions and specific fuel consumption per power output unit of the engine). These figures vary significantly in terms of validity, calculation methodology, and are commonly of low-resolution; for example they are only differentiated according to mode of transport and are commonly country-wide averages (Berglund 1999; Björklund 2005; Simongati 2010). Langley's (2012) comprehensive study outlines that worldwide only 26% of shipper respondents were able to rely on their outsourced logistics providers to provide accurate fuel efficiency and carbon emissions data.

Other common 3PL requirements focus on technical (vehicle age, fuels, engines, tyres, maintenance schedules), educational (eco-driving), management (internal environmental management systems, policies and goals), and judicial (former convictions due to environmental impacts) aspects of the transport providers operations (Björklund 2005). The Fiat Automobile Group for example, is committed to meeting its transport needs using only Euro III low-emission freight vehicles, while vehicles that fail to meet these standards are prohibited from delivering components to Fiat's assembly plants (Vilkelis 2011). Further yet, purchasing criteria can be extended for the benefit of the broader supply chain efficacy. For example, taking the approach that "environmentally responsible" logistics is hinged upon material flows from customers back to industrial channels (Goldsby & Stank 2000), Meade and Sarki (2002) have proposed a strategy for choosing logistics providers to partner with specifically for reverse logistics operations.

The extent to which 3PL capitalise upon the individual vehicle capacity of their fleet upon is yet to become an integral part of these decision making tools. While some authors have pointed to the potential of vehicle fill rates and amount of unloaded transports forming part of the carrier selection process (Björklund 2005; van Hoek 1999), the literature is silent regarding whether these aspects have ever been incorporated into real-life considerations. One possible reason for this is that the above-mentioned lack of vehicle utilization data is impeding companies' ability to have any justifiable expectations. The industry is still a long way away from a situation where commonplace performance measurement systems comprise truck fill rates, and would enable to differentiate between 3PL's prior to contractual relationships [see section 2.7.7] This signals that transport purchasers could use their existing partnerships with 3PL's to encourage this data collection.

More importantly, it must be remembered that vehicle utilisation is predominantly a function of the operational environment (nature of consignment, scheduling, supply chain infrastructure etc.) that the customer imposes upon the logistics provider rather than the internal policies of the actual logistics operator. As logistical efficiency is often aligned with both economic and environmental reasons, the drivers for improved vehicle loading and return transports probably make themselves more apparent at later stages of the shipper-3PL interaction. One exception to this would be explicitly purchased group consignments (where one carrier works for several goods suppliers) wherein a concerned customer may well be looking to find an operator who fills their trucks best while delivering the desired service level.

All in all, given the above-mentioned limitations of environmentally-conscious 3PL selection, as well as the lack of vehicle fill data to go by, it would appear that a) improved vehicle utilisation rates can only be achieved if transport buyers demand it and b) the initial transport purchasing interaction is presently quite poorly suited for the application of vehicle fill capacity utilisation criteria.

2.8 Summary of push and pull factors

The findings of the literature review are summated in *Figure 2* below. The reasons behind vehicle under-utilisation and strong counteracting developments have been linked together. It must be remembered that the relevance and force behind each individual driver is in constant dynamism; a rapid rise in fuel prices may push transport purchasers to demand that their logistics providers share loads with the purchasers' competitors, while when fuel prices fall, the emphasis is placed more on service quality with smaller, more frequent shipments and ultimately a greater environmental impact (IBM 2010).

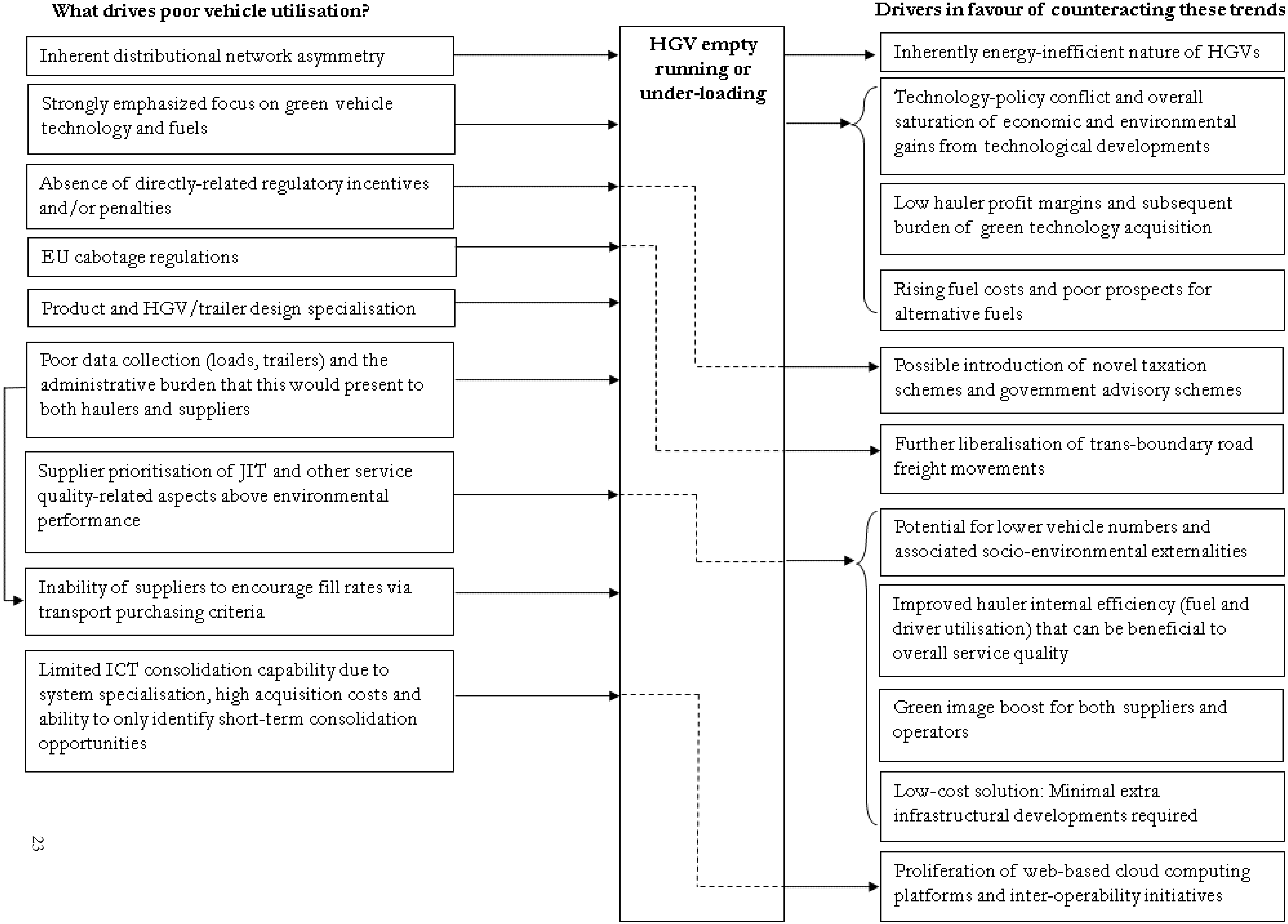

Figure 2. Summary of factors driving and counteracting poor HGV utilisation

3 Analysis: Counteracting poor vehicle utilisation

3.1 Improving vehicle fill rates through collaboration

As previously mentioned, opportunities for consolidating and/or obtaining return loads are either inherently limited by geographical imbalances of freight distribution networks, or are lacking as a result of complex interactions between political, technological, economic and human factors. Vehicle fill rates can nonetheless be raised through various initiatives. Aronsson and Huge Brodin (2006) outline that there are essentially three strategies for fulfilling this task; pertaining to logistical infrastructure, vehicle routing and multi-actor collaboration.

Firstly, the physical infrastructure has a large role to play. Structural changes in warehouse sizes, numbers and location can certainly restructure and create more centralized freight flows, thus invariably leading to more consolidation on individual vehicles. Several researchers have outlined that freight consolidation centres can minimise warehousing costs and CO_2 emissions while encouraging higher vehicle load factors or modal shifts (Vilkelis 2011; Delle Site & Salucci 2009, 2010). Next, modifications in the timing and routing of the vehicles can ensure that distances driven, fuel consumption and the number of operating vehicles are lowered while the remaining vehicles are being driven at higher capacities (Gebresenbet *et al.* 2011). Sophisticated algorithms for minimising the number of repositioning or empty runs (see Ergun *et al.* 2007 and references within) as well as holding times and dispatch quantity (Bookbinder & Higginson 2002; Cetinkaya & Bookbinder 2003) have long been devised.

Aronsson and Huge Brodin's (2006) third strategy relates to coordination with external supply chains who may be supplying the same customers or operating in the same geographical area. It has long been recognized that logistical activities shared between several actors are better adjustable when adapting to new market exchange relationships such as JIT, and thereby improve the actors' combined efficiency (Frazier *et al.* 1988). More recent literature also suggests that the sharing of resources and collaborative multi-actor efforts offer low-cost solutions to both greening and optimizing road freight operations' costs as well as overall market competitiveness (Groothedde *et al.* 2005; Clements 2008; Ergun *et al.* 2007; Piecyk & McKinnon 2009; Zhou *et al.* 2011). As outlined by Groothedde *et al.* (2005, 580):

> *"The main motivation behind the tendency to look for collaboration between partners in logistic networks is achieving economies of scale and scope. Through the combination of activities it is possible to share costs, through sharing of information it is possible to avoid unnecessary costs and through avoiding sub-optimization and acting as one organization the business units that co-operate can work more efficiently and become more effective at the same time."*

With retailers pushing for more frequent deliveries, manufacturers seeking lower supply chain costs, growing environmental pressures, and recession-induced low profit margins, more collaborative services are an appealing way out for both transport buyer's and logistics service providers (Waller n.d.). As suggested by Piecyk & McKinnon (2009), collaborative freight consolidation can be seen as low risk, self-financing best-practice measures that are applied at the most flexible decision-making level and can green operations without changing broader, fixed logistical structures. Clements (2008) reported that the savings that the European logistics industry could see as a result of collaborative efforts to tackle empty running amount to some 8.6 billion GBP every year, and that although considerable administrative processes are required, the actual implementation of such initiatives can be quick and simple. More recently, Audy *et al.* (2010) have demonstrated the existence of numerous mechanisms for the computation of potential financial gains of collaboration, as well as how these can eventually be shared among the involved actors. For an overview of these gain sharing mechanisms the reader is referred to Cruijssen (2012).

3.2 Vertical collaboration

When identifying examples of collaborative efforts that have improved the eco-efficiency of road haulage operations, it is important to distinguish between the two types of collaboration; "vertical" and "horizontal". The literature is rife with examples of "vertical" alliances between trading partners at different levels within a single supply chain (McKinnon & Edwards 2010; Wolf & Seuring 2010; Vachon & Klassen 2006; Stefansson 2006; Selviaridis and Spring 2007; Sandberg 2005). As underlined by Vilkelis (2011) and McKinnon and Edwards (2010), distribution networks are conventionally designed primarily with cost, and speed of deliveries in mind, which means that considerable optimisations can already be achieved internally.

Improved synchronisation of production processes and distribution patterns typically ensures that the downstream movement of goods through the supply chain occurs at lower costs and in fuller truckloads (Van Woensel *et al.* 2011). Manufacturers are becoming increasingly interested in collaborating with their raw materials and packaging suppliers, meaning that intra-supply chain partnerships can span Europe-wide distribution routes (Clements 2008). In turn these efforts can also improve customer service by ensuring quicker responses to demands (delivery frequency), maintenance of full shelves (that win more customers), and general supply chain flexibility under special requests (Tesseras 2011).

These efforts, albeit successful in improving fill rates, are nonetheless beyond the scope of this research. Synchronisation of processes within a single distribution network still entails an HGV's utility being exploited only by a single customer, thereby by-passing the "servicisation" aspects of the thinking developed herein [see section 5.4]. Often it is the degree of *external* operations' integration that decides the overall success of logistical optimisation strategies (Holweg *et al.* 2005).

3.3 Horizontal collaboration

Horizontal collaboration occurs between separate supply chains in an attempt to share risks and rewards thus leading to a greater competitive advantage and business performance than would be achieved by the involved actors individually. Typically horizontal collaboration in the logistics sector is driven by cost reduction. For example, in the Eye for Transport (2010) survey all stakeholders (industries/shippers, haulers and other 3PL's) unanimously stated that cutting costs was the dominant driver for them to consider horizontal collaborative initiatives. Further benefits include broader geographical coverage and access to larger contracts (leading to financial growth), inter-organisational learning, shared technological capacity, and improved operational flexibility (Cruijssen 2012).

Horizontal collaboration can occur between non-competing as well as competing companies. These may choose to share warehousing facilities or join their shipments together to buy full vehicle loads (FTL) as opposed to the more expensive part-load shipments (LTL) (Kaveh & Samani 2009). Often the most logical partner to collaborate with in terms of transport is actually a competitor, as they are essentially delivering the same service or product, to the same place, and at the same time (Tesseras 2011). Most importantly for the research herein, the sharing of assets with parallel supply chain actors has a considerable positive environmental impact, predominantly because this can offset increased transport demand as less equipment is needed to generate the same amount of tonne-kilometres (Dekker *et al.* 2012; Cruijssen 2012). Optimisations in vehicle capacity utilisation and reduction in empty running are thus an evident outcome of many such partnerships (Verstrepen *et al.* 2009). As outlined by Cruijssen (2012) back-loading and joint distribution measures can be achieved without the need for integrated business planning, and can be established through exchange of information between just a single activity or division of each partnering entity. Eye for Tranport's (2010) study also confirmed that by far the most popular way for industries to collaborate horizontally is by sharing truckloads, closely followed by the sharing of warehousing facilities.

3.4 Examples of horizontal collaboration

In the literature, virtually all examples of horizontal collaboration in road freight movements stem from the fast-moving consumer goods industry (hereafter FMCG). Food distribution probably has the most demanding logistical efficiency requirements owing to the perishable nature of the goods, customer quality requirements and the overall importance of supply system maintenance (Gebresenbet *et al.* 2011). It is also the single largest road freight sector in the EU, in terms of both tonnage and tonne-kilometres travelled (16.5% share of all road freight in 2011). An overview of different collaborative typologies and examples thereof in the logistics industry can be found elsewhere (see Cruijssen 2012 and references within). The focus herein is entirely on vehicle-level asset utilisation; hence on instances where horizontal collaboration involved the sharing of HGV cube fill and/or weight haulage capacity between two or more actors.

Several major British retailers (Tesco, Costcutter, Safeway) have for example been engaged in major back-loading initiatives since the early 1990's (McKinnon 1996). Other examples include Nestle and United Biscuits distributing goods in round trips so as to cut empty running trucks between manufacturing and retail outlets, as well as high-street retailers (Woolworths, WHSmith, Stylo Shoes) using a common logistics provider (Wincanton) to ensure for full truck loads on rural distribution routes (Clements 2008; McKinnon *et al.* 2010). In France, partnerships between three manufacturers: Bénédicta, Banania, and Lustucru who have close manufacturing locations, and the same retail customers have since 2006 been using a common logistics service provider to consolidate their deliveries. This has ensured for a 15% increase in vehicle fill rates (compared to that seen prior to the collaboration) and an associated 16% reduction in storage costs, as well as a reduced environmental footprint (Palmer *et al.* 2012). These examples illustrate that third-party logistics providers can provide a valuable platform for the establishment and operation of inter-company partnerships that favour optimised HGV utilisation.

The UK's Institute for Grocery Distribution (IGD 2008) has even issued a guide on how to reduce empty running through company partnerships initiated by the sharing of distribution operations information (production/distribution locations, fleet and out-/inbound load characteristics, 3PL involvement), establishment of review mechanisms, and a the running of a small-scale freight exchange and consolidation pilots. Their Collaborative Green Distribution workgroup aims to not only facilitate collaborative transport discussions between companies (via meetings and face-to-face interactive sessions), but also to ensure that these concepts are spread "across communities of retailers and suppliers by taking a many-to-many approach rather than via trading partners in a one-to-one relationship" (IGD 2007, 8). In 2008, it launched one of the largest road freight collaborations; the Sustainable Distribution Initiative. This involved some 37 food retailers and manufacturers, who committed to cutting fuel consumption (conserving 23 million litres of diesel fuel in a full year), number of HGV's[3], and the distances these travel on the roads (cutting 48 million food miles). The 2007 pilot alone saved some 16 million trucking miles. This is arguably the single best example of how road freight operations can be viewed as a service that can be shared among numerous actors. Efficiency gains also appear to be proportional to the amount of collaborating entities involved in the partnership (Cruijssen 2012).

However while the guidelines claim to be intended for "operating any size of transport fleet within retailers, wholesalers, manufacturers and logistics companies" (IGD 2008, 2), the provided case studies only outline adoption amongst the food and every-day consumer goods sectors. Clearly, perishable fast-consumed goods manufacturers have thus already made considerable headway in integrating their logistical operations. This is exemplified by McKinnon & Ge's (2006) study that compiled multi-company truck movements, and spatial modelling in order to retrospectively screen for possible backloads across some 29 fleets in the UK's grocery supply chain. The results outlined that further potential for reducing empty running trucks was indeed already very limited given the inherent operational and scheduling constraints of the sector. The authors however suggested that deliveries in other sectors are likely to be less constrained, but if back-loading analysis continued to be performed on a sector-specific basis, cross-sectoral opportunities may well be overseen. Accordingly, Eye for Transport's (2010) survey has revealed that most existing collaboration occurs with non-competitors,that deal with complementary goods (an explanation of what this complementarily entails has not been provided). This was followed by collaboration with competitors who still transported complementary goods. This signals that cross-sectoral opportunities are limited by the logistical behaviour of different consignments and that – at least among the studied companies – it is shipment compatibility rather than competitive dynamics which are the foremost driving factor behind collaborative decisions.

The literature is however – to the author's best knowledge – silent regarding the specifics and deliverables of similar collaborative efforts in industries outside the FCMG industry. Such initiatives are either truly scarce, or industries are simply hesitant to disclose details regarding their horizontal partnerships, thereby effectively creating a knowledge gap. Even if fitting initiatives exist, reporting on the deliverables of these collaborative efforts has indeed been limited over the years. The majority of transport contractors who responded to the Eye for Transport's (2010) survey, were indeed *not* from the food or consumer goods sector, but pharmaceuticals and healthcare producers. Horizontal collaboration is thus not restricted to FMCG producers, it just that it is poorly reported upon. It would still be interesting to investigate to what extent this kind of thinking has been developed in industries working with more heavy and sizeable goods. As it stands, one can appreciate that the degree of collaborative road transportation activity is sector-specific and highly dependent on compatibility of the transported goods' logistical behaviour.

Finally it must be mentioned that on the whole the environmental gains of such collaborations have rarely been extensively reported upon. Almost a decade ago Abukhader and Jönson (2004b) concluded that discussions were being dedicated to the implementation of environmental technologies and strategies, but had done little to evaluate the actual impact of

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[3] Additional logistical environmental sustainability strategies in the sector involve utilisation of 4.9-metre tall double-deck freight vehicles which can cater for low density freight demands with a lower number of individual vehicles (McKinnon 2010d).

these decisions. More recently, Dekker *et al.* (2012) have outlined that while many logistics strategies and concepts have definite benefits for both operational efficacy and the environment, research that comprehensively covers both aspects is still lacking.

Urban-distribution initiatives

Finally it must be mentioned that given its popularity in the FMCG sector, the sharing of HGV capacity has become synonymous with urban deliveries. There are many examples of "City-Logistics" wherein inter-company cooperation agreements have enabled for significant reductions in distances driven and truck numbers. One of the earliest known projects took place in the German city of Kassel, where already back in 1994 ten local forwarder agents agreed to co-operate and develop a "neutral carrier" of their goods within the city centre. Load consolidation meant that no more than 3 vehicles were needed daily to perform all the needed deliveries from the common transhipment centre (Köhler 1998). A 70% reduction in vehicle kilometres travelled and 11% reduction in number of delivering trucks were achieved (Whitelegg & Haq 2003).

In Freiburg (DE) groups of logistics contractors chose assign their urban deliveries to a single independent contractor. This has enabled to reduce journey times from 566 to 168 hours per month, truck operations from 440 to 295 (33% reduction) and the time spent by trucks in the inner city from 612 to 317 hours per month (Whitelegg & Haq 2003). All this has occurred with the number of customers and shipments unaltered – in what is essentially another perfect example of increased utilization of the driver/vehicle combination incurring considerable operational cost savings as well as benefits to the public and the environment. A similar collaboration took place in the Swedish city of Gothenburg. The initiative was widely accepted by all relevant stakeholders (drivers, transport operators and municipality) but the expected results of reduced delivery numbers and pollution in the city's inner "environmental zone" have not been achieved, perhaps because restrictions on goods volumes and vehicle types had not been resorted to (Delle Site & Salucci 2009).

Although urban distribution logistics do illustrate collaborative success stories, the nature of the operations as well as the stakeholders involved means that their analysis is still outside of the realms of this research. City logistics involve public-private partnerships between shippers, operators, residents and administrators which are of little relevance to the long distance haulage scope herein. Best-practice lessons for urban distribution have also been summarised elsewhere (see Wisetjindawat 2010 and references therein). What is more, although this discussion is not included in this review, conversations with researchers have revealed that city freight consolidation efforts are mostly very short-lived (Rydén and König pers. comm. 2013; also see Hedenus 2008).

4 Case studies

4.1 The biggest culprits

As has been demonstrated above, horizontal collaboration is well established in a few road haulage sectors. If vehicle utilisation rates are nearly optimal in the FMCG sector, this raises the question of which sectors are contributing to the reported Europe-wide trends of un- and under-loaded HGV operations [see section 1.2]. As a matter of fact, there is quite little official sector-specific analysis of road freight loading and empty running. This is in line with previously reported findings of poorly monitored vehicle capacity utilisation [see section 2.7.3].

Communications with the Swedish national statistics office have nonetheless revealed that locally this sort of data has been monitored and reported on. The 2012-released Swedish national and international road goods transport report (Sveriges officiela statistik 2012) revealed that in 2011, products of agriculture, forestry and fishing accounted for the largest amount of empty driven miles (over 96 million km), of which round wood transport alone made up some 73 million empty run kilometres. This was followed closely by ores and other mining-derived products (51 million km), wood and products of wood, cork (excluding furniture), pulp, paper and printed matter (38 million km), and other non-metallic mineral products (34 million km).

4.2 Round wood transport logistics efficiency

Not surprisingly, it was decided that round wood transports should be further looked into in order to determine whether potential for improved vehicle utilisation remains. The literature has revealed that the general flow of material in this supply chain is one-way – that is from the forest to the industry and that empty running is subsequently rife on return journeys. Not surprisingly, back loading is a well researched aspect of these operations. Forsberg (2002) summarised the results of Carlsson & Rönnqvist (1998) study that modelled the six major round wood supply chains in northern Sweden outlining that 46% of the transported volume was suitable for back hauling, leading to potential transportation cost savings of 8.7%, fuel cost savings of 7.2% and a 9.2% reduction in working time. Only 10 to 15% of this potential was actually being utilised at the time of the research. Horizontal cooperation between different overlapping supply chains was assumed to hold significant cost reduction potential.

Although this collaboration may be gaining popularity in Sweden, it is quite uncommon in other parts of Europe (eg. France), where transports are carried out by small, specialised operators who tend to be involved in one-to-one relationships with their contractors (Le Net *et al.* 2011). More recently Carlsson and Rönnqvist (2007) have provided a more elaborate tactical route planning model that makes a strong emphasis on back haul operations, the success of which again depended on the geographical coverage and number of companies involved in the partnership (also see Puodžiūnas *et al.* 2004 for similar model in Lithuania).

Today literature outlines that efforts to improve the environmental performance of round wood transportation logistics are looking towards larger capacity vehicles (Haraldsson *et al.* 2012; Löfroth *et al.* 2012; Le Net 2011), on-board diagnostics that should aid in eco-driving, and the selection of the best suited vehicle models for round wood haulage operations (Devlin 2010). In Sweden particularly, finding backloads is not considered to be the most environmental measure, and attention is being diverted to lighter and more efficient vehicles as well as internal route optimisations (Le Net *et al.* 2011). This is suggesting that back loading opportunities have slowly been exhausted. Opportunities for collaboration with other industries are evidently very limited because trucks are travelling fully laden between the forest and the closest industry or train loading terminal, and there is no need for transport of goods back to the forest. Additionally there are few other loads that are suitable for the open loaded round wood truck trailers (Sjögren pers. comm. 2013).

Clearly the round wood industry's poor vehicle utilisation is a result of the inherent nature of the operations in a raw material industry; which has unavoidable freight distribution asymmetry. In the next section it will investigated how vehicle utilisation maps onto a more complex logistical distribution system of a multipart manufactured product.

4.3 The automotive industry

The automotive industry has experienced rapid growth worldwide, and it arguably contains some of the most complicated logistical flows, which are highly capital-, technology-, and knowledge intensive (Liu *et al.* 2010; Uttamrao & Rajashree 2009). It is also not uncommon for the industry to operate a lean logistics mode based on JIT (Liu *et al.* 2010; Sihn & Schmitz 2007; Pelagagge 1997), which as we have previously seen, can lead to poor HGV capacity utilisation [see section 2.7.5], and has been reported to have clear negative effects on transportation's cost and environmental impact (Holweg & Miemczyk 2003). The push for JIT comes from customer demand for rapid vehicle deliveries as well as strong specialisation in the made-to-order vehicles (Holweg & Miemczyk 2002; Miemczyk & Holweg 2004)

With regards to HGV utilisation, in situations where a component supplier dispatches trucks directly to a single manufacturer, few high-volume shipments are observed. However the most common arrangement is a "milk-run" wherein a 3PL owned truck visits more than one supplier and collects deliveries destined for a single production facility. This single-actor consolidation is common in the industry and has been reported to be flexible enough to allow day-to-day route planning adjustments (Miemczyk & Holweg 2004; LaSota pers. comm. 2013). Alternatively it has been suggested that goods from several suppliers can be consolidated in hubs prior to release to a single manufacturer (Sihn & Schmitz 2007), effectively meaning that more FTL's can be aggregated (Schittekat & Sörensen 2009).

Multi-manufacturer usage of HGV's however has been largely neglected, except in multi-franchise distribution of the finished vehicles (as confirmed by LaSota pers. comm. 2013). Cases of back-loading have also been reported in these outbound deliveries, but as outlined by Holweg & Miemczyk (2003), these largely depend on informal contacts of the vehicle scheduler to his counterparts at competitors sites. Uttamrao & Rajashree (2009) have outlined that there is a strong and well recognised case for auto-manufacturers to have a designated supply chain department, as the logistical side of manufacturing is invaluable to the entire business. On the other hand, despite the risk of reduced interaction with clients, the need to focus on core business activity has meant that the industry now outsources most of its logistical operations. Regardless of who is to manage this partnership, more strategic distribution alliances between different manufacturers are still required. These can either be managed through a 3PL or via a manufacturer that is large enough to build a logistics operating unit themselves (Liu *et al.* 2010).

4.3.1 Analysis of green logistics efforts

In the light of what has been mentioned in the literature, a survey of different personal vehicle manufacturer's sustainability reports was made. The aim was to determine how the environmental aspect of logistics maps onto this industry's broader strategies for corporate-social responsibility. More importantly, this was done to ascertain whether (despite their tight

JIT operations) manufacturers have considered the eco-efficiency effect of HGV utilisation rates, and even more so, whether they have considered inter-company collaboration as a means of improving this aspect [see Appendix 8.4].

This review has revealed that the automotive industry has generally quite good awareness of the environmental externalities of their in- and outbound logistics operations, and are keen to demonstrate initiatives to reduce logistics-derived emissions. A major focus is put onto modal shifts, which is an area where most reported success stories are coming from.

Vehicle load and weight capacity utilisation have also received considerable attention. First of all, it must be mentioned that virtually every sustainability report that had a transport logistics section also mentioned efforts to reduce and optimise packaging, meaning that the "stack-ability" of component deliveries may well be contributing to improved HGV utilisation rates. Fill rates appeared to be otherwise encouraged via:

- Load aggregation in consolidation centres between component suppliers and assembly plants.
- Single truck "milk-runs" to pick up consignments from several suppliers as opposed to direct deliveries between each individual supplier and assembly plant.
- Collaboration with external logistics providers to incentivise loading efficiency. This for example involves payment per volume of goods transported (rather than simply payment per individual shipment), which automatically incentivises a 3PL to maximise its HGV capacity utilisation.

The latter goes to show that as a purchaser of freight transport services, a car manufacturer has a key role in pushing for operational eco-efficiency by adapting their internal routing assignments, infrastructure and overall contractual expectations.

There is however only one manufacturer (Fiat and Chrysler Group) whose logistics initiatives included the sharing of transport capacity with horizontal supply chains. Fortunately this was also the manufacturer who had agreed to an interview. It was outlined that both truck and railcar utilisation was monitored by the company, and that although many component shipments were limited by weight rather than volume, generally shipments were believed to be utilising the majority (over 90%) of a vehicle's available capacity. Freight consolidation centres and *daily* demand-tailored route optimisation invariably had a large role to play in this, but interestingly it was also mentioned that if high amounts of LTL shipments were identified in a certain geographical region, Chrysler has been known to co-load freight vehicles with General Motors (GM) products – predominantly because of their suppliers' and assembly units' proximity. (Interestingly GM had virtually no mention of logistics in its latest sustainability report).

This was not done routinely and agreements to share transport capacity were largely based upon informal talks. However, competitive concerns were low, as the collaboration is based entirely on the mutual benefit of cost savings and does not involve disclosure of any sensitive information regarding prices and technology (LaSota pers. comm. 2013). Similarly, transport sharing has also occurred on some outbound shipments of completed vehicles to dealerships. This has been the case between Volvo and Land Rover as well (Hambeson pers. comm. 2013).

When asked whether such collaborative initiatives can be further promoted, it was mentioned that communication between different manufacturers is set up and monitored by an independent group (AIG Action Group), who organises regular workgroups headed by a rotationally assigned member manufacturer executive (LaSota pers. comm. 2013). Presumably this is to give equal chances for each manufacturer to steer the discussions. The group's primary aim is to standardise industry practices, which means that if capacity sharing were on the agenda, it is in an excellent position to promote such horizontal supply chain collaboration.

All in all, freight vehicle capacity sharing is appealing to the industry predominantly as a result of the operational cost savings that it offers. However, as outlined in manufacturer sustainability reports, vehicle fill is increasingly being viewed as an environmental measure as well. Horizontal collaboration may well still be in its infancy, but is set to become more commonplace as the price of transport continues to rise. The role of the filling degree in transport operator selection requirements could increase in the future, but is exceedingly difficult to reliably monitor (Hambeson pers. comm. 2013). This again highlights that it remains up to the transport contractors to realise the cost and environmental benefits of reduced HGV under-loading and to create an environment that incentivises their logistics operators to act accordingly.

5 Discussion: Insights into the contractor-operator relationship

5.1 The service of logistics

Supply chains are not only spreading geographically, but they also involve ever more companies. Traditionally, the "do it yourself" transportation model has been appealing for – amongst other things – the extremely close coordination of production and delivery schedules, better risk management opportunities, and opportunity for free advertising on company-owned vehicles (Flood 1961). Today transport is the most commonly outsourced business activity to external third party operators. Rather than purchasing and managing the operations of their own vehicles, the vast majority of product manufacturers and receivers (collectively referred to as transport buyers) are choosing to partner with external haulers and logistics specialists [hereafter third party logistics providers or 3PL]. These service providers are in most cases asset-based and thus possess trucks, trailers as well as handling equipment and distribution facilities (Stefansson 2006).

What is more, outsourced transportation services rarely involve simply finding a vehicle owner who can move goods between a shipper and a receiver. External partners provide further physical services such as warehousing, goods handling, sorting, sequencing, repackaging as well as administrative and information processing (Fabbe-Costes *et al.* 2009; Stefansson 2006). These services can come in isolation, be bundled together in packages, or be entirely customized to the needs of the transport purchaser (Stefansson 2006). It would appear that because 3PLs are able to serve multiple customers, they should also be well positioned to maintain higher capacity utilization and improve the environmental performance of haulage operations. Although it is acknowledged that significant environmental gains can be reaped from optimisations in a variety of services that 3PLs offer, this thesis will focus solely on the HGV loading component of these operations.

From a transport buyer's perspective, partnering with external logisticians enables to access higher levels of operational competence and flexibility while enabling their business to focus more on its core activity. Transport outsourcing thus provides transport buyers with advantages such as reduced costs and increased competitiveness (Sink & Langley 1997; Björklund 2005; Stefansson 2006; Selviaridis & Spring 2007; Wolf & Seuring 2009). Of course these relationships are not without their downfalls. For a transport buyer the outsourcing comes at the cost of reduced control over goods flow, reduced customer contact, increased risk and the overall burden of monitoring transport costs and external relations (Björklund 2005). The ecosystem of intertwined players requires complex information exchanges and managerial procedures to maintain functionality and quality service offerings to the final customer (Perego *et al.* 2011).

Nonetheless, 80% of executives in IBM's (2010) survey reported that they expect the number of third party partnerships to increase. It must however be said that the 2008/09 economic crisis has hit European for hire and reward transport activities most, as they dropped by some 13.4% compared to the 2.3% experienced by own account transports, effectively meaning that in times of economic hardship more companies attempt to carry out the transportation of their goods by themselves (EC 2011c). Still the latest figures suggest that third party logistics service providers are increasing their revenues worldwide, with three times as many shippers continuing to use outsourced services as opposed to in-sourced logistics. In Europe currently as much as 71% of total logistics expenditures are dedicated to spending on transportation provided by third parties (Langley 2012).

5.2 Outsourcing and vehicle-utilisation rates

Interestingly, some EU statistics do support the hypothesis that outsourced logistics have already resulted in improved vehicle utilisation. Although more recent metrics have not been made available at the time of writing, in 2010 the share of empty runs was indeed higher in own-account transports (30.6%) than in transport for hire and reward (21.4%) (EC 2011c). It would seem intuitive that finding a backload is much more difficult for a truck that is operating within a single company only. However, other researchers have reported that empty running rates between the two types of vehicle operator are almost identical, and that a strong causal link between the historical reduction in empty running and the long-term shift from own-account to third party transport cannot be established (McKinnon & Ge 2006; Cmilt 2008; Vilkelis 2011).

Outsourced haulage has nonetheless also been demonstrated to be somewhat more efficient in terms of load factor – which if higher means that fewer vehicle kilometres are needed to generate a set amount of tonne-kilometres. In 2010, EU own-account haulage had a total (summated national and international) load factor of 8.8 tonnes while hired transports saw almost double that, at 15 tonnes (EC 2011c). Additionally, in Sweden it appears that the heavy truck sector is the only type of road transport vehicles where the number of hired trucks exceeds the number of company owned vehicles, and concomitantly these outsourced trucks are used more intensively and closer to their full capacity (Stefansson & Woxelius 2007). Other Swedish-based studies have confirmed that company owned vehicles tend to be on the whole poorly utilized when compared to coordinated 3PL vehicles, and a shift to more freight being handled by logistics firms could well incur improvements in load factor and emissions' reductions (Björklund 2005; Hedenus 2008). If measured by utilisation per unit of vehicle, own-account transports in urban distribution channels are also much less efficient compared to outsourced trucks (Danielis *et al.* 2010).

It is unclear whether these trends can be at least partially – if at all – attributable to the eco-efficiency effect that is commonly ascribed to collaboration. It is in fact quite likely that because for-hire vehicles made up some 95% of international transports (EC 2011c), the sheer driving distance and subsequent cost of this service are driving *individual* transport buyers to adjust their shipments to better capitalise upon the capacity that the 3PL's vehicles offer. Empty running for example is indeed typically more prevalent in domestic operations compared to international hauls where there is a stronger financial incentive to find a backload for the return journey (Vilkalis 2011; McKinnon & Edwards 2010). This means that in terms of the statistics regarding empty distances run, few long-hauls done in 3PL trucks and many shorter hauls on in-house trucks could essentially equate and reveal little about collaborative sharing of en-route truck capacity.

Hence, the question of whether the potential for further efficiency gains has been truly exacerbated remains. The lack of horizontal collaborative efforts mentioned above makes it difficult to envisage that their higher vehicle utilisation can be made attributable to large scale collaborative sharing of vehicle space between several transport buyers. As has been previously observed, 3PLs are actually quite badly positioned to innovate and exchange information (see eg. Waller n.d.) [see section 2.7.7]. This is highly limiting to proactive initiatives. 3PL competition is likely to remain focussed on lowest price (Cruijssen 2012) rather than superior service quality let alone environmental benefits of co-transportation initiatives. However because eco-efficiency via improved vehicle utilisation is aligned with cost savings, there is potential for a strong signal for better vehicle utilisation to come from 3PL's customers themselves. Having said that, the next section will examine that contracted operators can make some progress in improving their HGV utilisation without their customers' explicit demand.

5.3 The role of 3PLs in encouraging improved vehicle loading

As has been outlined earlier, addressing loading inefficiencies could well be a win-win situation for both businesses and the environment. This means that vehicle sharing and freight consolidation could be among the many initiatives of road freight operators for improving the sustainability of their operations (Lieb & Lieb 2010; Arvidsson *et al.* 2013). Energy efficiency is of paramount importance to third party logistics operators. Liimatainen *et al.* (2012) demonstrated that this issue is predominantly associated with fuel consumption monitoring either at truck or driver-level. The monitoring of tonne-kilometres, on the other hand, has been extremely low, with only 8% of 303 respondents being able to provide an accurate figure of their annual haulage in tonne-kilometres. The selection of vehicles to better suit the nature of the contracted operations is the closest thing that the survey's 3PL respondents appeared to be doing to maximise load fills, but it is unlikely that this will become a widely adopted measure in the industry as most operators have very small vehicle fleets to choose from (Liimatainen *et al.* 2012).

On the other hand, it cannot be ignored that grouped haulage forms part of – or in some cases is even the speciality – of certain 3PLs. These services are essentially created for customers whose shipments are not extensively time-sensitive and are too large for express carrier operators, yet too small to justify designation of an entire vehicle[4]. Typically these operations involve scheduled trucks running on pre-determined international routes, and include loading capabilities that are flexible according to the characteristics of the different consignments. The environmental benefit (eco-efficiency) of such operations however does not appear to be advertised, and most operators try to differentiate their services according to delivery speed, reliability and network coverage. Perhaps improved marketing communications of not just the economic but also the environmental benefits of grouped transports could widen the customer base of such transports.

Unfortunately, despite having approached a dozen third-party logistics providers, only one responded to the author's query regarding the nature and popularity of grouped transports. It was outlined that full-truckloads were always achieved as this was cost-efficient for both customers and their business. However, this operator (LPR-la palette rouge) worked with the pooling of pallets from the FMCG sector only (Olshewski pers. comm. 2013), thus shedding little light onto whether collaborative truck capacity sharing is appealing to other sectors (as well as cross-sectorally). Grouped haulage operations indisputably require further research. Interestingly, Klaas-Wissing and Albers (2010) have reported that small and medium sized logistics service providers – which as mentioned earlier make up most of the EU's 3PL businesses (EC 2011a) – generally experience low capital, technical and management know-how, as well as geographical reach and subsequent customer shipment quantities. Alongside

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[4]See eg. www.twt-logistics.com; www.barringtonfreight.com/groupage-freight.php; www.irishgroupage.co.uk/freight-services-ireland.htm; www.groupage-express.co.uk/about-us/; www.pchoward.com/uk-groupage.htm; www.impexfreight.com; www.dbschenker.com/ho-en/products_services/land_transport/core_products/schenker_system.html

contractual limitations, this in itself may well be prohibitive to the regular accumulation of different customers' consignments into full truckloads, suggesting that freight groupage operations can only form a relatively marginal part of overall haulage operations.

Nonetheless, it must also be mentioned that 3PL's who are operating with LTL shipments, can join dedicated alliances, which in Europe are largely German-based; IDS Logistik, System Alliance, Cargo Trans Logistik, CargoLine and System24plus. These essentially help to overcome the operators' size-related strategic disadvantages (Klaas-Wissing & Albers 2010). A study of these associations' web-sites revealed that the push factors for joining operator alliances include improved communication with customers and order identification via what is essentially a brokerage network that allows shipments to be assigned to different 3PLs through the association's centralised system; access to reputable track-and-trace and other ICT systems that customers often demand from their freight operators (which 3PL's may not have the capacity to invest into alone); improved emissions monitoring, reporting and benchmarking; and finally the ability to operate in a hub-and-spoke distribution network.

The latter is of particular interest because it essentially allows concentrating and reloading goods between carriers at a centralised distribution centre. Effectively this means that deliveries are better tailored to the geographical reach of operators and that the number of direct deliveries is reduced. As such, the risk of vehicles running empty – or at least the distances that they would do so – is minimised. This aspect however is not explicitly mentioned as a function of the above-mentioned 3PL alliances. On the other hand, literature reveals that hub networks offer opportunity for freight flow consolidation, and improve the loading of trucks in terms of both volume and weight (Lapierre *et al.* 2004; Cheun & Muralidharan 1999) as well as facilitating intermodal shipments (Ishfah & Sox 2012). Poor interviewee response rates among logistics service providers limit this study's ability to assess the extent to which these alliances are capable of, or are intended to aggregate LTL's into FTL's. In the light of the road freight servicisation concept, it is strongly suggested that this become an area for further research. 3PLs are able to offer load consolidation services directly, and may have ample opportunity to do so if they partner amongst themselves. However there is little indication of how widespread these operations may be in the wider road haulage sector.

To conclude, it is evident that the dematerialisation and outsourcing of road freight operations can be considered as an "enabling service" (Tomiyama *et al.* 2004), for the wider servicisation and multi-stakeholder sharing of individual truck capacity. Despite widespread transport outsourcing, collaborative sharing of transport capacity and associated eco-efficiency is still limited, primarily because third-party logistics providers are restricted by contractual terms and service-related demands of their customer (transport purchasers) (Rydén and König pers. comm. 2013). Hence, despite their competencies in the field, from a 3PL perspective, logistical eco-efficiency is predominantly dependent on their customers' demands, rather than on internal oversight of optimization potential. Liimatainen *et al.* (2012) outlined that energy efficiency remains unimportant to shippers, and if they are to improve transport energy efficiency, operators would like to see changes in route planning (to avoid empty running), eased delivery time-windows, as well as bigger individual shipments. Most importantly 3PL's outlined the need for longer contracts that permitted cooperative planning of logistics operations (Liimatainen *et al.* 2012).

The trends above are in line with previous findings that suggest that the sustainability aspect of outsourced operations has so far been poorly considered by transport buyers [see section 2.7.7]. Not surprisingly, third party operators thus remain the single largest source of environmental externalities in the industry (Abbasi & Nilsson 2012; Lieb & Lieb 2010; Wolf & Seuring 2010). As we have seen it is nonetheless not uncommon for FMCG customers to collaborate horizontally to incur cost benefits environmental gains that are ultimately felt by themselves as well as their contracted hauliers. An effort should be made to make this a more common trend in other transport purchaser sectors as well. The author takes the position that vehicle utilisation rates can be further raised if road freight vehicles are viewed less as closed offerings to individual transport buyers, and more as a freight movement service that is available for multiple customers to benefit from. The next section will develop a framework for this kind of thinking.

5.4 Servicisation for eco-efficiency

The increasing reliance on third-party logistics providers over in-company HGV ownership essentially means that road haulage is being catered for through an increasingly dematerialised system. The road haulage sector thus fits well into the framework of product-service system (hereafter PSS) which entails "a shift from separate systems to one that designs products, services and supporting infrastructure to minimise the environmental impacts of consumption" while delivering "the same utility or function" (Mont 2000, 28). With fewer goods manufacturers and receivers choosing to purchase freight vehicles, road freight operations have become a *product use service* (Meijkamp 1994) or a *use-oriented service* (Sakao *et al.* 2009) which theoretically results in "a more intense use of a product (i.e. the HGV) while reducing the need for individual ownership" (Mont 2000, 34).

The more intense use would in this case be defined as higher load and fill rates as well as less frequent empty trips. HGVs that are company-owned and subsequently utilised by a single actor in isolation from the requirements of others, would be expected to operate at sub-optimal loads, with their full haulage potential being rarely exploited.

To the author's best knowledge, road freight has not been considered in the context of a PSS in the literature. The sector nonetheless provides a perfect opportunity for this sort of approach, as the two initial stages of Shimomura and Arai's (2009) "extended service blueprint" have already been defined – that is the identification of customer value, and design of service contents; leaving just the design of the service activity to be fulfilled. In other words, we are well aware of the customers' demands from road freight, as well as the operations necessary to deliver this service. Additionally we have seen that it may be merely a case of applying the existing service thinking (in FMCG sector) to a different field. All that remains is to define and operationalise a service-mentality. Herein it will be the individual HGV that is viewed as a service offering.

An attempt to define road freight servicisation can be done by analogy to the well established car-sharing concept. Here the service offered is that of *personal* mobility and the largest environmental benefits of this PSS are obtained from better utilisation of a single vehicle's "idling capacity" (Botsman & Rogers 2011) – that is the time the car spends not being used. We are less concerned about whether the car is always filled with passengers when driven (although of course this would be most eco-efficient) but aim to reduce the time a vehicle is unused by sharing its availability among a multitude of customers. This in turn should make the customers no longer feel the need to purchase their own vehicles, thereby reducing the need for vehicle manufacturing (and associated environmental externalities) and ultimately making the customer think twice about whether they really need the convenience of a car at all.

In the case of HGV's however, the service offered is mass movement of freight. Hence the idling capacity is not considered to be the time the truck spends being stationary (which is certainly lower in 3PL operated vehicles) but the amount of unfilled space within this truck when it is moving under a single customers demands. The approach is similar to car-sharing in that the reduction of idling capacity also has to involve multi-actor utilisation of the HGV, as after all openness and collaboration are the basis of a PSS's ability to create environmental benefits (Mont 2000). However given the above-mentioned high rates of sub-optimal vehicle utilisation – which is occurring despite the fact that transport purchasers are quite flexible in terms of their service providers – we are not only concerned with ensuring that vehicles are being used as often as possible, but also ensuring that they are used to their fullest possible capacity.

One can also consider what servicisation means for the customer and the environmental benefits of the changed customer-product interaction. When it comes to car sharing the customer is an individual who can be swayed to not use a car at all unless it is absolutely necessary, and the benefits of reduced car ownership and usage become immediately apparent. With trucks the customer is a business that is either producing or buying some form of a product, which means that their absolute transport needs are not very flexible because ultimately they need their product to be transported to make an income. This is why unless production patterns are also altered, not owning an in-company truck achieves little in terms of reducing the number of trucks on the roads; they are simply being sourced in the same numbers from someone else. Of course, the purchasing of transport service means that a transport buyer is driven to adapt shipments so that these utilise each individual contracted HGV's capacity best, however once this had reached the full extent of what final consumer demands (eg. JIT) allow, hiring a vehicle through a 3PL still does not necessarily mean that that vehicle's capacity will be "servicised" and shared among several actors.

If however multiple customers realise that their road freight requirements are aligned, and that their individual consignments are rarely occupying all the available space within an HGV, they can begin to view the cubic space within a vehicle as something that they can share, thereby splitting the costs of the vehicle hire. This is also believed to be beneficial to the environment, as several empirical studies have confirmed that shared service business models bring economic benefits while simultaneously decreasing total environmental impacts (Komoto & Tomiyama 2009 and references within). The biggest environmental benefit of servicising HGV's is that ultimately the number of them on the road will be reduced while transport buyers will maintain existing distribution volumes.

All in all the following criteria have to be met road freight to be considered as a PSS:

- Shipments from two or more actors from different supply chains are being transported within the cubic capacity of a single moving HGV.
- These actors can be competitions or even operate in entirely different industrial sectors.
- The HGV is not owned by any of these actors.
- The average operational cycle of the HGV involves minimal empty run kilometres and load/fill rates that are close to the vehicle's maximal capacity.

5.5 Shipper demand for collaborative transport

Cases of logistics providers joining forces to avoid empty running are quite well researched (Cruijssen *et al.* 2007). In the broader scheme of things we have nonetheless seen that logistics operators have only very marginal ability in encouraging eco-efficient freight movements. Some have even suggested that freight operators would be against increased load factors as these could mean reduced delivery trips and thus potential revenue losses (ECR 2010; Stefansson & Woxelius 2007; Rydén and König pers. comm. 2013). The strongest driver of multi-actor HGV utilisation is thus the transport purchaser. In fact, it has been outlined by Baines *et al.* (2008) that successful PSS development can only be achieved if it is designed from a client perspective, underlining that shipper demand will be both necessary and sufficient for the development of the above-mentioned HGV as-a-service mentality.

A recent press release (Cassidy 2013) on the National Shippers Strategic Transportation Council (NASSTRAC) survey revealed that alongside collaboration with trucking partners and other 3PLs (32.4% of surveyed shippers), some 55% of surveyed shippers said that they were in fact collaborating with other shippers too. Although the depth and significance of these collaborative arrangements was questionable, this still suggests that shipper collaboration is gaining popularity. In line with the HGV as-a-service model, there was indeed talk about the consolidation of LTL shipments from multiple shippers into full truckloads. However progress is limited not by a lack of interest in such initiatives, but by the fact that no shipper wanted to be the first innovator to step out of line. The majority (86%) of shippers identified barriers to this sort of collaboration, hinged primarily upon misalignments in corporate culture, existence on in-house efficiency improvement potential, and non-disclosure issues (Cassidy 2013; IBM 2010).

Accordingly, literature outlines that even in the presence of a very positive business (and in this case environmental) case, collaboration projects require high levels of trust (to avoid the danger of opportunistic behavior), aligned long term visions and company culture, and finally operational synergy in terms of required vehicle specifications, geographical coverage, and load characteristics (Palmer *et al.* 2012; Cruijssen *et al.* 2007; Fisher *et al.* 2009; Waller n.d.; IBM 2010).

5.6 Independent mediation of collaboration opportunities

Although this idea is still in its infancy, researchers have outlined that a major step towards improving shipper collaboration will involve the establishment of an independent external body that is able to arrange and monitor information exchange and thus identify collaborative opportunities without shippers having to disclose sensitive information directly to each other (Rydén and König pers. comm. 2013; Cruijssen 2012). This should effectively rule out any instances where competitive concerns as well as internal company culture incongruities prevent the initiation of information exchange (for the ultimate goal of collaboration). Cruijssen (2012) refers to such an external mediator as a "trustee". The greatest benefits of this arrangement involve:

- The trustee's ability to start-up information disclosure – which companies and especially competitors are extremely hesitant to initiate amongst themselves.
- The trustee's ability to analyse the provided data and identify whether there is positive business case. This can be done independently and without the bias of internal company beliefs or pre-conceptions.

What is more such a trustee should not only be overseeing shippers, but also their logistics providers, thereby ensuring that identified consolidation opportunities precipitate down to on-the-road operations. Cruijssen (2012) also offers a list of more generic qualities that this trustee must possess – including neutrality, permanent availability, legal compliance, and above all confidentiality.

The existence of such an independent communication mediator has previously been outlined in the automotive sector [see section 4.3], and although the consolidation of freight between manufacturers is not the AIG Group's main function, it could well be a potential platform for this cause. In Europe, a non-sector specific intermediary for road freight information exchange is Green Freight Europe (GFE), whose function is the collection of CO_2 emissions from member transport operators. GFE was only launched a year ago, and is currently still in process of developing a data collection platform. When launched, it will enable member operators to benchmark their CO_2 emissions against those of other members. GFE could thus be instrumental for better incorporating environmental criteria into the shipper-carrier relationship, presumably because a hauler could use their GFE benchmark as a selling point to the more environmentally conscious transport buyer (Trail pers. comm. 2013). Although it is not intended to be a platform for load-matching, the lessons that we can learn from GFE are that an intermediary body has to operate under a high degree of confidentiality, and that the data offered by members must technically remain owned by these members only. In addition, the fact that one of the primary concerns of this platform is the reliability of data that members are entering into the system (Trail pers. comm. 2013), means that a horizontal collaboration trustee would also encounter the issue of member data quality standards.

5.7 ELUPEG - A real life trustee

The European Logistics Users Providers & Enablers Group (ELUPEG) is taking on the role of freight consolidation trustee in Europe. ELUPEG provides a forum and a platform for information exchange between like-minded companies who can identify freight compatibilities and alignments in seasonal distribution patterns. The member circle is very inclusive, involving own-account hauling companies, shippers, carriers, and other forms of 3PLs. These are brought together in quarterly meetings, networking dinners, case history presentations and "break-out" sessions. The outcome of these sessions are group-specific action plan that are continually built upon over consecutive sessions (Bolam pers. comm. 2013). In this way ELUPEG can not only help to identify supply chain alignments, but also aid in later stages of the partnership such as agreeing on how savings are shared, and reinventing the first savings to drive deeper collaboration (Bolam n.d.). Although discussions are often divided into groups according to industry type, the inclusive nature of the platform should be permissive to cross-sectoral collaboration as well. The talks are held under non-disclosure agreements, meaning that no competitive violations are incurred in the process (Bolam pers. comm. 2013; Bolam n.d.).

ELUPEG can act as a neutral third party so all confidential information is neutralised before it is seen by a competitor (Tesseras 2011). For example, ELUPEG currently has information regarding most of the European car manufacturers' finished product routes – information that it does not disclose to anyone else but merely uses for identification of synergies. What is more, this data has enabled ELUPEG to take a more pro-active approach in the wider scene of European freight movements. Currently it is looking to establish out-of-town finished vehicle consolidation centres and thereby encourage showrooms to move out of the cities into larger infrastructures that require less individual deliveries (Bolam pers. comm. 2013).

On the whole, the platform allows to accelerate what is normally a very long process of networking and trust development between different companies. It has also been instrumental in advertising the entire notion of horizontal collaboration, by making members aware that sooner or later the low profit margins seen by logistics operators (as a result of vehicle under-loading and empty running) will be passed onto the shippers, thereby encouraging the economic case behind collaboration and improved vehicle utilisation. It is likely that in time collaboration will be viewed as an environmental measure, because it will effectively reduce the number of running trucks and be very welcome in a business environment where carbon footprint disclosure is becoming ever more prevalent. This is indeed used as a selling point for companies to join ELUPEG today (Bolam pers. comm. 2013).

All in all, this entire platform will continue to be instrumental in pushing the case for improved freight vehicle utilisation. Most importantly it has underlined the fact that HGV fill rate optimisations cannot be achieved via transport operators' initiatives alone, and that innovation in favour of improving road freight environmental performance requires multi-stakeholder dialogue and alignments in much wider business structures.

6 Deliverables and Conclusions

6.1 Barriers to efficiency

This study has demonstrated that there is a strong case for maximising the extent to which the capacity of every individual running HGV is utilised. This is the result of the inherently low energy efficiency of this transport mode, the high levels of socio-environmental externalities, and the fact that as result of its flexibility road freight will remain an important part of any supply chain. What is more, technical solutions have very limited scope for reducing the emissions of the road freight sector, especially given the present restrictive policy environment. This means that in the light of current EU objectives for greener road transportation, there is an apparent disconnect between environmental targets and the feasibility of maintaining a profitable road freight business. Improving vehicle loads will be highly beneficial for reducing trip numbers, kilometres covered, fuel usage and tailpipe emissions – all without significant capital investments and the need for vehicle stock turnover. There are however several drivers behind the reportedly widespread un- or under-loading of HGVs. These include the following:

- High degree of specialisation among the logistical requirements of transported freight consignments. This has also meant that HGVs are frequently specialised to a certain type of consignment, and their utilisation is thus limited to the availability of a narrow range of cargo.
- Inherent asymmetries in distributional networks. This is particularly true – and to an extent unavoidable – in the transportation of raw materials, as has been exemplified by the round wood industry's logistical operations.
- Lacking initiatives to monitor individual vehicle cubic fill and weight haulage capacity utilisation. The collection of this data is seen as an additional administrative burden, especially as standardised means of measuring these aspects do not exist. This effectively creates a vicious circle wherein transport purchasers cannot impose vehicle utilisation demands upon their operators.
- Changes in production and consumption patterns which have lead to less stock warehousing and rapid deliveries of small amounts of goods for immediate purchase or consumption. This means that products coming off a single production line are distributed very rapidly and typically cannot be aggregated into full truckloads.
- Highly diverse in-house ICT systems and therefore very limited ability for information exchange to facilitate inter-company consignment consolidation and back haul opportunity identification.
- Lack of web-based platforms for establishment of long-term business-to-business freight exchange operations.

Although we can anticipate further liberalisation in EU cabotage regulations, additional taxation on HGV ownership and operation, as well as development and better penetration of sophisticated freight exchange software, it appears that the outlook for the future is rather bleak. In the light of rising fuel prices and environmental penalties hauliers will be finding it increasingly more expensive to operate. What is more, while the hauliers are the first to suffer from these developments, their ability to maximise asset utilisation is limited by contractual obligations, as well as low profit margins that limit pro-active innovation.

6.2 Existing opportunities

Collaborative sharing of transport capacity between several shippers is beneficial for reducing both transport purchasing cost, operational cost and – assuming that it leads to fewer vehicles on the road – the transport's environment impact. This has been underpinned by the deliverables of partnerships within the FMCG sector. The literature is however somewhat divided on the ease of establishing such partnerships, with some authors suggesting that collaboration does not require significant business adaptation, while others have outlined that misalignments in company culture and inability to build trust are prohibitive to logistical collaboration. This suggests that either the depth of collaboration varies significantly, or that there are sector-specific barriers to establishing co-loading operations. Further research is needed into the collaborative potential of individual sectors, and this should eventually aid in identifying broader cross-sectroal (and not just inter-company) supply chain symmetries.

There are nonetheless several existing trends that offer opportunity for future road freight consolidation trends. First and foremost this includes third party logistics operators that are specialised in aggregating consignments that have relatively lax delivery time windows. Even as a customer willing to ship some personal goods, it is possible to do so on a "going there anyway" basis, which technically means that no additional transport volume is assigned for one's shipment. What is more, operators can form alliances that will enable to concentrate goods from a certain geographical range and then complete the vast majority of the journey in fewer, fully laden trucks. The appeal of such initiatives is nonetheless limited by the fact that operators are contracted to deliver consignments rapidly and to exact locations. If however (as one example from the automotive manufacturing sector has demonstrated), transport operators are paid according to the volume of goods that they transport, and not just individual shipment blocks, they may have considerable internal incentive to deliver the service with the least number of trucks. This is of course assuming that the delivery time windows allow for load aggregation.

Finally the fact that most transport operations are today being outsourced creates an opportunity to view 3PL vehicle cubic capacity as a service that is available to several shippers. The concept of product servicising appears to be very applicable to the road freight transportation sector as there is considerable idling capacity (characterised by unused truck/trailer space) that could be further distributed among contractors.

While most examples of road freight co-loading in the literature stem from the fast-moving consumer goods sector, an overview of sustainability strategies in the automotive sector has outlined that vehicle fill rates are increasingly being considered as a cost-saving and environmentally beneficial measure by this industry as well. The propagation of this awareness will be crucial to achieving loading efficiencies that transport operators are not able to achieve on their own. The largest vehicle utilisation increments must be encouraged by the purchaser of transport services, and not the contracted operator.

6.3 Shipper-driven effiency gains

For the above reason there is an evident need for shippers to move away from a silo view of one-truck-to-one-customer and towards a collaborative model wherein distribution patterns are disclosed in order to identify long-term synergies with parallel supply chains. There is actually reason to believe that the most aligned supply chains are those of direct competitors, which has again been underlined by the informal co-loading agreements in the automotive industry. It is suggested that in order to overcome concerns about disclosure of sensitive information that could weaken competitive position, logistical information must only be disclosed to an independent intermediary body. It can analyse this information confidentially, and identify opportunities for synergies. In the road freight sector dematerialisation has not necessarily meant servicisation, let alone significantly improved environmental performance. Widespread transport outsourcing will not foster eco-efficiency unless transport buyers are involved in a platform that facilitates collaborative operations. Improvement of vehicle fill rates provides insight into a much broader topic of cross-company information exchange and asset sharing, which in this case has been demonstrated to hold potential for considerable environmental benefits, and not just mutual cost savings.

Even given the existence of an independent freight consolidator trustee in Europe, important questions remain. These revolve around methods used to calculate the potential benefits of collaboration (given that cubic fill data is rarely collected); ensuring that member data is of sufficient quality and collected in a standardised way; and finally the means of identifying and recruiting more members to maximise consolidation possibilities.

6.4 Further research

It has been observed that load fill optimisation is attractive to both 3PL's (whom it saves on fuel costs and paid driver hours), and shippers (who would like to use the transport they purchase to its maximum capacity). Ultimately however, it would appear that a shipper's ability to align and consolidate shipments will be blocked by customer demand. As previously mentioned, a major concern for collaborating shippers is the arising reduction in service quality delivery to their final customers. For example, in Palmer *et al.*'s (2012) extensive survey, customer pressure for more frequent, faster deliveries of smaller quantities, was outlined to be a major barrier for shippers to consider external collaboration. Not surprisingly, several authors have reported that collaboration for efficiency maximization is easiest to maintain when shipment deadlines are long (Zhou *et al.* 2011; Bookbinder & Higginson 2002; Gümüs & Bookbinder 2004; Kohn & Brodin 2008 and references within).

Collaboration however does not always have to work against JIT. After all, the sharing of vehicle capacity reduces the need for an individual shipper to wait to aggregate enough cargo to fill a truck, and instead it can dispatch a part-load along with someone else's shipment straight away (Bolam pers. comm. 2013). Clearly then, considerable further research is needed into how collaborative vehicle utilisation affects the service quality for the final consumer.

Even more importantly, we also require a better appreciation of the extent to which the environmental benefits of improved fill rates can be communicated to the final customer and whether they would then be willing to accept more lenient delivery schedules that enable for this sort of consolidation and back load identification. Naturally this will probably have to be done on a product- or sector specific basis (i.e. can we accept some more delays in provision of product X?). This means aside from the shipper-hauler interface investigated in this paper, vehicle utilisation parameters must invariably be considered in the context of the customer-shipper interface as well.

7 Bibliography

Abbasi, M. and Johnsson, M. 2012. Themes and challenges in making urban freight distribution sustainable. 24th Annual NOFOMA Conference, Turku School of Economics at the University of Turku (pg. 21-39). Available at: http://www.lunduniversity.lu.se/o.o.i.s?id=24732&postid=2796961

Abbasi, M. and Nilsson, F. 2012. Themes and challenges in making supply chains environmentally sustainable: A logistics service providers' perspective. *Supply Chain Management: An International Journal* 17(5): 517-530.

Abukhader, S.M. and Jönson, G. 2003. The environmental implications of electronic commerce: A critical review and framework for future investigation. *Management of Environmental Quality* 14(4): 460-476.

________. 2004a. E-commerce and the environment: A gateway to the renewal of greening supply chains. *International Journal of Technology Management* 28 (2): 274-288.

________. 2004b. Logistics and the environment: Is it an established subject? *International Journal of Logistics Research and Applications* 7(2): 137-149.

Alvarsson, E. and Andersson, T. 1995. The impact of transport on the environment: A calculation model for the determination of the environmental effects caused by chains of transport. Thesis No. 5323/1995. Department of Engineering Logistics. Lund University.

Aronsson, H. and Huge Brodin, M. 2006. The environmental impact of changing logistics structures. *The International Journal of Logistics Management* 17(3): 394-415.

Arvidsson, N., Woxenius, J. and Lammgård, C. 2013. Review of road hauliers' measures for increasing transport efficiency and sustainability in urban freight distribution. *Transport Reviews* 33(1): 107-127.

Audy, J.F., D'Amours, S., LeHoux, N. and Rönnqvist, M. 2010. Coordination in collaborative logistics. International workshop on supply chain models for shared resource management. Brussels, 21-22 January, 2010.

Baines, T., Lightfoot, H., Evans, S., Neely, A., Greenough, R., Peppard, J., Roy, R., Shehab, E., Braganza, A., Tiwari, A., Alcock, J., Angus, J., Bastl, M., Cousens, A., Irving, P., Johnson, M., Kingston, J., Lockett, H. and Martinez, V. 2008. State-of-the-art in product-service systems. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture* 221(10): 1543-1552.

Berglund, A. 1999. Incorporating Environmental Aspects in Transport Purchasing. Licenciate Thesis. Department of Design Sciences and Packaging Logistics, Lund University.

Bernadet, M. 2009. The construction and operation of the road freight transport market in Europe. Paris International Transport Forum 2009. OECD/ITF Forum Paper 2009-1.

Björklund, M. 2005. Purchasing Practices of Environmentally Preferable Transport Services: Guidance to increased shipper considerations. PhD Thesis. Department of Industrial Management and Logistics, Lund University.

Bolam, B. n.d. Exploding the myths around horizontal collaboration in the supply chain. Working papers of ELUPEG 2006-2013. Available at http://www.elupeg.com/AnInner.cfm?PageName=./doc/doc_public.htm

Bookbinder, J.H and Higginson, J.K. 2002. Probabilistic modeling of freight consolidation by private carriage. *Transportation Research* 38: 305-318.

Botsman, R. and Rogers, R. 2011. *What's mine is yours: How collaborative consumption is changing the way we live*. Collins, London, United Kingdom.

Carlsson, D. and Rönnqvist, M. 1998. Tactical planning of forestry transportation with respect to backhauling. Report LiTH-MAT-R-1998-13. Linköping Institute of Technology. Linköping.

Carlsson, D. and Rönnqvist, M. 2007. Backhauling in forest transportation: Models, methods, and practical usage: *Canadian Journal of Forest Research* 37(12): 2612-2623.

Carter, C. and Jennings, M. 2002. Social responsibility and supply chain relationships. *Transportation Research Part E: Logistics and Transportation Review* 38(1): 37-52.

Cassidy, W.B. 2013. Collaborating for capacity: Shipper are moer willing to work with carriers – and each other – to find space for freight. Surface and Domestic Transportation. Journal of Commerce (15307557), April 29th 2013: 60-61.

Cetinkaya, S. and Bookbinder, J.H. 2003. Stochastic models for the dispatch of consolidated shipments. *Transportation Research* 37: 747-768.

Cheung, R. K. and Muralidharan, B. B. 1999. Impact of dynamic decision making on hub-and-spoke freight transportation networks. *Annals of Operations Research* 87(1-4): 49-71.

Clements, A. 2008. Green Collaboration. Retail Week [online]. 26th September 2008. URL: http://www.retail-week.com/green-collaboration/5001865.article

Cmilt, K.D. 2008. Empty running – A waste of space? CILT Supply Chain (Opinion): 42-45. Available at: www.transportplanningsolutions.com/pdfs/empty-running.pdf

Commercial Motor. 2007. Hauliers aim to be green. 28th June 2007. 205 (5235).

Commercial Motor. 2008. Green credentials helping hauliers to capture contracts. 31st July 2008. 208 (5291).

Commercial Motor. 2010a. No 'green' incentives for haulage is a crime. Commercial Motor Beta Version Archive [online]. 8th March 2010: 12. URL: http://archive.commercialmotor.com/article/8th-april-2010/12/no-green-incentives-for-haulage-is-a-crime [consulted on 7th January 2013].

Commercial Motor. 2010b. Curves in all the right places. 24th June 2010. Pg. 34. Available at: http://archive.commercialmotor.com/article/24th-june-2010/34/curves-in-all-the-right-places

Cook, F. 2012. European road freight 2012 – the long road to optimized assets. Roadtraffic Technology, Features: 24th April 2012 [online]. URL: http://www.roadtraffic-technology.com/features/featureeuropean-road-freight-2012-economic-crises [consulted 21st March 2012].

Cook, F. 2012. European road freight 2012: The long road to optimized assets. Roadtraffic Technology, Features: 24th April 2012 [online]. URL: http://www.roadtraffic-technology.com/features/featureeuropean-road-freight-2012-economic-crises [consulted 21st March 2012].

Craig, R. C., Rahul, K. and Curtis M. G. 2000. Environmental purchasing and firm performance: an empirical investigation. *Transportation Research Part E: Logistics and Transportation Review* 36: 219-228.

Cruijssen. F. 2012. Horizontal collaboration: A CO3 position paper. (FP7-SST-2011-RTD-1-7.6) Deliverable D2.1.

Cruijssen, F., Dullaert, W. and Fleuren, H. 2007. Horizontal cooperation in transport and logistics: A literature review. *Transport Journal* 46(3): 22-39.

Cullinane, S. and Edwards, J. 2010. Assessing the environmental impacts of freight transports. pg. 31-48 [Ch.2] in *Green Logistics: Improving the Environmental Sustainability of Logistics* (ed. McKinnon, A., Cullinane, S., Browne, M. and Whiteing, A.). Kogan Page Limited: London, United Kingdom.

Danielis, R., Rotaris, L. and Marcucci, E. 2010. Urban freight policies and distribution channels. *European Transport* 46: 114-146.

Dekker, R., Bloemhof, J. and Mallidis, I. 2012. Operations Research for green logistics: An overview of aspects, issues, contributions and challenges. *European Journal of Operational Research* 219: 671–679.

Delle Site, P. and Salucci, M.V. 2009. Thematic Research Summary – Urban Transport. European Commission, DG Energy and Transport. Transport Research Knowledge Centre. Available at: http://www.transport-research.info/Upload/Documents/201002/20100215_145249_66950_TRS%20Urban%20Transport.pdf

Delle Site, P. and Salucci, M.V.2010. Thematic Research Summary – Freight Transport. European Commission, DG Energy and Transport. Transport Research Knowledge Centre. Available at: http://www.transport-research.info/Upload/Documents/201002/20100215_130009_1238_TRS_Freight_Transport.pdf

Devlin, G. 2010. Fuel consumption of timber haulage versus general haulage. COFORD Connects. Harvesting / Transportation No. 22.

den Boer, L.C. and Schroten, A. 2007. Traffic noise reduction in Europe: Health effects, social costs, and technical and policy options to reduce road and rail traffic noise. CE Delft publication no. 07.4451.27.

Department for Transport (DfT). 2010. Performance Management for Efficient Road Freight Operations. Available at: www.freightbestpractice.org.uk

DeSimone, L. and Popoff, F. 1997. *Eco-Efficiency: The business link to sustainable development*. MIT Press: Cambridge, United Kingdom.

DFF International LTD. 2012. RHA Cost Tables. UK Road Haulage Association. Available at: http://costs.dffintl.co.uk/Cost_Tables_2012.pdf

Efficient Consumer Response Europe (ECR). 2010. ECR Sustainable Transport Project: Case Studies. Available at: http://ecr-all.org/upload/iblock/e41/Combined-Case-studies-_v1-8_220508_pro.pdf

Engel, R. 2008. Going green with reverse logistics. EE Times, Design: 19th September 2008 [online]. URL: http://eetimes.com/design/smart-energy-design/4013545/Going-green-with-reverse-logistics?pageNumber=1 [consulted 14th May 2013].

Ergun, O., Kuyzu, G. and Savelsbergh, M. 2007. Reducing truckload transportation costs through collaboration. *Transportation Science* 41(2): 206-221.

European Commission (EC). 2011a. European Union Greenhouse Gas Reduction Potential for Heavy-Duty Vehicles. The International Council on Clean Transportation. Available at: http://ec.europa.eu/clima/policies/transport/vehicles/heavy/docs/icct_ghg_reduction%20_potential_en.pdf

________. 2011b. Reduction and Testing of Greenhouse Gas (GHG) Emissions from Heavy Duty Vehicles – (Lot 1: Strategy). DG Climate Action. Issue 4. 22nd 2011. Available at: http://ec.europa.eu/clima/policies/transport/vehicles/docs/ec_hdv_ghg_strategy_en.pdf

________. 2011c. Road freight transport Vademecum 2010 report: Market trends and structure of the road haulage sector in the EU in 2010. European Commission DG for Mobility and Transport (Unit D.3: Land transport). Available at: http://ec.europa.eu/transport/modes/road/doc/2010-road-freight-vademecum.pdf

________. 2011d. White paper on transport. Roadmap to a single European transport area: Towards a competitive and resource-efficient transport system. Available at: http://ec.europa.eu/transport/themes/strategies/doc/2011_white_paper/white-paper-illustrated-brochure_en.pdf

________. 2011e. EU-27 road freight transport by group of goods. Eurostat [.png table] Available at: http://epp.eurostat.ec.europa.eu/statistics_explained/index.php?title=File:EU-27_road_freight_transport_by_group_of_goods.png&filetimestamp=20130409130351

________. 2012. Road transport: Reducing CO_2 emissions from vehicles. Climate Action – Policies [online]. Available at: http://ec.europa.eu/clima/policies/transport/vehicles/index_en.htm [consulted 1st April 2013].

________. 2013. Towards a strategy to address CO_2 emissions from Heavy-Duty Vehicles. Climate Action – Policies [online]. Available at: http://ec.europa.eu/clima/policies/transport/vehicles/heavy/index_en.htm [consulted 1st April 2013].

Eurostat. 2011a. Road freight transport statistics. Available at: http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Road_freight_transport_statistics

________. 2011b. A fall in average vehicle loads: Average loads, distances and empty running in road freight transport 2010. Issue 63. Available at: http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-SF-11-063/EN/KS-SF-11-063-EN.PDF

________. 2012. Road freight transport statistics. Available at: http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Road_freight_transport_statistics

Eye for Transport. 2010. European horizontal collaboration in the supply chain. European supply chain horizontal collaboration report 2010. Available at: http://events.eft.com/SCHC/documents/2010-2011EuropeanSupplyChainHorizontalCollaborationReport.pdf

Fabbe-Costes, N., Jahre, M. and Roussat, C. 2009. Supply chain integration: the role of logistics service providers. *International Journal of Productivity and Performance Management* 58(1): 71-91.

Fischer, T., Gebauer, H., Gustafsson, A. and Witell, L. 2009. Managerial recommendations for service innovations in different product-service systems. Pg. 237-259 [Ch. 12] in *Introduction to Product Service-System Design* (ed. Sakao, T. and Lindahl, M.). Springer-Verlag, London, United Kingdom.

Flood, K.U. 1961. Questions in Company-Operated Transport. *Harvard Business Review* 39(1): 127-136.

Forsberg, M. 2002. Estimating the efficiency of a forest supply chain and the value of horizontal co-operation. Symposium on Models and Systems in Forestry, Chile 2002.

Frazier, G. L., Spekman, R. E., and O'Neal, C. R. 1988. Just-In-Time exchange relationships in industrial markets. *Journal of Marketing* 4: 52-67.

Freight Best Practice. 2010. Achieving Supply Chain Efficiency through Backloading and Multi-modal Transport. Case Study: Kronospan UK. Available from: www.freightbestpractice.org.uk

Freight Transport Association (FTA). 2012. The Logistics Report 2012. Available at: http://www.fta.co.uk/export/sites/fta/_galleries/downloads/logistics_report/LR12_web.pdf

Gebresenbet, G., Nordmark, I., Bosona, T. and Ljungberg, D. 2011. Potential for optimised food deliveries in and around Uppsala city, Sweden. *Journal of Transport Geography* 19: 1456-1464.

Goldsby, T.J. and Stank, T.P. 2000. World class logistics performance and environmentally responsible logistics practices. *Journal of Business Logistics* 21(2): 187-208.

Groothedde, B., Ruijgrok, C. and Tavasszy, L. 2005. Towards collaborative, intermodal hub networks: A case study in the fast moving consumer goods market. *Transportation Research* 41: 567-583.

Gümüs, M. and Bookbinder, J.H. 2004. Cross-docking and its implications in location-distribution systems. *Journal of Business Logistics* 25 (2): 199-228.

Halldórsson, Á. and Kovács, G. 2010. The sustainable agenda and energy efficiency: Logistics solutions and supply chains in times of climate change. *International Journal of Physical Distribution* & *Logistics Management* 40(1/2): 5-13.

Haraldsson, M., Jonsson, L., Karlsson, R. Vierth, I., Yahya, M.R., and Ögren, M. 2012. Cost benefit analysis of round wood transports using 90-tonne vehicles. VTI rapport 758. The Swedish Energy Agency, the Swedish Transport Administration.

Hedenus, F. 2008. On the road to climate neutral freight transportation: A scientific feasibility study, Swedish Road Administration, Publication 2008: 92. Available at: http://kneg.org/wp-content/uploads/2010/03/2008_92_on_the_road_to_climate_neutral_freight_transportation_a_scientific_feasibility_study1.pdf

Helmreich, S. and Keller, H. 2011. *Freightvision: Sustainable European freight transport 2050: Forecast, vision and policy recommendation*. Springer: Berlin Heidelberg, Germany.

Holweg, M., Disney, S., Holmstrom, J. and Smaros, J. 2005. Supply chain collaboration: making sense of the strategy continuum. *European Management Journal* 23(2): 170-181.

Holweg, M. and Miemczyk, J. 2003. Delivering the '3-day car': The strategic implications for automotive logistics operations. *Journal of Purchasing & Supply Management* 9: 63-71.

IBM (Institute for Business Value). 2010. The smarter supply chain of the future. Available (as registered user download) from: www.ibm.com

________. 2011. The new business case for inbound transportation management. IBM Software, Transportation. Available (as registered user download) from: www.ibm.com

Institute of Grocery Distribution (IGD). 2007. ECR UK Collaborative Green Distribution. Available at: www.igd.com/ecr

Institute of Grocery Distribution (IGD). 2008. Transport Collaboration Guide: Simple tools and techniques to help retailers and suppliers identify and implement opportunities to increase vehicle utilisation, reduce miles and cost [MS Powerpoint presentation]. Available at: http://www.igd.com/our-expertise/Supply-chain/Logistics/3608/Transport-Collaboration/

International Transport Forum (ITF). 2012. Transport Outlook: Seamless transport for greener growth. OECD report. Available at: www.internationaltransportforum.org

Ishfaq, R. and Sox, C.R. 2012. Production, manufacturing and logistics: Design of intermodal logistics networks with hub delays. *European Journal of Operational Research* 220(3): 629-641.

Johnsson, M. 1998. Packaging logistics – A value added approach. Lund Institute of Technology, Department of Engineering Logistics.

JW Suckling Transport. 2008. Consolidate and Save. Freight Best Practice: Case Study. UK Department for Transport. Available at: *www.freightbestpractice.org.uk/consolidate-and-save*

Kaveh, N. and Samani, N.D. 2009. How collaborative logistics management increases supply chain efficiency. Master Thesis, School of Engineering, University of Borås, Sweden.

Klaas-Wissing, T. and Albers, S. 2010. Cooperative versus corporate governance of LTL networks. *International Journal of Logistics Research and Applications* 13(6): 493-506.

Knight, I., Newton, W. and McKinnon, A. 2008. Longer and/or longer and heavier goods vehicles (LHVs): A study of the likely Effects if permitted in the UK - Final Report. TRL Limited, Project Report 285. Available at: http://www.nomegatrucks.eu/deu/service/download/trl-study.pdf

Kohn, C. C. and Brodin, M. H. 2008. Centralised distribution systems and the environment: How increased transport work can decrease the environmental impact of logistics. *International Journal of Logistics* 11(3): 229-245.

Komoto, H. and Tomiyama, T. 2009. Systematic generation of PSS concepts using a service CAD tool. Pg. 71-91 [Ch. 4] in *Introduction to Product Service-System Design* (ed. Sakao, T. and Lindahl, M.). Springer-Verlag, London, United Kingdom.

Köhler, U. 1998. City-logistics concept for Kassel. Freight - Proceedings of seminar B European transport forum, Brunel university, 1-5th September 1997. Volume P412: 97-103.

Lammgård, C. 2007. Environmental perspectives on marketing of freight transports: The intermodal road-rail case. PhD thesis. University of Gothenburg. Available at: https://gupea.ub.gu.se/handle/2077/17014.

Langley, J. 2012. 2013 Third-party logistics study: the state of logistics outsourcing - Results and Findings of the 17th Annual Study. Capgemini Consulting, Insights & Resources. Available at: http://www.capgemini.com/insights-and-resources/by-publication/2013-thirdparty-logistics-study/

Lapierre, S., Ruiz, A. and Soriano, P. 2004. Designing distribution networks: Formulations and solution heuristic. *Transportation Science* 38(2): 174-187.

Le Net, E., Bajric, F., Vötter, D., Berg, S., Anderson, G. and Roux, S. 2011. Identification of existing transport methods and alternative methods or new approaches with data about costs, labour input and energy consumption. European Forest Institute, Technical Report 76.

Lieb, K.J. and Lieb, R.C. 2010. Environmental sustainability in the third-party logistics (3PL) industry. *International Journal of Physical Distribution & Logistics Management* 40(7): 524-533.

Liimatainen, H., Stenholm, P., Tapio, P. and McKinnon, A. 2012. Energy efficiency practices among road freight hauliers. *Energy Policy* 50: 833-842.

Lin, C., Choy, K.L., Lam, H.Y. and Wong, D.W.C. 2012. A web-based intelligent collaborative logistics management decision support system for enhancing the cost effectiveness of door-to-door delivery. Proceedings of PICMET '12 - Technology Management for Emerging Technologies: 744-753.

Liu, Y., Huan, J. and Zhang, Q. 2010. Development mode of automotive logistics and optimizing countermeasure of china's automotive enterprises. *International Business Research* 3(3): 194-200.

Löfroth, C., Larsson, L. and Enström, J. 2012. ETT – A modular system for forest transport: A three-year round wood haulage test in Sweden. Available at: http://hvttconference.com/wp-content/uploads/2012/09/Plen_I_2_Lofroth-et-al.pdf

Marasco, A. 2008. Third-party logistics: A literature review. *International Journal of Production Economics* 113: 127-147.

Mattila, T. and Antikainen, R. 2011. Backcasting sustainable freight transport systems for Europe in 2050. *Energy Policy* 39: 1241-1248.

McKinnon, A., Ge, Y. and McClelland, D. 2004. Assessment of the Opportunities for Rationalising Road Freight Transport. Link Research Project (FIT 022). Future Integrated Transport Programme, Logistics Research Centre, Heriot Watt University.

McKinnon, A. and Ge, Y. 2006. The potential for reducing empty running by trucks: A retrospective analysis. *International Journal of Physical Distribution & Logistics Management* 36(5): 391-410.

McKinnon, A. 1996. The empty running and return loading of road goods vehicles. *Transport Logistics* 1(1): 1-19.

________. 2010a. Environmental sustainability: a new priority for logistics managers. pg. 3-30 [Ch.1] in *Green Logistics: Improving the Environmental Sustainability of Logistics* (ed. McKinnon, A., Cullinane, S., Browne, M. and Whiteing, A.). Kogan Page Limited, London, United Kingdom.

________. 2010b. European Freight Transport Statistics: Limitations, Misinterpretations and Aspirations. 15th ACEA Scientific Advisory Group Meeting, Brussels. 8th September 2010.

________. 2010c. The role of government in promoting green logistics. pg. 341-360 [Ch.17] in *Green Logistics: Improving the environmental sustainability of logistics* (ed. McKinnon, A., Cullinane, S.,Browne, M. and Whiteing, A.) Kogan Page Limited, London, UK.

_________. 2010d. Britain without Double-deck Lorries - An Assessment of the Effects on Traffic Levels, Road Haulage Costs, Fuel Consumption and CO2 Emissions. Heriot-Watt University Publications, Edinburgh, United Kingdom. Available at: http://www.sml.hw.ac.uk/downloads/logisticsresearchcentre/BritainwithoutDouble-deckLorries%28finalreport%29.pdf

McKinnon, A. and Edwards, J. 2010. Opportunities for improving vehicle utilization. pg. 195-213 [Ch. 9] in *Green Logistics: Improving the Environmental Sustainability of Logistics* (ed. McKinnon, A., Cullinane, S., Browne, M. and Whiteing, A.). Kogan Page Limited, London, United Kingdom.

McKinnon, A., Allen, J. and Woodburn, A. 2010. Development of greener vehicles, aircraft and ships. pg. 140-167 [Ch. 7] in *Green Logistics: Improving the environmental sustainability of logistics* (ed. McKinnon, A., Cullinane, S.,Browne, M. and Whiteing, A.) Kogan Page Limited, London, UK.

Meade, L. and Sarkis, J. 2002. A conceptual model for selecting and evaluating third-party reverse logistics providers. *Supply Chain Management* 7(5): 283-295.

Miemczyk, J. and Holweg, M. 2004. Building cars to customer order: What does it mean for inbound logistics operators? *Journal of Business Logistics* 25(2): 171-197.

Mont, O. 2000. Product-service systems. Swedish Environmental Protection Agency (AFR), Report 288. Stockholm, Sweden.

Nordic Energy. 2013. Nordic Energy technology perspectives: Pathways to a carbon neutral energy future. International Energy Agency publications. Available at: http://www.iea.org/media/etp/nordic/NETP.pdf

Palmer, A., Jesus Saenz, M. van Woensel, T. and Ballot, E. 2012. Characteristics of collaborative business models. CO^3 position paper. Logistics Research Centre, School of Management and Languages, Heriot-Watt University.

Peake, S. 1994. *Transport in transition : Lessons from the history of energy.* The Royal Institute of International Affairs, Earthscan, London, United Kingdom.

Pelagagge, P.M. 1997. Advanced manufacturing system for automotive components production. *Industrial Management & Data Systems* 97(8): 327-334.

Perego, A., Perotti, S. and Mangiaracina, R. 2011. ICT for logistics and freight transportation: A literature review and research agenda. *International Journal of Physical Distribution & Logistics Management* 41(5): 457-483.

Pope, C.A., Burnett, R.T., Thun, M.J., Calle, E.E., Krewski, D., Ito, K. and Thurston, G.D. 2002. Lung cancer, cardio-pulmonary mortality, and long-term exposure to fine particulate air pollution. *Journal of the American Medical Association* 287(9): 1132-1141.

Puodžiūnas, M., Rönnqvist, M. and Fjeld, D. 2004. The potential for improvement of tactical planning of round wood transport in Lithuanian state forest enterprises. *Baltic Forestry* 10(1, 18): 79-88.

Sakao, T., Panshef, V. and Dörsam , E. 2009. Addressing uncertainty of PSS for value-chain oriented service development. Pg. 137-157 [Ch. 7] in *Introduction to Product Service-System Design* (ed. Sakao, T. and Lindahl, M.). Springer-Verlag, London, United Kingdom.

Sandberg, E. 2005. Logistics collaboration in supply chains: A survey of Swedish manufacturing companies. Licentiate Thesis No.93 (IMIE Thesis No. 1180), International Graduate School of Management and Industrial Engineering, Linköping University, Sweden.

Sarkis, J. 1995. Supply chain management and environmentally conscious design and manufacturing. *International Journal of Environmentally Conscious Design and Manufacturing* 4(2): 43-52.

Schittekat, P. and Sörensen, K. 2009. supporting 3pl decisions in the automotive industry by generating diverse solutions to a large-scale location-routing problem. *Operations Research* 57(5): 1058-1067.

Selviaridis, K. and Spring, M. 2007. Third party logistics: a literature review and research agenda. *International Journal of Logistics Management* 18(1): 125-150.

Shimomura, Y. and Arai, T. 2009. Service engineering – Methods and tools for effective PSS development. Pg. 113-135 [Ch. 6] in *Introduction to Product Service-System Design* (ed. Sakao, T. and Lindahl, M.). Springer-Verlag, London, United Kingdom.

Sihn, W and Schmitz, K. 2007. Extended Multi-Customer Supplier Parks in the Automotive Industry. *Annals of the CIRP* 56(1): 479-482.

Simongati, G. 2010. Multi-criteria decision making support tool for freight integrators: Selecting the most sustainable alternative. *Transport* 25(1): 89-97.

Simons, D., Mason, R. and Gardner, B. 2004. Overall vehicle effectiveness. *International Journal of Logistics Research and Applications* 7(2):119-135.

Stefansson, G. 2006. Collaborative Logistics Management: The role of third-party service providers and the enabling information systems architecture. Department of Logistics and Transportation, Chalmers University of Technology. PhD thesis. Chalmers Reproservice, Gothenburg, Sweden.

Stefansson, G. and Woxenius, J. 2007. The concept of smart freight transport systems: The road haulier's perspective. 19th annual NOFOMA conference, Reykjavik, Iceland, 7-8 June 2007.

Srivastava, S. 2007. Green supply-chain management: A state-of-the-art literature review. *International Journal of Management Reviews* 9(1): 53-80.

Sveriges officiela statistic [Sweden's official statistics]. 2012. Lastbilstrafik 2011: Swedish national and international road goods transport 2011. Statistik 2012:6. Available at: http://trafa.se/PageDocuments/Lastbilstrafik_2011.pdf

Sveriges officiela statistic [Sweden's official statistics]. 2013. Fordon 2012 [Vehicles 2012]. Trafik Analys Statistik 2013:8, Publiceringsdatum: 20130327. Available at: http://www.trafa.se/statistics/

Tesseras, L. 2011. Collaboration: Dangerous to ignore it. Logistics Manager SCS, October 2011: 36-38. Working papers of ELUPEG 2006-2013. Available at: http://www.elupeg.com/AnInner.cfm?PageName=./doc/doc_public.htm

Tomiyama, T., Shimomura, Y. and Watanabe, K. 2004. A note on service design methodology. Proceedings of DETC, ASME, 57393.

Tracey, M., Tan, C.L., Vonderembse, M. and Bardi, E.J. 1995. A re-examination of the effects of Just-In-Time on inbound logistics. *International Journal of Logistics Management* 6(2): 25-38.

United States Department of Energy (US DOE). 2006. 21st Century truck partnership – Road map and technical white papers. Available at: http://www1.eere.energy.gov/vehiclesandfuels/pdfs/program/21ctp_roadmap_2007.pdf

Uttamrao, K.S. and Rajashree, S. 2009. Effectiveness of supply chains for auto component manufacturing industries. *Advances in Management* 2(12): 40-43.

Vachon, S. and Klassen, R.D. 2006. Extending green practices across the supply chain: The impact of upstream and downstream integration. *International Journal of Operations & Production Management* 26(7): 795-821.

van Hoek, R.I. 1999. From reversed logistics to green supply chains. *Supply Chain Management* 4(3): 129-134.

Van Woensel, T., Dabia, S. and de Kok, T. 2011. Managing supply chains: Transport optimization and chain synchronization. Pg. 119-137 [Ch. 7] in *Transitions towards sustainable mobility: New solutions and approaches for sustainable transport systems* (ed. Nunen, J., Huijbregts, P. and Rietveld, P.) Springer, Berlin, Germany.

Vanek, F.M. and Morlok, E.K. 2000. Improving the energy efficiency of freight in the United States through commodity-based analysis: Justification and implementation. *Transportation Research* 5: 11-29.

Verstrepen, S., Cools, M., Cruijsse, F. and Dullaert, W. 2009. A dynamic framework for managing horizontal cooperation in logistics. *International Journal of Logistics Systems and Management* 5(3-4): 228-48.

Vilkelis, A. 2011. Utilisation of transport capacities and opportunities to mitigate negative environmental impact of logistics operations. Selected paper from TRANSBALTICA 7th International Conference, 5-6th May 2011. Available at: http://www.slideshare.net/Vilkelis/utilisation-of-transport-capacities-and-opportunity-to-mitigate-negative-environmental-impact-of-logistics-operations-9084866

Waller, A. n.d. Collaboration: The key to success! Logistics Connect Features: 20-21. Working papers of ELUPEG 2006-2013. Available at: http://www.elupeg.com/AnInner.cfm?PageName=./doc/doc_public.htm

Whitlegg, J., and Haq, G. 2003. New directions in world transport policy and practice. Pg. 293 in *World transport: Policy and practice* (ed. Whitlegg, J., and Haq, G.). Stockholm Environment Institute. Earthscan Publications, London, United Kingdom.

Wisetjindawat, W. 2010. Review of good practices in urban freight transportation. Department of Civil Engineering Nagoya Institute of Technology. Available at: http://www.unescap.org/ttdw/common/TPT/egm_eco_efficiency/dr_wisinee_report.pdf

Wolf, C. and Seuring, S. 2010. Environmental impacts as buying criteria for third party logistical services. *International Journal of Physical Distribution* & *Logistics Management* 40(1): 84-102.

World Energy Council 2007. Transport technologies and policy scenarios to 2050. Transport Specialist Study Group. Available at: http://www.worldenergy.org/documents/transportation_study_final_online.pdf

World Economic Forum. 2009. Supply chain decarbonization – The role of logistics and transport in reducing supply chain carbon emissions. Logistics and Transport Partnership Programme, with support from Accenture. Available at: http://www3.weforum.org/docs/WEF_LT_SupplyChainDecarbonization_Report_2009.pdf

Zhou, G., Hui, Y.V. and Liang, L. 2011. Strategic alliance in freight consolidation. *Transportation Research Part E* 47: 18-29.

7.1 Personal communications

Bolam, B. Vice Chairman ELUPEG Limited. Personal communication via telephone on the 13th of May 2013.

Hambeson, S. Environmental manager at Volvo Group logistics services. Personal communication via telephone on the 30th of April 2013.

LaSota, F. Chrysler manager of transportation strategy. Personal communication via telephone on the 18th of April 2013.

Olschewski, S. Operations & Asset Manager at LPR - La Palette Rouge Deutschland GmbH. Email response to questionnaire on April 11th 2013.

Rydén, P. and König, J. Project manager and coordinator at Öresund EcoMobility Project. Face to face discussion on 10th April 2013.

Selvén, J. 2013. Business owner at Volvo trucks Dynafleet management and driver development. Personal communication via telephone on the 5th of April 2013.

Sjögren, H. Skogsindustrierna: Rådgivare transportpolitik. Email response on April 5th 2013.

Trail, A. Advisor to Green Freight Europe. Personal communication via telephone on the 1st of May 2013.

8 Appendix

8.1 Sample automotive manufacturer survey

IIIEE MESPOM MSc Thesis Research | Lund, April 2013

Dear Frank,

I am investigating the reasons behind the inefficiency of road freight transport operations and why much of the heavy good's vehicles are still running well below their weight and volume haulage capacity. In essence I would like to develop a framework for promoting full truck load usage and looking at an individual truck as a "service" that is available for several actors to use simultaneously. This approach is quite well developed in the fast-moving consumable goods sector, but I would like to see if potential for this kind of thinking exists among other industries too. I was hoping you could elaborate on the following questions:

1. What are Chrysler's main strategies for reducing the environmental impacts of associated logistics operations? Do these strategies differ between component deliveries and completed vehicles distribution? What are your main motivations for greening these operations? Do you this is an industry-wide trend and how would differentiate yourself from other manufacturers in these aspects?

2. Are the road freight operations involved in component shipments outsourced to external operators (or does Chrysler also own truck fleets)?

3. Do you have any requirements regarding the road vehicles (and trailers) that are used in your supply chain (technical aspects, vehicle age, emission standards etc.)?

4. For outsourced road freight logistics, what selection criteria do you have for choosing which logistics service provider to hire? Are any of these criteria related specifically to environmental performance and energy efficiency? If so, how are these weighted against other criteria?

5. Do you feel that you have the ability to change an external hauler's environmental performance? As a purchaser of transport services, could you encourage transport suppliers to perform above the minimal requirements laid out by environmental regulations? If so, in what specific operational aspects?

6. How well do you think individual truck capacity is utilised in your supply chain? What are the rates of partially loaded and empty running trucks operating your supply chain? Do you have initiatives to reduce these inefficiencies?

7. As you may know, it is common practice in the fast-moving goods sector to combine shipments from different suppliers in a single truck – thereby effectively serving separate supply chains with fewer trucks. Have your logistics operations ever overlapped with other supply chains, and why or why not would you say there could be potential for horizontal collaboration (within the automotive industry or perhaps with entirely different sectors) in freight movements?

8. The most successful freight consolidation initiatives have involved different suppliers disclosing information about their supply chains to an independent body. Do you feel that Chrysler could ever be encouraged to disclose supply chain information to such an independent body so that opportunities for optimisation of collective logistics (with other industries or even potential competitors) could be identified?

9. How could such a service arrangement be made appealing to you, and what expectations would you have from it?

I realise that some of this information could be sensitive and you may not want to share with academia. At the moment I am not anticipating this work being published outside the usual Lund University Master's Thesis publications. I would be extremely grateful for as much help as you can provide.

Best regards,

Alex Leshchynskyy
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8.2 Sample 3PL survey

IIIEE MESPOM MSc Thesis Research **Lund, April 2013**

Dear LPR,

I am investigating the reasons behind the inefficiency of road freight transport operations and why so much of the HGV's around the EU are still running well below their weight and volume haulage capacity. In essence I would like to develop a framework for how full truck load usage can be promoted and for several actors to use the same truck so as to reduce the environmental impact of logistical operations while still delivering the same degree of service (just with fewer trucks). I am assuming that your FTL service involves the grouping of consignments from different customers in a single truck, and I was hoping you could elaborate on the following questions;

1. What kinds of customers purchase your full truck load service? Do these suppliers communicate their motivations for choosing this grouped transport? Does this vary with type of consignment and/or industry sector?

2. What sort of goods are most frequently transported by LPR's FTL fleets? Is the trucks full weight haulage capacity generally reached before its volume capacity, or *vice versa*?

3. Have the types of goods carried by this scheme changed and/or diversified over time? How many suppliers' goods are typically carried within a single truck today?

4. How does LPR ensure that the trucks are loaded to their full capacity every time? Are ICT systems involved and if so what are your experiences with using such systems?

5. What type of truck is used for this service? Are different truck/trailer variants offered to enable for larger quantities and more diverse goods to be loaded? Are different trucks used for less-than-truckload operations?

6. What management challenges does a scheme like this present compared to a more traditional one truck per customer approach?

7. What are the customer's experiences with this service? Have they suggested any modifications?

8. How does LPR plan to promote the use of this service in the future? Is there a general trend among logistics service providers to encourage this sort of eco-efficient consolidation service?

9. In LPR's experience, what are the reasons for why customers are choosing to avoid using such a consolidation service? Is it likely that these can be overcome for the ultimate goal of "greening" logistics?

I realise that some of this information could be sensitive and you may not want to share with academia. However I would be extremely grateful for any help you can provide.

Best regards,

Alex

8.3 Sample ICT developer survey

IIIEE MESPOM MSc Thesis Research **Lund, April 2013**

Dear Johan,

As you know I am investigating the reasons behind the inefficiency of road freight transport operations and why so much of the HGV's around the EU are still running well below their weight and volume haulage capacity. In essence I would like to develop a framework for how full truck load usage can be promoted and for several actors to use the same truck so as to reduce the environmental impact of logistical operations while still delivering the same degree of service (just with fewer trucks). I am assuming that your Dynafleet service could be involved in grouping of consignments from different customers in a single truck, and I was hoping you could elaborate on the following questions;

1. For how long and in what parts of the world has Volvo been providing this software package? What are its key strengths compared to other fleet management systems? Are there any fundamental differences between the ICT packages offered by third party logistics providers and vehicles manufacturers?

2. What types of customers (and types of goods) are choosing to use Dynafleet? Have these changed and/or diversified over time? What are their main motivations for using Dynafleet and do these differ according to their core business activity?

3. What are the customer's experiences with this service? Have they suggested any modifications?

4. How does Volvo plan to promote the use of this service in the future? Is there a general trend in the road freight logistics sector to encourage this sort of eco-efficient fleet management?

5. What are the main barriers to making this system more widespread?

6. Can the package only be used on newly purchased Volvo trucks or is it also made available to companies that do not own internal truck fleets and choose to outsource their road freight logistics? Are Dynafleet's compatibilities limited to specific sectors or vehicle types?

7. Which specific function (fuel cost, driver behaviour, load and vehicle specification matching etc.) of the package is most popular among your customers?

8. Do you think that any single function offers the greatest environmental benefit? If so, why?

9. I am particularly interested in the system's ability to identify under-loaded vehicles. What experiences have you had so far regarding the system's ability to reduce the number of trucks on the road? As a vehicle manufacturer could that hypothetically be counter-productive to making the greatest vehicle sales?

10. Could the system be used to identify loading possibilities across different supply chains and/or industry sectors (if for example two distinct companies are using this package)? Do you have any experiences with encouraging such external cross-sectoral partnerships?

I realise that some of this information could be sensitive and you may not want to share with academia. At the moment I am not anticipating this work being published outside the usual Lund University Master's Thesis publications. I would be extremely grateful for as much help as you can provide.

Best regards,

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8.4 Vehicle manufacturer sustainability report assessment

Manufacturer	**Success data disclosed**	**Initiatives relevant to modal shift**	**Initiatives relevant to HGV utilisation**	**Other initiatives**	**Long-term goals**	**Publication name**
BMW Group	- Rail transport share in overall transport volume increased from 8.2% in 2011 to 8.9% in 2012	- Avoidance of air freight - Emphasis on rail and sea freight in both incoming component deliveries and outgoing completed vehicles - Several quantified examples of environmental gains from mode changes	- Merely a mention of striving for increased utilisation and reduced empty runs - Concentration of deliveries to ensure full loads wherever possible	- Transportation orders assigned to service providers are paid by volume ensuring for an automatic incentive for planning efficiency	- Enhancement of worldwide logistics strategy to become the market leader in logistics in the premium sector	BMW Group Sustainable Value report 2010, 2012
Honda Group	- 4% reduction in per unit CO_2 emissions (finished vehicles and component distribution) relative to 2011 as a result of modal optimisation - 51% reduction as a result of collaboration with transport partners	- Modal shift from truck to marine transport for distances over 500km - Consolidated sea shipments with other companies	- Achieved a 2% increase in loading efficiency, reducing the number of trucks operating per day by 27%	- Development of environmental management systems jointly with transport companies - Encouraged eco-driving in partner companies who are transporting finished vehicles	*Not explicitly mentioned*	Honda Environmental Annual Report 2012

Fiat and Chrysler Group	- 4% reduction in CO_2 emissions from logistical processes relative to 2010	- On-going evaluation of new rail routes for components and vehicle transports - In US vehicles were co-loaded with products of other manufacturers to optimise railcar density occupation	- Streamlined deliveries using a coordinated pool of logistics providers who organise collection from several suppliers to maximise capacity utilisation - This milk-run approach saved over a million running miles - 92% cube utilisation on direct truckload deliveries - Sharing of outbound services to dealerships - Some consolidation of freight with other manufacturers and even non-automotive freight, reducing some 4 million driving miles and saving 6.5 thousand tonnes CO_2	- Access to plants is already prohibited for vehicles with emission levels worse than Euro III - At least 50% of supplier fleets consist must consist of Euro IV or higher vehicles - US Smartway membership as a requisite for contracted carriers - Adopted a set of environmental KPIs (defined on the basis of GRI-G3.1 guidelines) for monitoring logistics processes	*Not explicitly mentioned*	Fiat 2011 Sustainability Report : Economic, Environmental and Social Responsibility
Ford	*Not explicitly mentioned*	- Maximise use of rail, river and short-sea transport, to achieve a potential 40% reduction in CO_2 emissions - Using interchangeable	- Regional distribution centres coordinate deliveries and reduce number of vehicles delivering to multiple factories - Several collection points on	- "Green logistics" intranet site designed for standardising procedures and internally communicating best practice	- Dialogue with carriers and service providers for innovative solutions - Implement strong monitoring schemes	Ford Sustainability 2011/12 (Supply chain section)

		swap-bodes to facilitate shift from road onto rail and vice versa when necessary	single truck milk-run routes to reduce the number of journeys required - Development of 3PL contracts that encourage them to find back-hauls	- Strong emphasis on GHG emission reporting: sixteen major 3PLs contributed to carbon disclosure surveys	that should aid with the modal shift	
PSA Peugeot Citröen	*Not explicitly mentioned*	- New rail route between France and Russia, replacing the equivalent of 36 outbound trucks per day, shortening delivery times by 3 days and driving a sharp reduction in emissions	*Not explicitly mentioned*	- Eco-driving resulted in a 15% CO_2 emission reduction in the logistics subsidiary - Plans to renew fleet, install speed-limiting devices and fuel consumption tracking	*Not explicitly mentioned*	PSA Peugeot Citröen 2011 Corporate Social Responsibility Strategic guidelines, commitmens and indicators
VW Group	*Not explicitly mentioned*	- Invested 8.6 million € into rail links between production sites and ports, saving some 57000 truck journeys every year - Audi: finished vehicle delivered from factory in Ingolstadt to North Sea by trains powered by renewable energy; thus saving 35 kg CO_2 per car	- Full loads achieved via freight aggregation in consolidation centres	- Pilot project on gas-powered trucks for short-distance transport (reducing emissions and noise)	*Not explicitly mentioned*	Volkswagen (Aktiengesellschaft) Sustainability report 2011; Das Audi Umweltmagazin 2012

Volvo Group	- Between 2009 and 2011, 18% reduction in emissions from road, rail and sea transportation	- Since 2010, all contracted sea carriers have been required to report the environmental impact of each of their vessels - Part of the Clean Shipping Project; a network of 30 of the largest export and import companies in Sweden, Germany and the Netherlands	- Uses the longest (32 metre) truck available in Sweden aimed at reducing carbon dioxide emissions. This means that two 40-foot-long containers can be transported instead of one, a reduction of 20 grams of carbon dioxide per tonne kilometre - In favour of longer truck allowances in Europe as this would mean that two trucks could carry what is currently transported by three trucks, with a benefit for the environment and reduced congestion	- In 2011 88 percent of the major transport suppliers were certified in accordance with the environmental standard ISO 14001 or equivalent - The EnvCalc tool is used to calculate emissionsto air for new or changed transport routes - Requires suppliers of road transportation to comply with engine class requirements and have their drivers trained in fuel efficient driving. These requirements are followed up by an annual supplier survey	*Not explicitly mentioned*	Volvo Group Sustainability report 2012; Volvo Group CSR and Sustainability report 2011
Jaguar Land Rover	- CO2 emissions from inbound logistics (components and materials inbound to manufacturing facilities) cut by 22% since 2007 per vehicle	*Not explicitly mentioned*	*Not explicitly mentioned*	*Not explicitly mentioned*	- 15% reduction in total emissions from logistics operations by March 2013	Jaguar Land Rover Sustainability Report 2011/12

	produced. - CO2 emissions from outbound logistics (finished products to market) cut by 9% per vehicle since 2008					
Toyota Group	*Not explicitly mentioned*	*Not explicitly mentioned*	- Improvement of transport efficiency via truck modifications leading to reduction of total transport distance	*Not explicitly mentioned*	*Not explicitly mentioned*	Toyota Motor Corporation Sustainability Report 2012
General Motors	*No mention of transport logistics efficiency, environmental performance or initiatives in* General Motors Sustainability Report: Sustainability in Motion 2012					
Daimler	*No mention of transport logistics efficiency, environmental performance or initiatives in* Daimler Sustainability Report 2012					